OSCILLATORY BEHAVIOR DURING APPROACH-AVOIDANCE CONFLICT¹

ELIOT HEARST

UNIVERSITY OF MISSOURI²

During one stimulus, food rewards and electric shocks were intermittently delivered to rats regardless of their behavior. Subjects could either terminate or initiate this stimulus by pressing a lever. Effects of the relative frequency of food and shock were studied by manipulating the variable-interval schedules associated with each. Increases in the relative frequency of shocks led to decreases in the amount of time each rat spent in the stimulus. Subjects initiated and terminated the stimulus most often at intermediate relative frequencies of food and shock, rather than in situations where the conditions were either very favorable (e.g., only food was possible) or very unfavorable (e.g., only shock was possible). This technique thus provides quantitative data on oscillatory behavior during conflict which confirm and extend results previously obtained by qualitative observation.

After a formerly neutral stimulus has been associated with both positive and negative reinforcement, it presumably can act simultaneously as a conditioned positive reinforcer (Kelleher and Gollub, 1962) and as a conditioned punishment (Hake and Azrin, 1965; Azrin and Holz, 1966). Because of this dual function, a subject's behavior with regard to such a stimulus is often loosely described as ambivalent or vacillatory. "Approach-avoidance conflict", a term frequently applied to situations of this type (see Miller, 1944; 1959), reflects the fact that in the presence of the stimulus subjects may respond both to prolong the stimulus and to terminate it, whereas in the absence of the stimulus, subjects may respond both to produce and to prevent its occurrence. The supposed source of "conflict" lies in the incompatibility of these simultaneously-aroused response tendencies.

Although studies of conflict behavior in animals (Miller, 1944; 1959) have often included qualitative descriptions of vacillation and oscillation (e.g., cycles of approach-and-retreat in a runway situation where goalbox entry is both rewarded with food and shocked), quantitative data on oscillatory behavior are lack-

ing. One reason is that no specific avoidance response has been defined in most of these experiments. Usually, the only clearly specified response is the one that receives both primary positive and primary negative reinforcement; in the runway, for example, the response of entering the goalbox is reinforced with both food and shock. In such situations the avoidance "response" actually proves to be any-other-response-except-goal-entry. Precise quantitative measures of the so-called avoidance tendency, uncontaminated by a variety of competing behaviors, are thus not easy to obtain.

The present technique sought to remedy this defect by requiring subjects to make both a specific approach response (producing a simultaneously positive and negative conditioned reinforcing stimulus) and a specific avoidance response (terminating that same stimulus). The rate of the subject's oscillation between the stimulus-on and stimulus-off condition can then be continuously measured, and quantitative estimates of so-called "vacillation in the face of conflict" should thus be obtainable. The studies of Tolcott (1948) and Winnick (1956) also analyzed vacillation in an operant conflict situation, but they employed a procedure quite different from the present one.

Some early data from the present technique have already been reported (Hearst and Koresko, 1964). In those experiments rats could press a lever either to initiate or terminate a stimulus associated with intermittent food

¹The suggestions and assistance of Minnie B. Koresko and Roger Poppen are gratefully acknowledged. Reprints may be obtained from the author, Dept. of Psychology, University of Missouri, Columbia, Missouri 65202.

²These experiments were performed at the NIMH Clinical Neuropharmacology Research Center, St. Elizabeths Hospital, Washington, D.C.

presentation and shock delivery. The animals divided their time between the stimulus-on and the stimulus-off condition and oscillated between them. The total number of oscillations, as well as the total time spent in the stimulus, were systematically affected by varying shock intensity and food deprivation.

One would expect performance in this situation to be sensitive to manipulations of the relative frequency of food reward and electric shock during the stimulus-on condition. Extremely favorable payoffs (frequent food, very infrequent shock) and extremely unfavorable payoffs (very infrequent food, frequent shock) should not produce strongly competing approach and avoidance responses, as compared to those produced by intermediate relative frequencies of food and shock; oscillations between the stimulus-on and stimulus-off conditions ought thus to be relatively infrequent under extremely favorable and unfavorable payoffs, and much more frequent at some intermediate payoff values.

The present experiments concentrated on the effects of such variations in the relative frequencies of food and shock. Because variations in relative frequencies were being examined for the first time on this procedure, an attempt was made to sample quite a variety of different schedule combinations. The experiments may thus be considered more exploratory than definitive.

METHOD

Subjects

Six male albino rats of the Osborne-Mendel strain were maintained at about 75% of their free-feeding weights. They were about six months old at the start of the experiment and had not been used in any prior studies. Condensed-milk reinforcements were delivered during test sessions and were supplemented by Purina rat pellets after sessions and on weekends. Water was continuously available in the home cages. Five of the subjects had provided the earlier data reported in Hearst and Koresko (1964).

Apparatus

A standard chamber (Foringer and Co.) with a single lever served as the experimental enclosure. It has been described elsewhere (Hearst, 1963). Food reinforcement consisted

of 3-sec presentations of a motor-driven dipper containing 0.1 ml of sweetened condensed milk. Electric shocks of 0.4-sec duration were delivered through a grid scrambler. Contingencies were programmed and data recorded automatically with relay circuitry.

Procedure and Preliminary Results

General aspects of preliminary procedures (*i.e.*, before work began on relative frequencies of reward and punishment) have been summarized in Hearst and Koresko (1964). For the sake of completeness, and because some of the early work may well have influenced the results obtained here, additional details of these procedures are given below.

After one session devoted to magazine (dipper) training for condensed milk, subjects were placed on a procedure in which only food presentations were possible. Whenever one stimulus condition (S^D)—a clicking sound for half the subjects (No. 1, 3, and 5) and a silent period for the others—was present, food was delivered at irregular intervals averaging 1 min (variable interval or VI 1). These reinforcements were response-independent, *i.e.*, no response was required to produce the food. However, a single lever-press terminated S^D and started a 5-min time out (TO) during which no food was delivered. For half the subjects, TO was a period of silence; for the others, it was the clicking sound. As soon as TO ended, S^D was reinstated. If the subject never pressed the lever, S^D remained on for the entire session. Lever presses in TO had no effect during this preliminary phase. Throughout this phase, as in all the work here summarized, experimental sessions lasted 90 min and occurred daily except for weekends.

This procedure continued for 10 sessions. Subjects rarely pressed the lever. Over the last five sessions it was unusual for any subject to produce more than three TOs per session.

Response contingencies on the next procedure were maintained for the remainder of the experiments to be described. The TO no longer lasted a predetermined time but was dependent on the subject's behavior. In S^D subjects could press the lever to terminate S^D and thus produce TO, and in TO they could press the lever to terminate TO and thus produce S^D . Since sessions always began with an S^D period, S^D would remain on for the entire session if subjects never pressed the lever.

Once a subject had produced TO, further failure to respond meant that TO would continue for the rest of the session.

Food was delivered in S^D on the same response-independent 1-min VI schedule. No shocks were possible during the first 50-55 sessions of exposure to the new procedure. The object was to determine whether, under conditions of positive reinforcement alone, subjects would repeatedly turn the stimulus on and off, as prior work (e.g., Hundt and Premack, 1963; Valenstein and Valenstein, 1964) with positive reinforcement might suggest.

During the first 23 to 24 sessions of exposure to this schedule three subjects (No. 2, 4, and 6) almost never produced TOs (the median number of TOs over the last five sessions for these rats was either 0 or 1 TO per session). The other three subjects produced TOs more frequently (medians were 33, 78, and 10 TOs per session for No. 1, 3, and 5 respectively). The cumulative records of these latter subjects indicated that S^D was usually terminated after a relatively long period without any reinforcement, i.e., during one of the longer intervals on the VI schedule. Since these subjects generally restored S^D very quickly after producing TO, the occasional delivery of reinforcements immediately after S^D was restored could possibly have "accidentally" reinforced oscillations between TO and S^D .

To check this possibility, a procedure analogous to a changeover delay (COD, see Herrnstein, 1961) was instituted for all subjects, including the three that almost never pressed the lever. On this procedure, reinforcement was not possible during the first 30 sec of each S^D period. Presumably, if lever pressing were being maintained by the fortuitous occurrence of food reinforcements at the start of some S^D periods, the addition of the COD would reduce the frequency of lever pressing. Subjects were exposed to the procedure for 14 sessions. By the end of this period the number of lever presses by the TO-producing rats was appreciably reduced (medians over the last five sessions were 7, 18, and 9 TOs per session for rats No. 1, 3, and 5 respectively).

The COD was then shortened to 2 sec for 16 to 17 sessions. The production of TOs did not change for any of the subjects. The COD was therefore held at 2 sec for the remainder of the experiment.

All subsequent work involved the possibility

of both food and shock in S^D . In addition to the VI schedule that provided food at specified intervals, a separate and independent VI schedule programmed shocks in S^D . Food presentations and shocks were both response-independent. On the first exposure to this procedure, food was delivered on a 1-min VI schedule and shocks on a 4-min VI schedule. If the subject pressed the lever in S^D , thus producing TO, no further shocks would occur; but the opportunity for food reinforcement would thus be lost so long as the subject remained in TO.

Different rats had to be left on the procedure for different amounts of time before they began to oscillate between S^D and TO. (An oscillation is defined as one onset-offset cycle; see Hearst and Koresko, 1964). Since individual sensitivity to shock apparently differed among rats, shock values had to be adjusted for each subject until an appreciable amount of oscillatory behavior occurred; intermediate intensities, between approximately 0.45 and 0.65 ma, proved to be optimal. After about 40 sessions with both food and shock, five of the six rats were producing from 45 to 107 oscillations per session.

Only rat No. 3 appeared insensitive to a wide variety of procedural modifications. Many different shock levels were tested and several different combinations of food and shock schedules in S^D were tried without any noticeable oscillatory behavior developing. These manipulations involved about nine months of work. Rather suddenly, however, this rat started to produce an appreciable number of oscillations on a particular combination of parametric values. Subsequent data from this rat did not differ in any obvious way from those of the other subjects, and results for rat No. 3 are therefore included in the present report.

During the months that rat No. 3 showed no evidence of conditioning, the effects of (a) variations in shock intensity, and (b) satiation with milk, were studied on the lever-pressing behavior of the other five rats. Additional procedural details and some results from those experiments were described in Hearst and Koresko (1964).

Manipulation of the

Relative Frequency of Food and Shock

The present article concentrates on the effects of variations in the relative frequency of

food and shock in S^D . These experiments were carried out after (a) and (b) above and involved all six subjects. The relative frequencies of food and shock were varied by changing the VI schedules associated with each. The VI schedules available were: 0 (either no food or no shock), 30-sec, 1-min, 2-min, and 4-min.

A variety of combinations of these schedules for food and shock were tested in each subject and a different mixed order was used for each. Performance on certain combinations was redetermined two or three times during the experiment to evaluate the reliability of behavior at these combinations and the extent of reversibility of the behavioral effects produced by other combinations. Rats usually remained on a particular combination for 10 consecutive experimental sessions, but additional time was occasionally scheduled if behavioral measures showed a systematically changing baseline over the last five sessions. With one exception, to be noted later, shock intensity was maintained at the intermediate level previously found optimal for each rat. Four subjects were studied at a shock intensity of 0.45 ma, one subject (No. 4) at 0.25 ma, and one subject (No. 2) at 0.53 ma.

RESULTS AND DISCUSSION

Two measures of performance are used in the summary of results. One, time spent in S^D out of the total 90-min session, may be considered an index of a subject's overall preference for S^D as opposed to TO. The other measure, number of oscillations between S^D and TO, is presumably an estimate of the interaction between a subject's tendencies to initiate and terminate S^D .

Even though subjects were exposed at one time or another to other combinations of food and shock schedules in S^D (see Fig. 5 and 6), the largest amount of data was collected for combinations in which the food VI was 1-min. Since the behavioral effects of changes in the relative frequency of food and shock seem most effectively presented and analyzed with one of the VI schedules held constant and the other varied, schedule combinations in which the food VI was always 1-min are stressed in the following discussion. Results with some of the other combinations, as well as the entire sequence of schedules tested in three subjects, are summarized in Fig. 5 and 6.

Each subject did not experience all the available schedule combinations in which the food VI was 1 min. There were various reasons for this: one rat (No. 6) died of a respiratory infection before many values could be tested and redetermined, and another rat (No. 5) became insensitive to its supposedly optimal shock intensity (even when 0.25-ma shocks were delivered very frequently, this rat rarely terminated S^D). Therefore, in the middle of the experiment, rat No. 5 was shifted to a higher shock intensity (0.45 ma), under which all its data in Fig. 1-3 were obtained. For other subjects, appreciable time was devoted to food-shock combinations in which the food VI was not 1 min. Therefore, the data summarized in Fig. 1 and 2 do not include determinations at all available combinations for all subjects.

Only the last five sessions on a particular combination of food and shock VIs were used to calculate performance measures. The median of each such five-day period is called a "determination". The data points plotted in Fig. 1 and 2 are the means of one to four such determinations.

Figure 1 displays individual functions relating time spent in S^D to the density of shocks in S^D . As shocks became more frequent, rats permitted S^D to remain on for less time. When shock was not possible, but food was (0 on the abscissa), all subjects spent approximately 90% of the session in S^D . When food was not possible, but shocks were ("No Food, VI 1' Shock"), all subjects spent less than 10% of the session in S^D . When both food and shock were eliminated ("No Food, No Shock") the amount of time in S^D varied widely and unsystematically both between and within subjects (see also Fig. 5), as might be expected when conditions during S^D were neutral.

The individual data on number of oscillations in Fig. 2 are means of determinations for the same food-shock combinations as in Fig. 1. Figure 2 shows a nonmonotonic relationship between number of oscillations and shock density. Five of the six rats displayed a fairly clear maximum at some intermediate abscissa value, rather than at the extreme values. Rat No. 1 was the one exception to this general finding. Although this subject had often produced 20 to 50 oscillations in earlier experiments (see procedure section), its number of oscillations dwindled to fewer than 10 during most of the work summarized in Fig. 1 and 2.

Fig. 1. Mean time spent in S^D as a function of the shock density in S^D . Individual curves for each of the six rats are shown. When food was possible in S^D , it was always delivered on a 1-min VI schedule.

Unfortunately, this rat died while attempts were being made to see if changes in shock intensity would reinstate its oscillatory behavior.

Many studies performed within the traditional framework of "conflict behavior" (see Bitterman, 1944; Miller, 1944) have suggested that the amount of behavioral disruption in a conflict situation (as measured by increased vacillation, blockage, or neurotic symptoms) increases as the strengths of the opposing response tendencies approach equality. In order to see whether an analogous effect occurred in the present situation, it is necessary to derive measures of the separate approach and avoidance tendencies. One way of accomplishing this might be to compare time-in- S^D with time-in-TO and then to determine whether the point at which these measures are approximately equal is in fact the point at which the largest number of oscillations occur (the present measure of "vacillation" being number of oscillations). Do Fig. 1 and 2 indicate that the food-and-shock combination at which a subject spends half the session (45 min) in S^D

and half in TO is the point at which maximal oscillations occur? Because the individual functions in Fig. 1 and 2 do not include a large number of data points, a really rigorous analysis of this sort cannot be attempted. Nevertheless, the results in the figures do tend to support the above prediction, since the point of maximal oscillation is generally very close to the food-and-shock abscissa value at which a subject divides its time equally between S^D and TO. If relative amount of time spent in S^D vs TO is in fact a legitimate measure of opposing response tendencies, then it does appear to be true that as the relative response strengths approach equality, the amount of "vacillation" increases. Results from classical studies of conflict (see Miller, 1944) involving motivational manipulations have led to analogous conclusions. For example, when food drive was reduced by satiation, so that only the avoidance tendency was strong, and when shock intensity was lowered and food deprivation increased, so that only the approach tendency was strong, subjects appeared to show

Fig. 2. Mean number of oscillations between S^D and T_O as a function of the shock density in S^D . Individual curves for each rat are shown. When food was possible in S^D , it was always delivered on a 1-min VI schedule.

Fig. 3. Sample cumulative response curves for rats No. 4 and 5 under three different combinations of food and shock frequency. Downward deflections in the records indicate S^D offsets and upward deflections indicate S^D onsets. Shocks are shown by short vertical pips above the records. Each record comprises a complete session from one of the last five days of a test phase with the indicated procedure.

much less hesitation and vacillation in the runway.

Figures 3 and 4 present sample cumulative response curves for three of the subjects on several different schedule combinations. Each subject exhibited a decline in total S^D -time as the relative shock frequency increased, and maximal oscillations occurred when both food and shock were possible in S^D . The cumulative records again illustrate the large individual differences in rate of oscillation that were also obvious in the functions of Fig. 2. Rat No. 6 typically oscillated at a very high and steady rate when food was four times more frequent than shock (see also its data for VI 30" food, VI 2' shock in Fig. 6), whereas rats No. 4 and 5 characteristically had a much lower rate of oscillation on all the schedule combinations tested.

The records in Fig. 3 and 4 may be examined to determine (a) whether S^D terminations were most likely to occur immediately after a shock, and (b) whether there were intrasession changes in oscillatory behavior which might parallel the temporal recovery of performance reported for punished behavior (see Azrin and Holz, 1966). Concerning the former possibility, the records show little close temporal correlation between shock presentations and S^D terminations; S^D terminations often occur in the absence of shock, and shocks themselves do not consistently produce immediate S^D terminations. Similarly, no strong conclusion on

this point could be reached from an inspection of the other cumulative records gathered.

With regard to possibility (b), no very consistent findings can be gleaned from either Fig. 3 or 4 or from all the other records accumulated during this experiment. Certain subjects occasionally produced an extended TO (*i.e.*, 5 to 10 min long) at the very beginning of a session, even before obtaining any food or shocks; since they did oscillate between S^D and TO later in the session, this sort of behavior might be considered analogous to the warmup effects and recovery from punishment reported by Azrin and Holz. However, these effects were by no means reliable or widespread.

A complete summary of the sequence of procedures and the effects of the successive schedule combinations tested in rats No. 3, 4, and 6 is given in Fig. 5 and 6. The S^D -time measures in Fig. 5 reveal quite reliable and reversible effects in rats No. 3 and 6. Time in S^D for these subjects is generally inversely related to the relative frequency of shocks, regardless of the absolute values of the VI schedules used for food and shock. Rat No. 4, however, became rather insensitive to manipulations of food and shock frequency in the latter half of the experiment; only when food was removed (Determination 18 in Fig. 5), did its S^D -time return to a former level. This insensitivity to schedule manipulations was probably not due merely to "adaptation" to shock over a long period of time, because when food was elimi-

Fig. 4. Sample cumulative response curves for rat No. 6 under four different combinations of food and shock frequency. Downward deflections in the records indicate S^D offsets and upward deflections indicate S^D onsets. Shocks are shown by short vertical pips above the records. Each record comprises a complete session from one of the last five days of a test phase with the indicated procedure.

Fig. 5. Median session time spent in S^D over the last five sessions on each schedule combination for rats No. 3, 4, and 6. The numbers above each bar refer to the food and shock VIs (in that order) in effect at the time. Vertical lines within each bar indicate the range of scores from which the medians were calculated.

nated in Determination 18, behavior proved to be very much the same as that displayed during Determination 9, which involved the identical procedure.

In Fig. 6, the median number of oscillations during stabilized performance on each of the successive procedures are shown for the same three rats as in Fig. 5. For rats No. 3 and 6, the schedules which produced the most oscillations were fairly consistently those in which food was more frequent than shock. This was

not so clearly the case for rat No. 4. On the other hand, rat No. 4 consistently exhibited minimal oscillatory behavior when either "No Food" or "No Shock" (or both) was scheduled, as did rat No. 6. One of the obvious features of Fig. 6 is the large amount of variability that is often present around the plotted medians. It remains to be determined whether such variability is an intrinsic property of behavior when both positive and negative reinforcement have been associated with a specific stim-

Fig. 6. Median number of oscillations per session over the last five days on each schedule combination for rats No. 3, 4, and 6. The numbers above each bar refer to the food and shock VIs (in that order) in effect at the time. Vertical lines within each bar indicate the range of scores from which the medians were calculated.

ulus, or whether it developed out of the particular schedule sequences used or the specific history of the subjects.

In any event, the maximum and minimum values exhibited in Fig. 6 indicate that oscillatory behavior may vary over a wide range. The fact that different combinations of food and shock frequencies are required in different subjects to produce maximal oscillation effects, together with the complementary data on shock intensity presented earlier and in Hearst and Koresko (1964), imply that the present technique necessitates a variety of parametric adjustments during training of an individual rat in order to obtain optimal performance. And, it was noted above that, even after such adjustments, individual sensitivity to manipulations of certain independent variables may occasionally change over many weeks of experimentation so that further adjustment may be required. As is apparently the case with many methods of studying conflict, behavior in this situation is not as stable as might be hoped.

The present procedure resembles that used in several other experiments (e.g., Azrin, 1961; Appel, 1963; Hundt and Premack, 1963; Lockard, 1963) in which subjects could initiate as well as terminate a specific set of experimental conditions. In those studies, however, only positive reinforcement was programmed during the "on" condition. Despite the absence of explicit negative reinforcement, subjects often terminated the "on" condition and then produced it again. In the present study, oscillations were not very frequent when only food was possible in S^D , especially during the early phases before shock was first introduced (see pp. 77). It may be true that subjects will occasionally initiate and terminate a stimulus associated only with positive reinforcement, but they will clearly oscillate much more frequently when explicit negative reinforcement is included in the stimulus.

REFERENCES

- Appel, J. B. Aversive aspects of a schedule of positive reinforcement. *J. exp. Anal. Behav.*, 1963, **6**, 423-428.
- Azrin, N. H. Time-out from positive reinforcement. *Science*, 1961, **133**, 382-383.
- Azrin, N. H. and Holz, W. C. Punishment. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application*. New York: Appleton-Century-Crofts, 1966, pp. 380-447.
- Bitterman, M. E. Behavior disorder as a function of the relative strength of antagonistic response-tendencies. *Psychol. Rev.*, 1944, **51**, 375-378.
- Hake, D. F. and Azrin, N. H. Conditioned punishment. *J. exp. Anal. Behav.*, 1965, **8**, 279-293.
- Hearst, E. Escape from a stimulus associated with both reward and punishment. *J. comp. physiol. Psychol.*, 1963, **56**, 1027-1031.
- Hearst, E. and Koresko, Minnie B. Self-presentation and self-termination of a conflict-producing stimulus. *Science*, 1964, **146**, 415-416.
- Herrnstein, R. J. Relative and absolute strength of response as a function of frequency of reinforcement. *J. exp. Anal. Behav.*, 1961, **4**, 267-272.
- Hundt, A. G. and Premack, D. Running as both a positive and negative reinforcer. *Science*, 1963, **142**, 1087-1088.
- Kelleher, R. T. and Gollub, L. R. A review of positive conditioned reinforcement. *J. exp. Anal. Behav.*, 1962, **5**, 543-597.
- Lockard, R. B. Some effects of light upon the behavior of rodents. *Psychol. Bull.*, 1963, **60**, 509-529.
- Miller, N. E. Experimental studies of conflict. In J. McV. Hunt (Ed.), *Personality and the behavior disorders* (Vol. 1). New York: Ronald Press, 1944, pp. 431-465.
- Miller, N. E. Liberalization of basic S-R concepts: Extensions to conflict behavior, motivation, and social learning. In S. Koch (Ed.), *Psychology: A study of a science* (Vol. 2). New York: McGraw-Hill, 1959, pp. 196-292.
- Tolcott, M. A. Conflict: A study of some interactions between appetite and aversion in the white rat. *Genet. Psychol. Monogr.*, 1948, **38**, 83-142.
- Valenstein, E. S. and Valenstein, T. Interaction of positive and negative reinforcing neural systems. *Science*, 1964, **145**, 1456-1458.
- Winnick, Wilma A. Anxiety indicators in an avoidance response during conflict and nonconflict. *J. comp. physiol. Psychol.*, 1956, **49**, 52-59.

Received February 14, 1966