*SCHEDULES OF FOOD POSTPONEMENT.
II. MAINTENANCE OF BEHAVIOR BY
FOOD POSTPONEMENT AND EFFECTS
OF THE SCHEDULE PARAMETER*

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In Experiment I, food-deprived, feeder-trained squirrel monkeys pressed a lever to postpone brief electric shocks (Response-Shock=Shock-Shock interval=30 seconds). Forty-one three-hour sessions of shock postponement were followed by 120 sessions of concurrent shock and food postponement. The shock schedule was unchanged and the food schedule was Response-food interval=20 seconds, Food-food interval 10 seconds. After concurrent shock and food postponement, the shock schedule was discontinued and 40 sessions of food postponement ensued, followed by 53 sessions of extinction. After extinction, food postponement was resumed for 11 sessions. Stable responding with low food rates was maintained under food-postponement after the concurrent schedule. Responding decreased to low levels under extinction and recovered immediately to previous levels when the food-postponement schedule was re-instated. In Experiment II, a parameter of the food-postponement schedule was studied sequentially. Using the same subjects, the Response-food-Food-food interval was manipulated from four seconds to 80 seconds with several orders of presentation. Relations of response rates and food rates to the parameter were similar to those seen under shock postponement. Exposure to very short postponement times (four seconds), resulting in very high food rates, decreased but did not abolish subsequent responding at longer postponement times. Results are discussed from the point of view that reinforcing functions of stimuli consequent on responding depend on a prior history of scheduled contact with those stimuli.

Key words: food postponement, shock postponement, avoidance schedules, free-operant avoidance, concurrent schedules, schedule history, schedule control, law of effect, squirrel monkeys

Effects of environmental events on behavior depend on specific relations between behavior and those events, *i.e.*, a schedule of reinforcement. In addition, contemporary effects of stimuli consequent on responses depend on a particular history of schedule-controlled exposure to those stimuli (*cf.*, Morse and Kelleher, 1970, 1977). The elements of such a history include both a pattern of behavior unfolding in time up to a present pattern and a sequence of schedules determining the consequences of responding up to a current schedule. The current effect of a particular

scheduled consequence on behavior may be seen as the outcome of the interaction of both elements in such a schedule history. This view is readily supported from the analysis of behavioral effects of electric shocks. Under different circumstances, behavior can be maintained by shock postponement (Sidman, 1953), by response-independent shock presentation (Herrnstein and Sidman, 1958; Kelleher, Riddle, and Cook, 1963), or by production of shock (Kelleher and Morse, 1968; McKearney, 1968, 1969, 1970; Morse and Kelleher, 1970, 1977). Production of shock can both maintain and suppress responding in the same context (Kelleher and Morse, 1968; McKearney, 1972). Depending on ongoing behavior and present and past schedule conditions, signalled response-independent shocks can either increase or decrease responding (Barrett, 1975; Blackman, 1968*a, b*). Finally, many of the contextual and historical conditions that determine the nature and direction of effects of electric shock on behavior can be specified.

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Schedule histories leading to diverse effects of controlling events other than electric shock have been less extensively investigated, yet there are many parallels in schedule-determined effects of food and drugs as response consequences (*cf.* Morse and Kelleher, 1977). It is commonly recognized that schedules of food production can lead to either increased or decreased responding relative to an earlier state. The temporal patterning of behavior under schedules of food production is also a function of prior schedule contact. And, as in the case of electric shock, signalled response-independent food presentations can either increase or decrease responding (Herrnstein and Morse, 1957; Smith, 1974). Many of the schedule and contextual variables determining the direction of such effects are the same as in the case of electric shock.

In a previous experiment (Smith and Clark, 1972), we studied schedules of food postponement with food-deprived rats. The schedules used were identical to the two-parameter, free-operant, shock-postponement schedule developed by Sidman (1953). Under this schedule, food is presented periodically when no response occurs (Food-Food interval). Responses initiate a second interval, which is reset by additional responses and terminates with food delivery (Response-Food interval). Response rates were found to be related to temporal parameters of this schedule in much the same way as under schedules of shock postponement. Behavior was also maintained under food postponement when responding led to substantial reductions from potential food rates. However, response rates were lowered when the Response-Food interval equalled or exceeded the Food-Food interval, and responding could be abolished by lowering the Food-Food interval until very high food rates actually occurred. Temporal patterns of responding under food postponement did not much resemble maintained free-operant, shock-avoidance behavior. Most responses occurred in bursts following food delivery. Finally, all subjects in the earlier experiment had a history of food production (Response-Food interval=0) before food postponement.

The present experiments were undertaken to examine some interactions between schedules of shock and food postponement and to explore the possibility of maintaining be-

havior for extended periods under food postponement without a prior history of food production by the same response. Because of the long-term nature of the experiments, squirrel monkeys were used.

EXPERIMENT I: MAINTENANCE OF BEHAVIOR BY FOOD POSTPONEMENT AFTER CONCURRENT FOOD AND SHOCK POSTPONEMENT

METHOD

Subjects and Apparatus

Three adult, male squirrel monkeys were maintained at 80 to 85% of free-feeding weights. Animals' weights were maintained by feeding a constant ration 30 min after experimental sessions. Food was the same monkey diet used in the experiments (see below). Adjustments in an individual's ration were made occasionally in order to maintain weights in the desired range.

Experimental chambers have been described previously (Clark, 1969; DeLonge and Clark, 1971). In brief, animals were unrestrained inside cages 27 cm high, 30 cm long, and 25 cm wide (modified Scientific Prototype Model A-103). Each cage had a Switchcraft lever switch centered on one cage end 14 cm below the lid. Lever switches were outfitted with a machined aluminum rod projecting 4.5 cm into the cage. Depression of the switch handle produced an audible relay click. Directly below the lever was a dipper feeder (Ralph Gerbrands Model B). The recessed food aperture was partially masked with clear plastic so that food could be obtained only with a paw. Operation of the feeder introduced about 0.3 ml of semi-liquid food into the aperture for 1.75 sec. During the feeder cycle two, 3-W houselights were turned off and the food aperture and plastic mask were illuminated. Food was prepared from Standard Monkey Diet SK&F (Nutritional Biochemicals, Inc.) by blending with water and cottonseed oil, using methyl cellulose as an emulsifier. A pushbutton response key mounted above the lever was not used in these experiments. Electric shocks were delivered through a floor consisting of seven stainless-steel rods 1.5 cm in diameter extending between cage ends on 3-cm centers.

Shocks were produced by Grason Stadler Model 700 shock generators set for 0.5-sec duration and maximum current of 3 mA.

Experimental cages were mounted inside ventilated plywood chambers. Houselights and white noise were on during experimental sessions and water was continuously available. Subjects could be viewed through a wide-angle lens. Electromechanical programming and recording equipment was located at a distance from experimental chambers in the same room.

Procedure

Monkeys were trained to eat from the dipper feeders with levers removed from the experimental cages. Feeder training lasted three to four weeks, weights being reduced to 80 to 85% during the same period. During the initial phase of feeder training, food was never available in the home cage and feeder cycles were several seconds in duration. As a feeder discrimination was formed, the cycle was gradually reduced to 1.75 sec and a daily ration was made available in the home cage.

After feeder training, levers were installed in experimental cages, feeders were disconnected, and the three monkeys (M21, M24, and M25) were trained under a free-operant, shock-avoidance schedule (Sidman, 1953) for 41, 3-hr sessions. Sessions were scheduled five days each week. During avoidance training, Response-Shock and Shock-Shock intervals were both 30 sec ($RS=SS=30$ sec). That is, each lever response initiated or restarted a 30-sec shock-free period, and in the absence of responses shocks occurred every 30 sec (Clark and Hull, 1966).

After 41 sessions of shock avoidance, 120 sessions of concurrent food and shock postponement were scheduled. Sessions continued to be 3 hr in duration, and the Response-Shock=Shock-Shock interval remained at 30 sec. The food-postponement schedule (Smith and Clark, 1972) had a Response-Food interval of 20 sec and a Food-Food interval of 10 sec ($RF=20$ sec, $FF=10$ sec). That is, each lever response initiated a 20-sec period in which food was not delivered and each feeder operation initiated a similar 10-sec period. Thus, in the absence of lever presses, food was delivered every 10 sec. Responses during the FF interval terminated the interval and initiated a 20-sec (RF) interval with-

out food. Subsequent responses reset the RF interval. Except for the postponed event, this food schedule is identical to the free-operant, shock-avoidance schedule developed by Sidman (1953). Under the concurrent schedule ($RR=SS=30$ sec, $RF=20$ sec, $FF=10$ sec), conditions resulting in food delivery were the same, but in addition, a pause of 30 sec resulted in a shock. Under this particular schedule, a coincidence of food and shock delivery was possible. For example, in a pause of 30 sec or more, food would occur after 20 sec and food plus shock after 30 sec. Timers were arranged so that, in a coincidence of food and shock, shock occurred 0.5 sec after onset of the feeder cycle.

After 120 scheduled sessions of concurrent shock and food postponement, the shock schedule was removed and the food-postponement schedule alone continued for an additional 40, 3-hr sessions. Parameters of the food schedule remained at $RF=20$ sec, $FF=10$ sec.

Following 40 sessions of food postponement, the food schedule was terminated and extinction was in effect for 53 sessions. For the first 20 days of extinction, sessions were 3 hr in duration; the next 25 sessions lasted 2 hr, and on the final eight days of extinction, there were three, successive 1-hr sessions each day, with an additional requirement that each session end with a 1-min pause in responding. That is, each session ended after 1 hr if no response occurred in the last minute. Otherwise, a session ended with the first 1-min pause after 1 hr.

After extinction, the food-postponement schedule ($RF=20$ sec, $FF=10$ sec) was re-instated for 11 sessions. The first session consisted of 1 hr of extinction followed immediately by 2 hr of food postponement. Subsequent food-postponement sessions were 3 hr in duration.

RESULTS

Figure 1 shows performance of Monkey M21 on the last day of shock postponement and on the first and twenty-fifth days of concurrent food and shock postponement. Cumulative records show an entire session in each case. Note that three food-shock coincidences (dots above record) occurred on the first day of the concurrent schedule. Otherwise, the records show performances typical of the squirrel monkey under free-operant avoidance schedules.

Fig. 1. Cumulative records of responding on the last day of shock avoidance and the first and twenty-fifth days of concurrent shock and food avoidance (Monkey 21). Complete 3-hr sessions are shown in 1-hr segments. Slash marks on records of concurrent food and shock postponement indicate food delivery. Dots above slash marks indicate simultaneous food and shock delivery.

Figure 2 shows characteristics of responding by all three monkeys during the first 200 sessions of Experiment I. Data at the left are from the last 10 sessions of shock postpone-

ment. Data in the center are from the first and last 15 sessions of concurrent shock and food postponement, 90 intervening sessions being omitted. Data on the right are from

40 sessions of food postponement without shock. The upper frame of Figure 2 shows daily mean response rates for each monkey. The five points obtained within each week are joined. The lower two frames show food rates according to whether food delivery resulted from the RF or the FF intervals, respectively. Points represent session totals. During shock postponement only (Sessions 31 to 41), when no food was delivered, the number of interresponse times (IRTs) between 20 and 30 sec, and the number of shocks (IRTs > 30 sec) are plotted in lieu of RF and FF food deliveries, respectively. Except on the first day of concurrent food and shock postponement, the number of FF food deliveries and the number of shocks was the same throughout this treatment. That is, successive FF food presentations did not occur after the first session. Most of the observations in the lower frame of Figure 2 would be zeroes. To avoid cluttering the figure along the x-axis, these are not plotted. The lower frame shows only nonzero FF food (or shock) rates. Missing points elsewhere in Figure 2 indicate missed sessions or lost data.

The top frame of Figure 2 shows that response rates of all three monkeys increased after the food schedule was introduced (Session 42). However, after the first week of concurrent food and shock postponement, rates of responding returned to levels similar to those seen previously under the shock schedule alone. Only M24 continued to respond more rapidly under the concurrent schedule. The number of IRTs from 20 to 30 sec (second frame, Figure 2) decreased when the food schedule was introduced and pauses of 20 sec resulted in food presentations. Except for Monkey M25, food rates under the concurrent schedule remained very low. Shock rates were also lower after the food schedule was introduced. Only shock totals greater than zero are plotted in the lower frame of Figure 2. Although 120 sessions of concurrent shock and food postponement were scheduled, each monkey missed some sessions. During concurrent shock and food postponement, Monkey M21 received a total of 24 shocks in 109 sessions, M24 received 12 shocks in 115 sessions, and M25 received 36 shocks in 113 sessions. Thus, very few shocks were received under the concurrent schedule. The total number of shocks received by each monkey is, of

course, the same as the number of food-shock pairings for each monkey.

The right-hand portions of Figure 2 show that removal of the shock schedule after Session 161 had little effect on responding. Responding under the food-postponement schedule was maintained for 40 sessions over a period of eight weeks. Except for a transient increase in M21 during the fourth and fifth weeks, response rates under food postponement remained about the same as under the concurrent schedule. RF food deliveries (IRTs from 20 to 30 sec) remained low in M21 and M24 and decreased in M25. FF food deliveries, which were no longer accompanied by shocks, remained low except for a transient increase in M25 during the second week.

Figure 3 shows records of the performance of each monkey on the last day of food postponement (Session 201). Except that RF food deliveries occurred in each case, these records illustrate performances typically seen in squirrel monkeys under free-operant, shock-avoidance schedules.

After the 40 sessions of food postponement (RF=20, FF=10) shown in Figure 2, extinction was instituted by terminating the food schedule. Results appear in Figure 4, where response rates are plotted for the last five days of food postponement, for 53 days of extinction, and for 11 days of food postponement following extinction. During the first 20 days of extinction, daily sessions were 3 hr in duration. Results differed among the subjects. For the first five sessions, Monkey M21 continued to respond at about the same rate as under the food-postponement schedule. Thereafter, responding by M21 decreased, reaching very low levels by the fourth week (sixteenth to twentieth sessions) of extinction. Response rates of M24 decreased much less during the first 20 sessions of extinction, and at the same time, variability between sessions increased greatly. On the other hand, responding by M25 dropped precipitously on the first day of extinction to a rate of fewer than three responses per minute, but showed little variability and no trend for the next 20 sessions.

After 20, 3-hr extinction sessions (Day 221 in Figure 4), response rates of M21 were very low, average rates of M24 were about half those seen under food postponement but varied greatly, and rates of M25 were stable at about one-third the value obtained pre-

Fig. 2. Rate of responding (upper frame) and total food presentations (lower two frames) as a function of sessions for all three monkeys. Data are shown for the last 10 of 41 sessions of shock avoidance (shock only), for the first and last 15 sessions of concurrent shock and food postponement (90 sessions being omitted), and for 40 sessions of food postponement without shock. Food presentations are shown separately in the lower two frames according to whether they resulted from termination of the RF or the FF interval. Under shock only, IRTs from 20 to 30 sec are plotted in lieu of RF food presentations and shocks in lieu of FF food deliveries. Under the concurrent shock and food schedule, the number of FF food presentations is the same as the number of shocks. Zeroes, which constitute most of the entries, are not plotted in the lower frame.

Fig. 3. Cumulative records of responding by all three monkeys on the last day of the food-postponement schedule without shock. Records are arranged as in Figure 1.

viously under food postponement. During this time, a phenomenon that has been observed previously in extinction (*e.g.*, Clark, 1964) took place. After a number of sessions

in which responding decreased progressively during the session, response rates toward the end of the session began to increase. This change, which was most evident in M21 and

Fig. 4. Rate of responding during extinction after food postponement for each monkey. Mean rates during the last five sessions of food postponement appear at the left (Sessions 197 to 201). After 53 days of extinction, the food-postponement schedule (RF=20 sec, FF=10 sec) was re-instated. Data from 11 days of food postponement following extinction appear at the right.

M24, progressed until extinction performance resembled that maintained under a long fixed-interval schedule. Little responding occurred early in the extinction session, followed by an increase in responding near the end of the session. Our interpretation of this is that termination of the extinction session was maintaining responding. Subsequent changes in the extinction procedure were partly based on this interpretation, which suggests that low average rates would be maintained indefinitely.

After 20, 3-hr extinction sessions, daily session duration was decreased to 2 hr (Day 222 in Figure 4). Two-hour sessions were continued for 25 experimental days. Shortening the session had no initial effect on average response rates of M21 or M25. Rates of M24 increased initially and then declined over the remaining 25 sessions. Responding by M25 also decreased to low levels over this period, but rates of M21, which had been lowest under 3-hr sessions, increased. By the end of the treatment, responding by M25 had extinguished, but rates of about 200 responses per

hour continued to be maintained in M21 and M24. These animals displayed the fixed-interval pattern mentioned above.

At this point (Day 247 in Figure 4), a procedure was instituted to prevent lever presses from immediately preceding termination of extinction, and hence to break up the fixed-interval pattern in M21 and M24. Each daily treatment consisted of three successive 1-hr extinction periods, with the added condition that no lever responses occur in the last minute of each period. Responses in the last minute of the hour, or thereafter, extended the session by 1 min. This procedure continued for eight successive days (Days 247 through 254 in Figure 4). The result was a rapid decrease in average rates of M21 and M24, although some responding toward the end of sessions continued. By the last day of extinction, these animals were responding at rates of about 100 responses per hour. Lever-pressing rates of M25 continued near zero.

The food-postponement schedule (RF=20 sec, FF=10 sec) was re-instated after extinction. Results appear in the right section of

Figure 4. On the first day of food postponement after extinction, the session consisted of 1 hr of extinction followed by 2 hr of food postponement. Ten subsequent sessions consisted of 3 hr of food postponement. Rates plotted in Figure 4 for the first session are based on the last 2 hr when the food schedule was in effect.

Fig. 5. Cumulative records of responding when food postponement was re-instated (Day 255 in Figure 4). Extinction was in effect for the first hour of the session and food postponement (RF=20 sec, FF=10 sec) for the last 2 hr. The figure shows 20 min preceding and following re-instatement of the food schedule. The recorder reset at the end of the extinction period.

It is apparent in Figure 4 that food-postponement rates returned immediately to levels seen before extinction and remained stable thereafter. The transition from extinction to food postponement is shown in Figure 5. This shows cumulative records of performance of all three monkeys for 20 min preceding and following re-instatement of the food schedule on Day 255. The recorder reset lines in Figure 5 indicate the total number of responses in the preceding hour of extinction. Appreciable responding during extinction occurred only in M21. This was in accordance with the fixed-interval pattern described above. Upon re-instatement of the food schedule, all three monkeys assumed rates and patterns of responding seen before extinction.

EXPERIMENT II: FOOD POSTPONEMENT AS A FUNCTION OF THE RESPONSE- FOOD-FOOD-FOOD INTERVAL

Experiment I showed that, given an appropriate history, behavior could be maintained for extended periods on schedules of food postponement. Experiment I showed further that continued maintenance of behavior depended on the food-postponement schedule. Experiment II was concerned with effects of the parameters of food-postponement schedules on characteristics of responding. With equal Response-Food and Food-Food intervals, this temporal parameter was manipulated sequentially over a range comparable to that used in parametric experiments on shock postponement (Clark and Hull, 1966; Sidman, 1953).

METHOD

Subjects and Apparatus

The same three monkeys served with the same apparatus as in Experiment I.

Procedure

With equal Response-Food (RF) and Food-Food (FF) intervals in a free-operant, food-postponement schedule, the time between food deliveries in the absence of responding is equal to the interval by which each response postpones food. Analogous shock-postponement schedules have been studied by Verhave (1959) and Clark and Hull (1966). In the present experiment, the RF=FF interval was first manipulated in an ascending series of treatments from RF=FF=10 sec to RF=FF=80 sec. A second series of treatments then examined postponement intervals from 20 sec to 4 sec in descending order, followed by re-exposure to RF=FF=15 sec. Only M21 and M24 were used in the second series. (Following the first series of treatments, M25 displayed a progressive loss of limb function. This was diagnosed as arthritis and prevented use of M25 in the second series of treatments. This animal was later sacrificed as the disease progressed.) The duration of experimental sessions in both series of treatments was varied with the RF=FF interval in a manner designed to prevent satiation from very large numbers of food deliveries within a session. Each schedule was studied

Table 1

Order, duration, and number of sessions for each subject under each schedule during manipulation of the food postponement (RF=FF) interval.

Schedule	Session Duration	Number of Sessions		
		Monkey M21	Monkey M24	Monkey M25
RF=FF=10 sec	60 min	13	12	10
RF=FF=15 sec	90 min	12	11	13
RF=FF=20 sec	120 min	12	12	13
RF=FF=40 sec	180 min	16	20	17
RF=FF=80 sec	180 min	21	20	23
RF=FF=20 sec	120 min	10	9	—
RF=FF=15 sec	90 min	12	13	—
RF=FF=10 sec	60 min	7	7	—
RF=FF=6 sec	30 min	10	9	—
RF=FF=4 sec	30 min	10	10	—
RF=FF=15 sec	90 min	8	8	—

until daily average rates of responding showed no trend. The order, duration, and number of sessions for each animal under each schedule are given in Table 1.

RESULTS

Individual rates of responding as functions of the RF=FF interval during both series of treatments are presented in the left panel of Figure 6. Corresponding individual rates of food delivery appear in the right panel. Points represent the average rate for each of the last three sessions under each schedule. Straight lines join the means of the three sessions plotted under each schedule. Unfilled points represent data from the ascending series of schedules from RF=FF=10 sec to RF=FF=80 sec. Filled points represent data from the second series of schedules beginning at RF=FF=20 sec, descending to RF=FF=4 sec and returning to RF=FF=15 sec. Arrows between the filled points indicate the order of treatments.

As the postponement interval increased from RF=FF=10 sec to 80 sec (unfilled points, left panel Figure 6) response rates of all monkeys decreased in a negatively accelerated fashion. Response rates of all three monkeys at RF=FF=10 sec were on the order of 1200 to 1400 responses per hour, and decreased monotonically up to RF=FF=40 sec. At longer RF=FF intervals, rates of M24 were much higher than those of the other two animals. Except for the higher rates at shorter postponement time in Figure 6, these functions from the ascending series are similar to those

obtained under shock postponement in rats (Clark and Hull, 1966, Figure 2).

The unfilled points in the right panel of Figure 6 show that changes in response rate as the RF=FF interval increased from 10 to 80 sec were not accompanied by major changes in food rates. Food rates were only slightly higher at the shorter RF=FF intervals. (There are a number of coincident points.) Parametric data on shock postponement in squirrel monkeys are lacking in the literature. The low food rates maintained from RF=FF=10 sec to 20 sec in Figure 6, however, are in agreement with the general observation that squirrel monkeys maintain very low shock rates in this range under shock postponement. Similar results are also obtained from this species under postponement of other maintaining events (*e.g.*, Clark, Lange, and Belleville, 1973).

After the ascending series of schedules, the RF=FF interval was decreased from 20 sec to 4 sec in five steps, and then increased again to 15 sec. Only M21 and M24 served in this second series of treatments. The filled points in Figure 6 represent data from the second series. Rates of responding at RF=FF=20 sec after RF=FF=80 sec were comparable to those obtained at 20 sec in the first series, except for a small decrease in M24. Response rates of M21 increased from RF=FF=20 sec to 15 sec and then decreased at 10, 6, and 4 sec. Responding by M21 decreased further when RF=FF=15 sec was repeated after 4 sec. Responding of M24 increased at postponement times of 15 and 10 sec and decreased at 6 and

Fig. 6. Rate of responding (left panel) and food rate (right panel) as functions of Response-Food equals Food-Food (RF=FF) interval. Each frame shows results for one monkey. Unfilled points are from the ascending series from RF=FF=10 sec to 80 sec. Filled points are from the descending-ascending series beginning at RF=FF=20 sec descending to 4 sec and ending at RF=FF=15 sec. Arrows between filled points indicate the order of treatments. Individual points are means for the last three sessions under each schedule.

4 sec. Responding at RF=FF=15 sec after 4 sec was also lowered in M24 relative to earlier exposures of that schedule, but not as much as in M21. Thus, exposure to very short RF=FF intervals (and concomitantly high food rates) did not eliminate responding in either

monkey, although it did lower subsequent response rates at longer RF=FF intervals.

Changes in food rates during the second series of schedules are shown by the filled points in the right panel of Figure 6. Food rates increased markedly at 10, 6, and 4 sec

MONKEY M25

Fig. 7. Cumulative records of performance by Monkey M25 at different RF=FF intervals. Each record shows the entire final session at the schedule parameter indicated. All schedules in the ascending series except RF=FF=40 sec are shown. Records are arranged in half-hour segments.

for M21, but increased only at 6 and 4 sec in M24's data. Recovery at RF=FF=15 sec was as expected from the response-rate data: M21 maintained food rates of about 150 per hour on this schedule after exposure to RF=FF=4 sec, while M24 maintained food rates nearly as low as previously. It should be noted that food rates under RF=FF=4 sec are about as high as can be obtained under these schedules. The RF=FF interval includes the feeder cycle, and monkeys cease eating during some feeder cycles at postponement times shorter than 4 sec.

Cumulative records of representative performances during Experiment II are shown in Figures 7, 8, and 9. In each case, the entire

last session under the indicated schedule is shown. Figure 7 shows performance of M25 from RF=FF=10 sec to RF=FF=80 sec in the first series. All schedules are shown except RF=FF=40 sec. This animal exhibited the widest range of response rates obtained, the rate at RF=FF=10 sec being about the same as for M21 and the rate at RF=FF=80 sec being considerably lower than in the other animals. Similar data from Monkey M24 during the first series appear in Figure 8. This animals' rate decreased much less at longer postponement times.

Finally, Figure 9 shows performance of M24 under all schedules used in the second series of treatments. The schedules are ar-

MONKEY M24

Fig. 8. Performance of Monkey M24 at different RF=FF intervals in the ascending series. Records are arranged and labelled as in Figure 7.

ranged in the order of their occurrence. The lowered response rate and higher food rate at the beginning of the session under RF=FF=15-sec at the bottom of the figure occurred regularly after exposure to RF=FF=4 sec. However, when this animal was studied later under RF=FF=20 sec after six months in the home cage, performance was the same as that seen above in Figure 8. Behavior of M21 under RF=FF=20 sec after six months in the home cage was also the same as that displayed before exposure to very short RF=FF intervals.

DISCUSSION

The chief finding of the present experiments is that, after concurrent shock and food avoidance, behavior was maintained indefinitely by food postponement. The temporal

distribution of responses under food postponement was similar to that usually seen under free-operant shock avoidance. At the same time, animals ate vigorously whenever food occurred. Thus, eating continued to be controlled by food in the usual way. These results are not due to a failure of extinction to occur after shock-avoidance training. Lever pressing could be extinguished in the absence of the food schedule and was reconditioned immediately on re-instatement of food postponement. The persistence of behavior under food postponement was impressive. In these experiments, Monkey M21 responded under various schedules for 152 sessions and M24 for 190 sessions, excluding extinction, after the last shock was received. In Experiment II, rates of responding were related to the postponement interval in the same way as under shock postponement over the range

MONKEY M24

Fig. 9. Performance of Monkey M24 at different values of the postponement interval during the descending series followed by recovery at $RF=FF=15$ sec. All schedules except $RF=FF=20$ sec are represented in the order of their occurrence. In each case, the last session is shown.

from 10 to 80 sec. Appreciable order effects of the schedule parameter occurred only after exposure to very short postponement times (4 sec) with attendant very high food rates. Even this did not eliminate responding either at $RF=FF=4$ sec or subsequently at longer intervals ($RF=FF=15$ sec), although response rates were lowered in the latter case.

These results regarding the persistence of food postponement and characteristics of responding as a function of the schedule parameter must flow from the particular schedule-behavior interactions established during prior shock postponement and concurrent food and shock postponement. It is obvious that animals with other schedule histories do not respond steadily to avoid food, yet eat when food is presented. Certain features of the his-

tory of schedule contact in these experiments immediately suggest themselves as relevant. Shock-avoidance behavior is notoriously slow to extinguish. But the possibility that nothing but slow avoidance extinction was being observed after discontinuance of the shock schedule was virtually eliminated by extinction and reconditioning in Experiment I. Another possibility is that the pairings of food and shock that occurred occasionally under the concurrent schedule established food as a conditioned aversive stimulus. Further research with schedule interactions in which food-shock coincidences cannot occur will be required to answer this definitively. However, this possibility gains little credence from the observation that behavior was maintained for about a year after, at most 36 pairings of food and shock. A related possibility is that food may have become a conditioned aversive stimulus by becoming a signal for impending shock, and hence a discriminative stimulus for behavior controlled by shock postponement. This hypothesis is more intractable. It may be, in fact, incapable of disconfirmation, and hence, lacking in empirical utility. The same objections may be brought forth as in the case of pairings, but it is difficult to conceive of concurrent schedules in which temporal relations among successive events would not leave the hypothesis untouched. This hypothesis also suggests no distinction between schedule histories that do and do not lead to persistent food postponement. But such a distinction obviously exists. Investigation of subtler aspects of schedule-behavior interaction seems more likely to bear fruit. To quote Kelleher and Morse: "The performances studied in these experiments (on response-produced shock) depend relatively more on the characteristics of the ongoing behavior and less on the intrinsic properties of the shock than is the case in many experiments using food. In most experiments using response-produced electric shock, there is some ongoing responding when the shock is introduced; whereas in most experiments using food as a reinforcer it is initially presented following a response that is occurring infrequently. Since the effect of consequent stimuli depends in part on the quantitative properties of the preceding behavior, electric shock would be expected to have a wide range of effects when it is intro-

duced following a range of patterns and rates of responding." (Kelleher and Morse, 1968, p. 837.) In the present experiments, food was first introduced into an ongoing pattern of behavior occurring at a substantial rate. The initial effects of introducing food were limited to some shifting in the distribution of interresponse times, with little effect on overall rates of responding. The conditions were also such that high food rates did not occur, although they were possible under the schedule used. It is likely that the ongoing behavior pattern and the initial rate of the controlling event are no less important in determining effects of food than in the case of shock.

Certain characteristics of postponement schedules themselves can also be related to the present results and those of our previous experiment (Smith and Clark, 1972). Since postponement schedules have traditionally been used only with noxious events as consequences, it is probable that some properties of behavior under such schedules have been attributed incorrectly to the maintaining event, rather than to the schedule. Operations involving delay between a response and a consequent event have been conventionally treated in terms of the concept of "delay of reinforcement" (or delayed punishment). Dews (1960) was apparently the first to use a food-delay schedule in which all responses postponed food (*i.e.*, "reset the delay"). A free-operant postponement schedule (Sidman, 1953) can be seen as a disjunction of a delay schedule with reset (the RS or RF interval) and a schedule of response-independent stimulus presentation (the SS or FF interval). The response-independent component modulates the effect of the postponement component (Sidman, 1953; Smith and Clark, 1972). In the present experiments, the concurrent food and shock-postponement schedule contains at least four elements: two postponement contingencies for two different events, each with a particular value, and two schedules of response-independent presentation, also for different events and with different values. As remarked above, the particular pattern of ongoing behavior at the time of introduction of the food schedule (itself the product of an earlier schedule) is probably also a critical determinant of the outcome. Obviously, among these many virtually uninvestigated variables, a guess at the particular combina-

tions responsible for the persistence and tractability of behavior under food postponement would be foodhardy. A great deal of further research will be required. It may be remarked, however, that from the point of view of "delayed reinforcement", the use of postponement schedules with food would hardly seem logical, and such experiments would probably not be undertaken. As a matter of fact, the present and previous experiments (Smith and Clark, 1972) with these procedures were the outcome of a deliberate consideration of procedural sequences inverse to those used with electric shock by Kelleher and Morse (*e.g.*, 1968).

The literature on effects of electric shock, cited in part in the introduction, indicates that presentation of shock can maintain responding (function as a positive reinforcer) if the history of behavioral contact with shock falls within some class. This class is not yet completely specified. The present results indicate that postponement of food can maintain responding if the history of behavior-food contact falls in another class. Even less is known about this class. An obvious generalization is that the behavioral effects of all stimuli depend on some history of schedule contact with respect to specific responses. Because of traditional assumptions regarding reinforcement and punishment, usually not stated explicitly, many laboratory and commonplace examples of qualitative or quantitative changes in effects of consequent events are commonly ignored (*cf.* Morse and Kelleher, 1977). In changing from one schedule of reinforcement to another, the magnitude and/or direction of local effects on responding are usually altered on each occurrence of the controlling event. In second-order schedules (*e.g.*, Kelleher, 1966), the interweaving of two schedules of production of different events can render a previously neutral stimulus a reinforcer. Outside the laboratory, particular kinds of food usually become reinforcers because a history of contact with them usually falls in a special class (*e.g.*, weaning). When weaning does not take place, nutritive substances may not acquire reinforcing functions. Similar observations regarding noxious or biologically harmful stimuli are obvious.

Schedules of reinforcement have been considered as logical schemata determining the

conditions under which responses have stimulus consequences with presupposed effects. The resulting schedule control has been thought of as deriving from a process of reinforcement, applied intermittently, and possibly with the aid of ancillary processes such as discrimination. When schedules change and behavior patterns change concomitantly, reinforcement has, nevertheless, been considered to remain constant. But it appears that a sequence of schedules and the reproducible pattern of behavior unfolding in time under such a sequence, taken together, can determine the nature as well as the magnitude of the effects of consequent events. It is small wonder that attempts to catalogue reinforcers or to explain why certain events are reinforcing have failed. It would seem that motivational conceptualizations have been the greatest impediment to analysis. Understanding of the behavioral effects of electric shock has advanced as accounts in terms of fear or anxiety have retreated. An important factor in this was that data from behavioral pharmacology rendered motivational explanations biologically incongruent (*cf. e.g., Kelleher and Morse, 1964*).

Reinforcement theory derives historically from the law of effect. The law of effect involves a direct analogy from the twin Darwinian postulates of random variation and natural selection (*cf. Parsons, 1937, p. 115 ff.*) and derives, in turn, from nineteenth century evolutionary hedonism. Although explicit hedonism has been purged from the denatured law of effect (*e.g., Meehl, 1950; Skinner, 1938*), assumptions regarding the biological basis of reinforcement and punishment remain common. Spencer (1892, pp. 98-99) assumed that consequences of acts that produce pleasure or pain are biologically helpful or harmful, respectively, because organisms for which this is the case have been favored with survival. Thus, the law of effect, or its hedonistic precursor, would itself be a product of evolution (*cf. Skinner, 1966*). The assumption that reinforcement and punishment must be based on the physiological functions of stimuli has persisted. The most articulated recent form of this is drive-reduction theory (Hull, 1943; Richter, 1927). The principle that the reinforcing or punishing functions of stimuli are determined by a history of scheduled behavior-environment interaction may enlarge

the province of psychology among the biological sciences. The concept of schedule determiners may occupy a position similar to that previously held by "association" in accounting both for the flexibility of organisms' adjustments to altered environments, and for failures to survive that result from a disadvantageous combination of the behavioral and biological functions of stimuli.

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