AVOIDANCE RESPONSE RATES DURING A PRE-FOOD STIMULUS IN MONKEYS¹

WENDON W. HENTON

INSTITUTE OF NEUROPHYSIOLOGY
UNIVERSITY OF COPENHAGEN

Free-operant avoidance responding was maintained by a shock avoidance schedule in three monkeys. The frequency of avoidance responses during a stimulus terminated by response-independent food pellet presentation was dependent upon the method of pellet delivery. Avoidance rates were relatively increased when food retrieval responses followed pellet delivery. Avoidance rates were decreased when retrieval responses preceded pellet delivery.

Classical conditioning procedures and operant conditioning procedures may be concurrently scheduled in four general combinations (Millenson, 1967; Rescorla and Solomon, 1967). The effects of a stimulus preceding response-independent food presentation upon a concurrent avoidance response has been the least extensively investigated combination. Grossen, Kostansek, and Bolles (1969) reported that the latency of a shuttle box response was increased during stimuli previously paired with the presentation of food either response-dependent or response-independent. Bull and Overmeir (1969) reported that the rate of a similar avoidance response was decreased when a stimulus associated with a shock avoidance schedule was combined with a stimulus previously paired with food.

The present experiment was a simple exercise of laboratory curiosity: what would happen to operant avoidance rates during a pre-food stimulus when the method of pellet delivery was manipulated? A pre-food stimulus was superimposed upon a concurrent avoidance schedule, and the schedules controlling pellet delivery were manipulated in three phases. In acquisition, two response-independent food pellets remained available in a cup until removed by the subject. In the first reacquisition, the pellets were available only during a limited period and were delivered immediately behind the subject. In the second reacquisition, the limited hold was further

decreased and the pellets were delivered at a distance from the subject.

METHOD

Subjects

Three adolescent male African green monkeys (*Cercocebus aethiops*) were used. Each subject was previously trained for approximately 140 one-hour sessions on a three-component schedule involving two shock avoidance schedules (Sidman, 1966) and a timeout component. A response postponed shock for 30 sec in the presence of a 700-Hz tone, postponed shock for 3 sec in the presence of a 250-Hz tone, and had no scheduled effect in the absence of tone. If no responses were emitted during the tones, shock occurred every 30 sec during the 700-Hz tone and every 3 sec during the 250-Hz tone. The 3-sec avoidance component and the timeout component were 5 min in duration and were randomly presented twice per session. Schedule changes from the 30-sec avoidance component to the 3-sec avoidance component and to the timeout component were preceded by a green light and a red light, respectively, for 60 sessions. Subsequently, the green and red lights were merely presented but not terminated by a schedule change during 15 extinction sessions.

Apparatus

One-hour daily sessions were conducted in an isolated room with the subject positioned in front of a response panel. A 3.55-in. (9 cm) clear plastic response lever, 0.39 in. (1 cm) diameter, operated a microswitch when pressed with a force of 1.5 N. In initial acquisition,

¹This research was supported by a post-doctoral fellowship from the Statens Lægevidenskabelige Forskningsråd. Reprints may be obtained from the author, Universitetets Neurofysiologiske Institut, Juliane Maries Vej 36, Copenhagen, Denmark.

the subjects were placed in a standard primate restraint chair in front of the response panel. The lever was 6 in. (15 cm) in front of the subject's right hand. Food pellets were delivered through a 27 in. (69 cm) plastic tube into a 1.5 by 2.5 by 0.75 in. (4 by 6 by 2 cm) plastic cup. The cup was mounted 0.4 in. (1 cm) in front of the right-hand opening of the upper restraint plate. A 2.75 by 1.75 by 1 in. (6.5 by 4.5 by 2.6 cm) 3-w red light was mounted on the response panel 13 in. (34 cm) in front of the subject's head. A 700-Hz tone was presented through a 4-in. (10-cm) speaker mounted behind the response panel. The subject's left foot was secured to a 120 by 50 by 1 mm brass foot plate with Velcro tape. A 7-mA, 1500-v, 0.5-sec ac shock was delivered through wire electrodes attached around the waist and to the plate.

In the first reacquisition procedure, the food hopper and red light were mounted directly behind the subject's head. Food pellets were delivered through a 3.5-in. (9 cm) plastic tube directly into the mouth or fell onto the floor, depending upon the position of the subject's head. All openings of the upper restraint plate were covered with plastic inserts and prevented pellet retrieval with the hands. Additionally, an 18-gauge, 7 by 5.5 in. (18 by 13 cm) sheet metal shield was mounted 2 in. (5 cm) to the left of the response lever. This shield prevented pressing of the lever with the left hand.

In the second reacquisition procedure, the subjects were trained in a 31 by 24 by 20 in. (79 by 60 by 51 cm) metal and plastic cage. The response lever was positioned in the front left corner, 10 in. (26 cm) above the floor. The food hopper and red light were mounted on top of the cage in the back right corner. Food pellets were delivered through a 4 in. (11 cm) plastic tube directly into the subject's mouth or fell onto the floor, depending upon the position of the subject's head. Shock was delivered through the grid floor and flexible wire electrodes that were fastened around the subject's neck.

The experiment was controlled with standard solid state circuits. Responses were recorded with printout counters, a cumulative recorder, and a Nuclear-Chicago 7100 computer. The force exerted on the response lever was recorded with a strain gauge and displayed on a Brush 220 recorder. The subject's be-

havior was routinely monitored on a closed circuit television system.

Procedure

Phase I. All subjects were trained on a free operant avoidance schedule for 25 one-hour daily sessions. A 700-Hz tone was present throughout each session, and the houselights were extinguished. Shocks occurred every 30 sec in the absence of responses, and a press of the lever postponed shock for 30 sec and interrupted the tone for 100 msec. A 15-sec blinking red light (on/off phases = 100 msec) was presented five times within each of the next 10 avoidance sessions (adaptation). Five baseline control trials were also conducted each session in which response frequencies in two consecutive 15-sec periods were merely recorded. All trials were presented in an irregular sequence with intertrial intervals ranging from 10 to 750 sec. No trials, however, were presented during the first 3 min of each session.

Each subject was trained to retrieve food pellets from the delivery cup during additional 15-min sessions following each of the last three adaptation sessions. The houselights were turned on and the response lever was removed during each pellet retrieval session. Two pellets were delivered into the cup five times per session at irregular intervals ranging from 120 to 600 sec. The pellets remained in the cup until retrieved by the subject.

Each of the five presentations of the red light was terminated by the delivery of two food pellets independent of responses in each of the next 20 avoidance sessions (acquisition). The food hopper was activated 13 sec after stimulus onset, and the two pellets arrived in the cup approximately 1.5 and 2.3 sec later. A delay procedure prevented activation of the food hopper until a minimum of 0.5 sec had elapsed since the previous avoidance response. Interresponse times shorter than 0.5 sec thus delayed termination of a trial. The red light remained on at least 15 sec and until the food hopper was activated.

Phase II. The red light was not terminated by pellet delivery during the next block of 20 sessions (extinction). The apparatus was modified after the tenth extinction session. The subjects were trained to retrieve food pellets directly in the mouth during additional 15 min periods following each of the last three extinction sessions. The previously described

training procedures were employed in each hopper training session.

The red light was again terminated by pellet delivery in each of the next 20 sessions (first reacquisition). The food hopper was activated 13 sec after stimulus onset, and the pellets fell from the delivery tube approximately 0.8 and 1.5 sec later. A delay contingency between avoidance responses and pellet delivery was not employed in the reacquisition sessions. Pellets not retrieved during the 1.5-sec delivery cycle fell on to the floor and were "lost" to the subject.

Phase III. The extinction procedures were then reintroduced for the next block of 20 sessions. The extinction series was interrupted after the tenth session, and each subject was trained on the baseline avoidance schedule for five sessions while restrained in the metal and plastic cage. The subjects were restricted to the vicinity of the response lever during the first baseline session by a leather belt loosely connected to the neck electrode. The subjects had free access to all areas of the cage during the last four baseline sessions. The extinction series was then continued for 10 sessions. Additional 15-min food hopper training sessions followed each of the last three extinction sessions.

The red light was again terminated by pellet delivery in each of the next 20 sessions (second reacquisition). The food hopper was activated 13 sec after stimulus onset and the pellets fell from the delivery tube approximately 0.5 and 1.0 sec later. Pellets not retrieved during the delivery cycle were "lost" to the subject. A delay contingency between avoidance responses and pellet delivery was not used in the second reacquisition sessions.

Each subject received 30 pellets in the home cage following an acquisition session, and 40 pellets following an extinction session.

RESULTS

The frequency of responses during the stimulus was compared to the response frequency during the immediately preceding 15-sec period by the formula of

$$\frac{(\text{stimulus responses} - \text{pre-stimulus responses})}{(\text{pre-stimulus responses})}$$

(Hunt, Jernberg, and Brady, 1952). This inflection ratio yields negative values when the

frequency during the stimulus is decreased relative to the pre-stimulus period, and positive values when the frequency is increased during the stimulus. Thus, a decrease in response frequency of 100% yields a ratio of -1.00 ; an increase of 100% yields a ratio of $+1.00$; and no change yields a ratio of 0.00 .

Phase I. The avoidance rate during the stimulus in adaptation was disrupted, and typically increased up to 50%, within the first three sessions. The inflection ratio averaged 0.00 for each subject over the last seven adaptation sessions.

The inflection ratio was increased for all subjects during acquisition. Figure 1 presents the mean inflection ratio for each subject and acquisition session. The inflection ratio increased during the first two or three sessions, followed by a relative decrease and final stabilization at a terminal level. The response frequency during the pre-stimulus and stimulus periods over the last 25 trials ranged between 6 to 13 and 13 to 21, respectively, for Subject 1; 9 to 16 and 14 to 25, respectively, for Subject 2; and 16 to 25 and 22 to 35, respectively, for Subject 3. The lower baseline avoidance rate of Subject 1 was most increased, and the higher response rate of Subject 3 was least increased, during the pre-food stimulus. The mean interresponse time of each subject approached but rarely exceeded the 0.5-sec delay contingency.

Each subject continued to press the avoidance lever throughout the pre-food stimulus, initiating the sequence of pellet retrieval responses only after pellet delivery into the food cup. Frequently, one or more responses were emitted between the activation of the food hopper and the subsequent arrival of the first pellet 1.5 sec later. Avoidance responses during the stimulus before pellet delivery had no systematic pattern of acceleration across successive trials.

Phase II. The inflection ratio during extinction progressively decreased within the first three to five sessions, and averaged approximately 0.00 over the final 10 extinction sessions.

In the first reacquisition, the inflection ratio was initially increased for all subjects (Figure 1). The mean ratio was most increased during the first three sessions, followed by a relative decrease and stabilization at a terminal level. The frequency of responses during the pre-

Fig. 1. The mean inflection ratio of each subject during acquisition, the first reacquisition, and the second reacquisition. The arrows above each section indicate sessions in which one shock was delivered.

stimulus and stimulus periods over the last 25 trials ranged between 7 to 15 and 16 to 23, respectively, for Subject 1; 17 to 24 and 23 to 29, respectively, for Subject 2; and 25 to 35 and 18 to 24, respectively, for Subject 3. Similar to the initial acquisition data, the inflection ratio was relatively higher for the subject with the lowest baseline avoidance rate (Subject 1), and relatively lower for the subject with the highest baseline rate (Subject 3). The mean inflection ratio for each subject was lower during the first reacquisition sessions than during the initial acquisition sessions.

Initially, avoidance responses were emitted immediately after the food hopper was activated, followed by a changeover to the pellet retrieval sequence. This response pattern re-

sulted in a loss of the first available pellet, and infrequently, the second pellet. Subsequently, the response pattern during the stimulus was typically avoidance responses followed by activation of the food hopper, an abrupt changeover to the pellet retrieval sequence followed by pellet retrieval. All subjects retrieved 80 to 100% of the available pellets over the final 10 sessions. The avoidance rate of Subjects 1 and 3 was negatively accelerated during the stimulus. The response rate of Subject 2 had no systematic acceleration pattern over successive trials.

Phase III. The inflection ratio in the second extinction series remained relatively increased for Subject 1 and Subject 2, and relatively decreased for Subject 3, within the first three

sessions. The mean inflection ratio for each of the last 15 extinction sessions was approximately 0.00 for all subjects.

The inflection ratio in the second reacquisition was decreased for all subjects (Figure 1). The progressive change in the inflection ratio was closely associated with the number of pellets successfully retrieved, and followed a slightly different pattern for each subject. All subjects retrieved less than 30% of the available pellets during the first eight to 10 sessions. The changeover from avoidance responses to the pellet retrieval sequence reliably preceded activation of the food hopper by the eleventh session for Subject 1, and by the tenth session for Subjects 2 and 3. All subjects retrieved 80 to 100% of the available pellets over subsequent sessions. Concomitantly, the inflection ratio decreased to a terminal level over the final sessions. The frequency of avoidance responses during the stimulus and pre-stimulus periods varied between 6 to 11, and 0 to 3, respectively, for Subject 1; 10 to 14 and 0 to 6, respectively, for Subject 2; and 14 to 24 and 0 to 5, respectively, for Subject 3, over the last 25 trials. The avoidance rates of Subject 1 and Subject 3 were negatively accelerated during the stimulus. Subject 2 received one response shock approximately 15 sec following pellet delivery terminating the third trial of the fourteenth session. Over subsequent trials, Subject 2 alternated short bursts of one to three avoidance responses with pellet retrieval responses throughout the stimulus period, with a resultant relative increase in the mean inflection ratio during the latter sessions.

The mean inflection ratio for baseline control trials was approximately 0.00, with a range of -0.30 to $+0.30$, throughout the experiment.

DISCUSSION

The present data indicate that the baseline avoidance rate during a pre-food stimulus is systematically related to the temporal characteristics of the concurrent schedules of pellet delivery. The frequency of avoidance responses decreased, and the frequency of pellet retrieval responses concurrently increased, after pellet delivery (acquisition), during pellet delivery (first reacquisition), and before pellet delivery (second reacquisition).

In the initial acquisition procedure, the frequency of pellet retrieval responses was highest after pellet delivery and near zero before pellet delivery. Avoidance responses invariably preceded pellet delivery. This unscheduled relationship would favor adventitious reinforcement of avoidance responses by pellet delivery (Skinner, 1948). The brief 0.5-sec delay contingency would not be expected to prevent the adventitious reinforcement effects (Catania, 1966). This ever-present relationship between responses and response-independent events has previously been reported for various other classical and operant conditioning combinations (Sidman, Herrnstein, and Conrad, 1957; Herrnstein and Morse, 1957; Gottwald, 1967).

This relationship was altered in the subsequent reacquisition procedures. In the second reacquisition procedure, retrieval responses preceded pellet delivery, and avoidance responses contiguous with pellet delivery resulted in a loss of pellets. The avoidance rate during the stimulus was relatively decreased with this procedure, in contrast to the increased rates during initial acquisition.

Although not explicitly specified within the conditioned-unconditioned stimulus (CS-UCS) contingency, pellet retrieval responses could only be followed by pellet delivery during fixed temporal intervals within each procedure. In all procedures, the baseline response rate decreased and retrieval responses concurrently increased when the probability of pellet retrieval was maximal relative to the probability of shock. The baseline response rate during other classical-operant conditioning procedures is similarly dependent upon the relative probabilities of response-independent events as well as response-dependent events (*e.g.*, Stein, Sidman, and Brady, 1958; Meltzer and Brahlek, 1970; Pomerleau, 1970). More recently, concurrent responses have also been reported during other classical-operant conditioning procedures. Stein, Hoffman, and Stitt (1971) reported that "freezing" responses associated with an aversive UCS were increased concomitant with suppression of a positive operant response during a negative classical conditioning procedure. Azrin and Hake (1969) also reported rapid body movements, head movements, and "freezing" concomitant with suppression of a positive operant during a positive classical conditioning procedure.

The current data thus suggest that the baseline response may be directly and adventitiously affected by the UCS when the UCS controls concurrent responses that follow rather than precede UCS presentation. The data similarly indicate that the baseline response rate may be decreased during the CS when the UCS controls concurrent responses that precede UCS presentation. The operant response rate during classical conditioning procedures may thus depend upon the many parameters that control the frequency and temporal patterning of each response, as well as the changeover from one response to the concurrent response.

The results of these experiments are particularly congruent with the incompatible respondent analysis (Brady and Hunt, 1955) and the incompatible operant analysis (Weiskrantz, 1968) of negative classical conditioning procedures superimposed upon positive operant baselines. Both concurrent response analyses may be extended to account for the effects of positive and negative classical conditioning procedures superimposed upon positive and negative operant baselines. However, the distinctions between classical conditioning processes and responses and operant conditioning processes and responses are theoretical rather than empirical (Rescorla and Solomon, 1967). A theoretically more neutral position would suggest that combinations of classical and operant procedures may be viewed as concurrent schedules of experimental events in which two schedule components are operative during the CS.

Formally, classical conditioning procedures superimposed upon operant baselines are concurrent schedules of response-independent and response-dependent events (Ferster and Skinner, 1957). Previous data indicate that the mutual interaction between schedule components, in both (operant-operant) and (operant-classical) conditioning procedures, may be observed when each component has been conditioned before they are combined; are similarly sensitive to adventitious reinforcement effects; and are dependent upon similar parameters (e.g., Catania, 1966; Lyon, 1968). Thus, classical and operant conditioning combinations may have many of the functional characteristics of concurrent schedules.

The results of classical and operant con-

ditioning experiments may be easily interpreted as an interaction between underlying states. However, until the assumed emotional states and conditioning processes are directly measurable, the data may be more amenable to an analysis of concurrently scheduled experimental events (Henton and Brady, 1970). In contrast to previous accounts, which emphasize underlying emotions, a concurrent schedules analysis of classical and operant conditioning combinations would emphasize observed events.

REFERENCES

- Azrin, N. H. and Hake, D. F. Positive conditioned suppression: conditioned suppression using positive reinforcers as the unconditioned stimuli. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 167-173.
- Brady, J. V. and Hunt, H. F. An experimental approach to the analysis of emotional behavior. *Journal of Psychology*, 1955, 40, 313-324.
- Bull, J. A. and Overmeir, J. B. Incompatibility of appetitive and aversive conditioned motivation. *Proceedings of the 77th Annual Convention of the American Psychological Association*, 1969, 4 (pt 1) 97-98. (Abstract).
- Catania, A. C. Concurrent operants. In W. K. Honig (Ed.), *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 213-271.
- Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Gottwald, P. The role of punishment in the development of conditioned suppression. *Physiology and Behavior*, 1967, 2, 283-286.
- Grossen, N. E., Kostansek, D. J., and Bolles, R. C. Effects of appetitive discriminative stimuli on avoidance behavior. *Journal of Experimental Psychology*, 1969, 81 (No. 2) 340-343.
- Henton, W. W. and Brady, J. V. Operant acceleration during a prereward stimulus. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 205-211.
- Herrnstein, R. J. and Morse, W. H. Some effects of response independent positive reinforcement on maintained operant behavior. *Journal of Comparative and Physiological Psychology*, 1957, 50, 461-467.
- Hunt, H. F., Jernberg, P., and Brady, J. V. The effect of electroconvulsive shock (ECS) on a conditioned emotional response: The effect of post-ECS extinction on the reappearance of the response. *Journal of Comparative and Physiological Psychology*, 1952, 45, 589-599.
- Lyon, D. C. Conditioned suppression: Operant variables and aversive control. *Psychological Record*, 1968, 18, 317-338.
- Meltzer, D. and Brahlek, J. A. Conditioned suppression and conditioned enhancement with the same positive UCS: an effect of CS duration. *Journal of*

- the Experimental Analysis of Behavior*, 1970, 13, 67-75.
- Millenson, J. R. *Principles of behavioral analysis*. New York: Macmillan, 1967.
- Pomerleau, O. F. The effects of stimuli followed by response-independent shock on shock-avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1970, 14, 11-21.
- Rescorla, R. A. and Solomon, R. L. Two-process learning theory: relationships between Pavlovian conditioning and instrumental learning. *Psychological Review*, 1967, 74, 151-182.
- Sidman, M. Avoidance behavior. In W. K. Honig (Ed.), *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 448-498.
- Sidman, M., Herrnstein, R. J., and Conrad, D. G. Maintenance of avoidance behavior by unavoidable shock. *Journal of Comparative and Physiological Psychology*, 1957, 50, 553-557.
- Skinner, B. F. "Superstition" in the pigeon. *Journal of Experimental Psychology*, 1948, 38, 168-172.
- Stein, L., Sidman, M., and Brady, J. V. Some effects of two temporal variables on conditioned suppression. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 153-162.
- Stein, N., Hoffman, H. S., and Stitt, C. Collateral behavior of the pigeon during conditioned suppression of key pecking. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 83-93.
- Weiskrantz, L. (Ed.), *Analysis of behavioral change*. New York: Harper & Row, 1968.

Received 24 March 1971.

(Final acceptance 30 September 1971)