Maintenance of Responding under a Fixed-Interval Schedule of Electric Shock-Presentation

Abstract. *Squirrel monkeys trained to respond under a schedule in which each response postponed the delivery of electric shock developed a steady rate of responding. When a schedule in which an electric shock was presented following the first response occurring after 10 minutes (10-minute fixed-interval schedule) was programed concurrently, there was little effect on the pattern of responding. When the shock-postponement schedule was eliminated, the fixed-interval schedule of shock-presentation maintained a pattern of positively accelerated responding that is characteristic of fixed-interval schedules of reinforcement.*

The pattern of behavior that precedes an event and the manner in which the presentation of the event is scheduled are critical determinants of the effect of that event. Recently it has been shown that a stereotyped pattern of responding elicited by recurrently presented electric shock can be altered to a pattern of maximal responding just before each shock and then maintained under a fixed-interval schedule of shock-presentation (*1*). In the present experiments, a previously acquired response was maintained under a fixed-interval schedule of shock-presentation. Responding was maintained over an extended period under a schedule in which the only consequence of responding was the delivery of electric shock.

Three adult male squirrel monkeys (*Saimiri sciureus*) were the subjects; two (S-65 and S-85) had no prior experience with electric shock, and one (S-101) had been trained several months previously to terminate periodically presented electric shock. Experiments were conducted with individual monkeys seated in a restraining chair (*2*) within a sound-attenuating chamber. Electric shocks were delivered through brass electrodes which rested on a shaved portion of the monkey's tail. The shock source was a 650-volt a-c transformer; the current delivered to the electrodes through series resistance was either 5.2 or 7.0 ma for 250 msec. Electrode paste (EKG Sol) applied to the tail insured low resistance contact with the electrodes. A response key was mounted on a panel facing the monkey. A 25-watt overhead light illuminated the chamber during experimental sessions, which were usually 100 minutes long.

All monkeys were first trained under a shock-postponement schedule (*3*). Shocks (5.2 ma) were programed to occur every 10 seconds, but each depression of the response-key postponed the delivery of shock for 30 seconds. After a number of sessions under this schedule (see Table 1), a 10-minute fixed-interval schedule of shock-presentation was programed concurrently with the shock-postponement schedule. Under the 10-minute fixed-interval schedule, the first response occurring after 10 minutes produced a shock. During the concurrent operation of these schedules, the shock-postponement schedule was not in effect during the last minute of each fixed interval; therefore, the only shock delivered after the 9th minute was delivered immediately following a response under the 10-minute fixed-interval schedule. After a number of sessions (see Table 1) under the concurrent schedule, the shock-postponement schedule was eliminated. For the remainder of the experiments the only schedule in effect was the 10-minute fixed-interval schedule of shock-presentation. In subsequent sessions, each shock was followed by a 30-second time-out period during which the overhead light was extinguished and responses had no programed consequence. The removal and reinstatement of this time-out period was studied in two monkeys (S-65 and S-101).

Table 1 provides summary data for each monkey, and Fig. 1 (panels A through E) shows representative performances of monkey S-65 under the various procedures. The shock-postponement schedule engendered a low, relatively uniform rate of responding; when the 10-minute fixed-interval schedule was added, there was no change in the temporal pattern of responding (Fig. 1A), that is, the distribution of responding within the 10-minute intervals did not change. Elimination of the shock-postponement schedule, so that the only consequence of responding was delivery of shock under the fixed-interval schedule, increased response rates and markedly changed the temporal pattern of responding. Typically, response rate was very low immediately after each shock and then gradually increased until the next shock was presented (Fig. 1B). When a 30-second time-out period followed each shock, this pattern of positively accelerated responding was accentuated (Fig. 1C). Subsequent removal and reinstatement of the time-out period (Fig. 1, D and E) had no substantial effect on this response pattern.

Monkey S-101 was studied for only two sessions under the fixed-interval schedule without the time-out period, which was insufficient time for the pattern of positively accelerated responding to develop (see Table 1). However, this monkey showed the same pattern of responding as monkey S-65 after several sessions under the fixed-interval schedule with time-out after shock. The later removal and reinstatement of the time-out period

Table 1. Mean response rates (resp/sec) and quarter-lives (Q) under the various procedures. Figures are averages of the last four sessions under each of the schedules. The quarter-life (Q) is defined as the percentage of the interval taken for the first quarter of the response to occur. This was determined by linear interpolation from the number of responses occurring in each tenth of the fixed interval (FI) over the experimental session. When responses are being emitted at a constant rate throughout the interval, Q = 25 percent. This measure provides an index of the temporal patterning of fixed-interval responding which is relatively independent of response rate (*10*).

Schedule	Monkey S-65			Monkey S-85			Monkey S-101		
	No. of sessions	Resp/sec	Q (%)	No. of sessions	Resp/sec	Q (%)	No. of sessions	Resp/sec	Q (%)
Shock-postponement	17	.109	23.5	15	.136	25.3	11	.113	25.7
Shock-postponement + FI	14	.215	24.0	13	.264	26.7	11	.203	22.8
Fixed interval	21	.408	38.0	11*	.335	40.7	2	.248†	25.5†
FI with time-out	21	.482	60.0	56	.687	66.2	31	.367	66.0
Fixed interval	17	.455	60.5				16	.425	66.0
FI with time-out	11	.475	69.5				11	.627	66.0

* After the 11th session under the 10-minute fixed-interval schedule, the procedure was changed for monkey S-85 (see text). † Mean of two sessions.

did not affect the pattern of responding (Fig. 1F).

After 11 sessions under the 10-minute fixed-interval schedule, during which a positively accelerated pattern of responding had begun to develop, monkey S-85 ceased responding for prolonged periods. The shock intensity was increased to 7.0 ma, and shocks were delivered automatically if no response occurred within 1 minute of the end of the 10-minute fixed interval. After four sessions under this procedure positively accelerated responding was well maintained. Subsequently, shocks were no longer programed for automatic delivery, and were presented only following a response under the 10-minute fixed-interval schedule. Under the fixed-interval schedule with the added time-out period, the patterns of responding of this monkey were the same as those of the other monkeys (Fig. 1G).

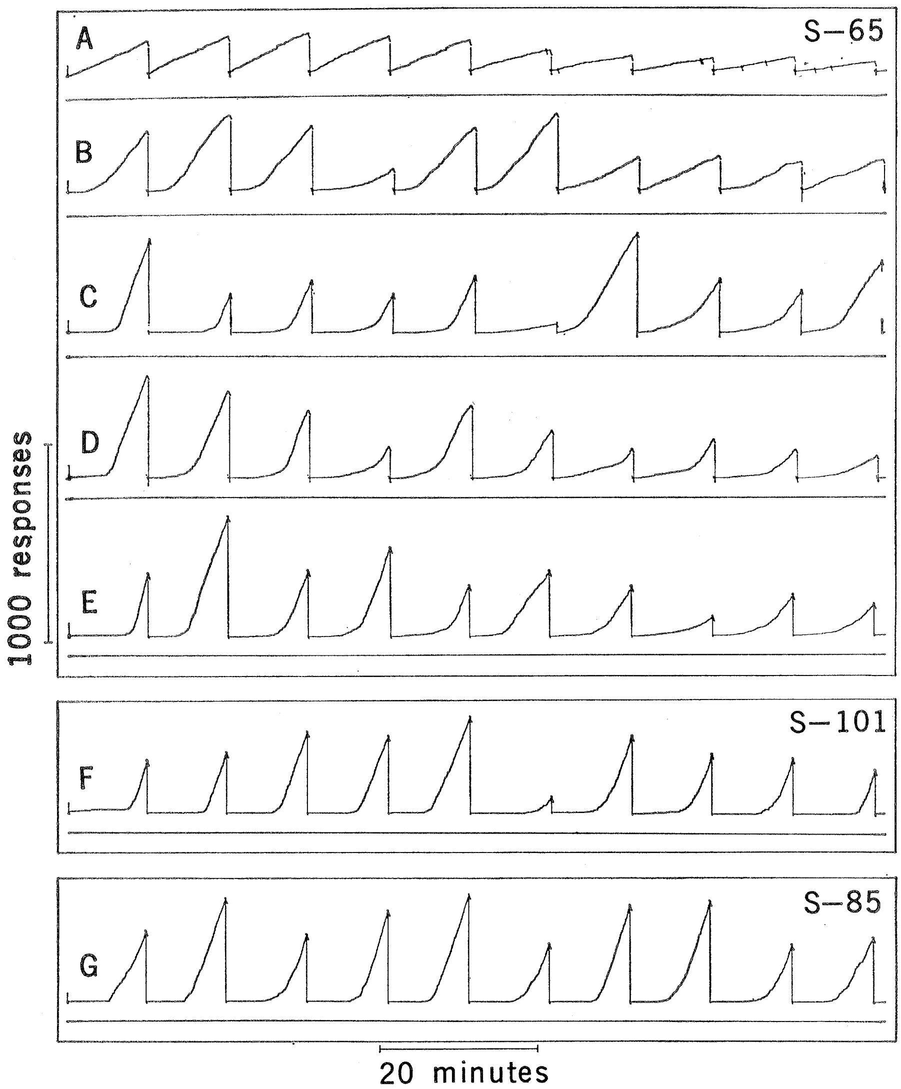

Fig. 1. Patterns of responding under different experimental conditions. Ordinate, cumulative number of responses per 10-minute fixed interval; abscissa, time. The recording pen was reset to the base line at the termination of each fixed interval. (A) Schedule of shock-postponement and 10-minute fixed-interval (FI 10) schedule of shock-presentation programed concurrently (tenth session after introduction of FI 10, monkey S-65). (B) FI 10 shock-presentation only (21st session after elimination of shock-postponement schedule, monkey S-65). (C) FI 10 shock-presentation, 30-second time-out period after each shock (14th session after introduction of time-out, monkey S-65). (D) FI 10 shock-presentation, no time-out period (16th session after removal of time-out period, monkey S-65). (E) FI 10 shock-presentation, 30-second time-out period reinstated (fourth session after reinstatement of time-out, 63rd session after elimination of shock-postponement schedule, monkey S-65). (F) Terminal performance of monkey S-101 under the FI 10 schedule of shock-presentation with a 30-second time-out after shock (57th session after elimination of shock-postponement schedule). (G) Terminal performance of monkey S-85 under the FI 10 schedule of shock-presentation with a 30-second time-out after shock (67th session after elimination of shock-postponement schedule). The variation in numbers of responses in successive intervals within a session is typical of fixed-interval schedules in general (*4*).

Characteristic patterns of positively accelerated responding were maintained under the fixed-interval schedule of shock-presentation. This schedule is procedurally equivalent to fixed-interval schedules of food or water presentation, and the pattern of positively accelerated responding is the same. Further, the tendency of the time-out period to accentuate this pattern is the same whether responding is maintained by food presentation (*4*) or by shock-presentation.

When behavior is changed by its consequences, the consequences are called reinforcers (*5*). Traditionally, psychological theories have assigned the property of "rewarding" to those stimuli which are *presented* (for example, food or water), and "fear-producing" to those that are *terminated* or postponed (for example, electric shock) (*6*). Yet the present experiments have shown that a stimulus that can function to maintain responses that terminate it will function, under appropriate conditions, to maintain responding preceding its presentation. In the course of these experiments the three monkeys responded over 800,000 times, producing over 3000 intense electric shocks. Furthermore, the pattern of responding which developed was identical in every respect to that which prevails under comparable procedures in which responding produces food or water (*4*). Because the effects of stimuli can be completely changed depending on how they are presented, it is misleading to assign a priori qualities to them.

A given stimulus can affect behavior in a variety of different ways (*5*, *7*). For example, under certain conditions the delivery of electric shock may elicit patterns of behavior that are relatively stereotyped for a given species (*8*). Under other circumstances electric shock may serve as a discriminative stimulus, setting the occasion for the occurrence of some behavior (*9*). Under some conditions, behavior is suppressed by the presentation of electric shock (punishment) (*8*), and under other conditions, as the present and related (*1*) experiments have shown, responding can be maintained and enhanced by the presentation of electric shock (reinforcement).

The way in which behavior is modified by the presentation of a strong stimulus depends on many factors in addition to the nature of the stimulus. One important determinant of the effects of a stimulus is the manner in which it is scheduled; that is, the manner in which its presentation is related to responses. Electric shocks of the intensity that maintained responding in the present experiments could quite effectively suppress responding under other circumstances, for example, if a shock followed *each* response.

The development and maintenance of responding in a situation in which the only consequence of responding is the delivery of electric shocks also depends upon the history of the experimental subject and upon the ongoing behavior at the time the shock schedule is introduced. An untrained animal exposed immediately to the fixed-interval schedule of shock-presentation would have little tendency to press the response key. Similarly, an animal that had been trained only under a schedule in which each response produces food would quickly cease responding if the response requirement were abruptly increased to several hundred, but would develop a stable pattern of responding if the requirement were increased in gradual steps to the same value. Thus, a dependence of schedule-controlled performance upon prior behavior is not peculiar to experiments involving electric shock.

The present experiments, in which responding was maintained initially by shock-postponement and then by shock-presentation, emphasize that stimuli do not have immutable qualities; the way in which behavior is affected by even a strong stimulus is not invariant. The schedule of presentation, and the ongoing behavior at the time the schedule is imposed, are critically important determinants of the effects of electric shock on behavior.

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References and Notes

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Visual Perception and Xerography

Abstract. *An electrostatic copying machine was used to model the perception of simultaneous brightness contrast. Such a model may assist the study of sensory inhibition by permitting the study of complex situations as they are transformed by rules similar to those at work in neural integration.*

A century ago Mach showed that in human vision perceived brightness effects are related to the second derivative of the physical luminance distribution of the stimulus and described what are now known as Mach bands (*1*). Even though the stimulus distribution contains no discontinuities, the observer may still experience clearly demarcated stripes or bands. Ratliff has pointed out that a similar phenomenon occurs in such physical optical systems as the xerographic process (*2*). We think that this coincidence is a fortunate one, for it allows one system to be used as a model of the other.

A hallmark of xerographic copies is the "edge-only effect" whereby only the edge of wide areas is copied. Grundlach has described methods for obviating this Mach-bandlike effect (*3*). Broad areas are uniformly charged on the xerographic plate, but they can be transformed into an array of dots or lines which are then developed by edge-fields, through masking the original stimulus during projection, through selectively discharging the plate surface, or through initially charging the plate in a screen pattern.

We may compare these techniques to ones that have been discovered in the history of vision research for affecting the visibility of contrast effects: the dependence of the perceived brightness in one visual-field location on the brightness in another location. With a stimulus such as that shown in Fig. 1 a classical demonstration of simultaneous brightness contrast in hu-

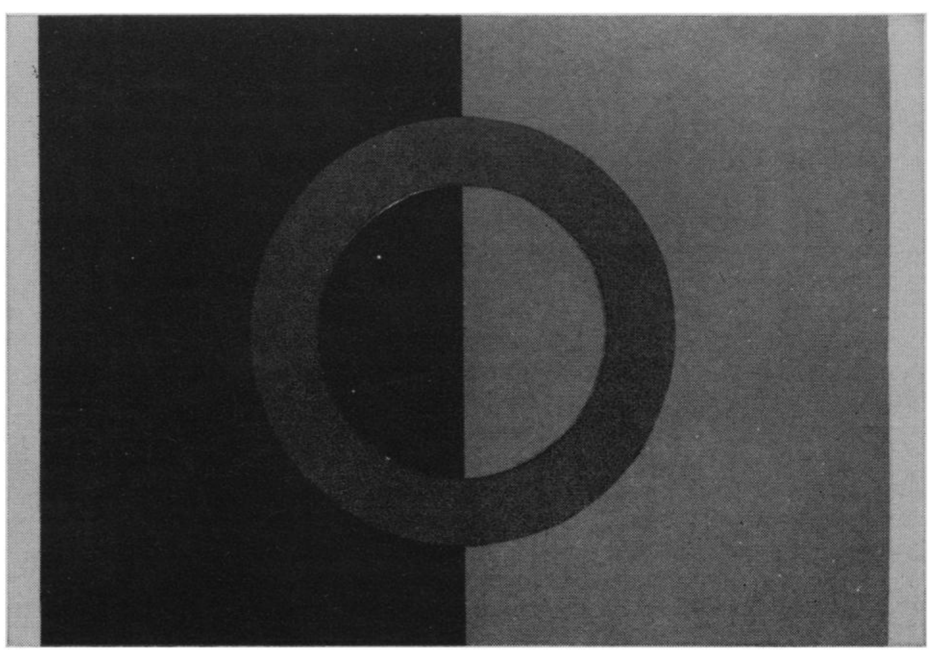

Fig. 1. A photograph of the original stimulus.