The effects of signaled response-independent shocks on behavior under avoidance and extinction schedules*

ELIOT H. SHIMOFF† and ARTHUR G. SNAPPER††
FDR Veterans Administration Hospital, Montrose, N.Y. 10548
and
WILLIAM N. SCHOENFELD
Queens College of the CUNY
and Cornell University Medical College, New York, N.Y. 10021

Response rates of rats were recorded during a 30-sec signal (CS) which preceded a response-independent electric shock when: (1) baseline avoidance shocks were withheld during the signal; (2) baseline avoidance shocks were available during the stimulus; and (3) baseline avoidance shocks were withheld but a response-independent shock was intruded on each trial at the midpoint of the signal. Two different adjusting avoidance baselines were used. The data suggest that the signal suppresses responding, but also that this effect can be overcome by shocks supplied either from the baseline schedule or intruded on a response-independent schedule.

It is becoming increasingly apparent that the behavioral effects of Pavlovian (response-independent) pairing of a "neutral" conditional stimulus (CS) and an aversive unconditional stimulus (UCS) may be measured in many ways and are determined by many factors. For example, when such a stimulus pair is superimposed on a schedule of positive reinforcement, a characteristic suppression of some operant responding is obtained, the degree of which depends upon the duration of the neutral stimulus (Stein, Sidman, & Brady, 1958) and the particular baseline schedule being used (e.g., Waller & Waller, 1963; Blackman, 1968).

Similarly, Pomerleau (1970) has shown with a baseline avoidance schedule that an operant rate during CS is under joint control of CS duration and the parameters of such a baseline. Operant rates could be either facilitated or suppressed when compared with baseline avoidance rates outside CS, the outcome depending (in his view) upon the actual incidence of shock reaching the S from the two sources of baseline schedule and Pavlovian pairings (see also Baron & Kaufman, 1968; and Brady, Libber, & Dardano, 1967). Roberts & Hurwitz (1970) have strengthened this possibility by an experiment that withheld baseline avoidance shocks during a Pavlovian CS. The operant suppression observed under this procedure was greater than that when CS was not followed by shock (UCS) if baseline shocks were also withheld during CS (i.e., discriminated avoidance-extinction). They concluded that the Pavlovian pairing thus produces rate suppression as its "primary" effect.

The present experiment was designed to study further the interaction of the baseline avoidance schedule with a superimposed Pavlovian CS-UCS pair (both using the same aversive stimulus) by comparison of operant rates (1) when baseline shocks were available during CS, (2) when baseline shocks were withheld during CS, and (3) when a response-independent shock was intruded at the midpoint of CS on each CS presentation. Comparisons were made with two adjusting avoidance schedules differing in the amount of time-out from shock that could be accumulated by each avoidance response.

SUBJECTS AND APPARATUS

Eight male Charles River CD rats served as Ss. They were individually housed with food always available in the home cage. Water was available 1 h daily immediately following each session.

Four commercial boxes (Scientific Prototype Model A-100) enclosed in sound-attenuating ventilated shells served as experimental chambers. All shocks (both response-dependent and response-independent) were 325 V ac at 2 mA, applied as a single sequential sweep across the 16 grid bars, with current on each grid for 20 msec. The CS was a 2 kHz tone presented through speakers mounted above each chamber. Experimental contingencies and data recording were controlled through a PDP-8 digital computer, using a system described by Snapper & Kadden (in press). The manipulandum was a standard rat lever requiring approximately 5 g to operate.

PROCEDURE

Barpressing was maintained throughout the experiment by an adjusting avoidance schedule similar to that described by Snapper, Schoenfeld, & Pomerleau (1970) (also see Pomerleau, 1970). This schedule was chosen because under its control that response is marked by rapid acquisition and high rate, with a resulting low shock density. In addition, it permits relatively long periods of shock-free nonresponding. For one group of four rats, shocks were delivered every 2 sec in the absence of a response. Each response produced a 2-sec time-out (TO) from the shock train, and up to 10 TOs (20 sec) could be accumulated. Thus, following a burst of at least 10 responses within 2 sec, the next shock would be delayed 20 sec. For a second group of four Ss, shocks were delivered every 5 sec in the absence of a response, and each response earned a 5-sec TO, up to a maximum of 10 TOs (50 sec).

Sessions were 530 min long, and run on alternate nights. Data for the initial 30 min of each session were recorded, but not used for analysis. When scheduled, 100 pairings of a 30-sec signaling CS followed by a response-independent shock were presented (Pavlovian "delay" procedure), with a 5-min mean intertrial interval, in the last 500 min of the session. At the end of the session, the houselights were extinguished and the Ss remained in the chambers until the next morning, when they were returned to their home cages.

The rats were initially given 15 sessions of avoidance baseline training. The remainder of the experiment may be divided into six phases. It should be

Table 1
Baseline Response and Shock Rates

	Responses/Min	Shocks/Min
	2-Sec TO	
R1	22.8	.26
R2	25.9	.50
R3	26.9	.32
R4	21.3	1.16
	5-Sec TO	
R5	8.9	.66
R6	10.0	.08
R7	9.9	.04
R8	9.9	.10

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†Now at Department of Psychology, University of Maryland Baltimore County, Baltimore, Md. 21228.
††Now at Department of Psychology, Western Michigan University, Kalamazoo, Mich. 49001.

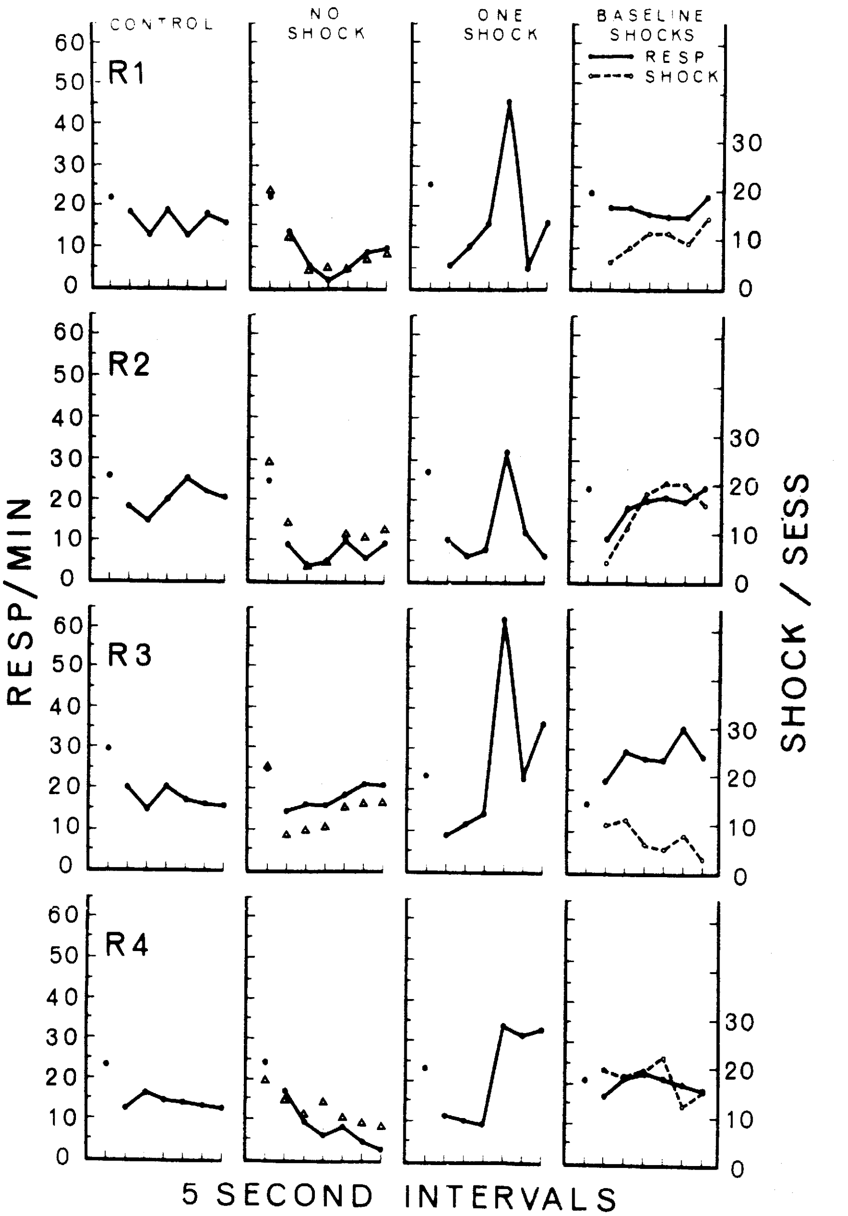

Fig. 1. Reponse rate of four rats under 2-sec TO baseline schedule. Each data point represents rate in successive 5-sec bins starting immediately preceding CS and continuing throughout the CS. The columns represent (from left to right) data from Phases 1, 3, 6, and 4, respectively. The data of Phase 5 is shown by open triangles superimposed on the data of Phase 3. The baseline shocks are shown in Phase 6 by the dashed line.

noted that the baseline avoidance schedule was always in effect in the absence of CS, and that CS presentations were always terminated by shock except in Phase 1.

Phase 1

Tones not followed by shock were superimposed on the avoidance baseline. In the presence of tone, the baseline schedule was withheld, i.e., responses did not increase the TO from shock, and no shocks were delivered. On termination of the tone, the baseline schedule was again in effect, and whatever TO had been accumulated prior to onset of the tone was reinstated. This phase lasted five sessions, and represents a control procedure of discriminated extinction.

Phase 2

In this phase, consisting of a single session, the lever was removed from the chamber, and 100 Pavlovian pairings of the tone and shock were presented.

Phase 3

Pairings of the tone and shock were superimposed on the avoidance baseline, with the baseline schedule withheld in the presence of CS for five sessions. This procedure may be viewed either as discriminated extinction with an unavoidable shock terminating the extinction component or, alternatively, as a CER procedure with baseline shocks withheld during the preaversive stimulus (cf. Roberts & Hurwitz, 1970).

Phase 4

CS-UCS pairings were superimposed on the avoidance baseline for five sessions, with the baseline schedule in effect throughout CS (the standard CER procedure).

Phase 5

This phase was a replication of the third phase, and lasted five sessions.

Phase 6

The baseline schedule was withheld during CS, as in the third and fifth phases, but two response-independent shocks were delivered in each CS presentation; one shock was scheduled 15 sec after CS onset, while a second shock, as before, was delivered on CS termination.

RESULTS

Baseline performance was characterized by steady responding and low shock density; response and shock rates from the last 500 min of the 15th baseline training session (i.e., the last session prior to Phase 1) are presented in Table 1. Baseline response rates did not vary systematically throughout the remainder of the experiment.

Response patterns in the presence of CS in the final three sessions of each phase were stable both within and across sessions; response rates in a 5-sec pre-CS sample, and in successive 5-sec samples within CS, are presented in Figs. 1 and 2. In the first phase, in which the baseline schedule was suspended during CS, response rates during the tone decreased for Ss in the 2-sec TO group; in the 5-sec TO group, little or no change in rates was observed. The addition of a single response-independent shock at the end of CS (Phase 3) was generally associated with further reductions in CS response rates. When the baseline schedule remained in effect in the presence of CS (Phase 4), as in the standard CER paradigm, response rates were higher than when the baseline schedule was suspended; the degree of suppression relative to pre-CS rates appeared greater for the 5-sec TO group than for the 2-sec Ss, confirming Pomerleau's (1970) finding with rhesus monkeys. Moreover, shock density increased in the presence of CS relative to pre-CS density, a finding similar to that noted by Hurwitz & Roberts (1969). In the fifth phase, when the baseline schedule was again withheld during CS, response patterns were generally similar to those observed on the first exposure to this

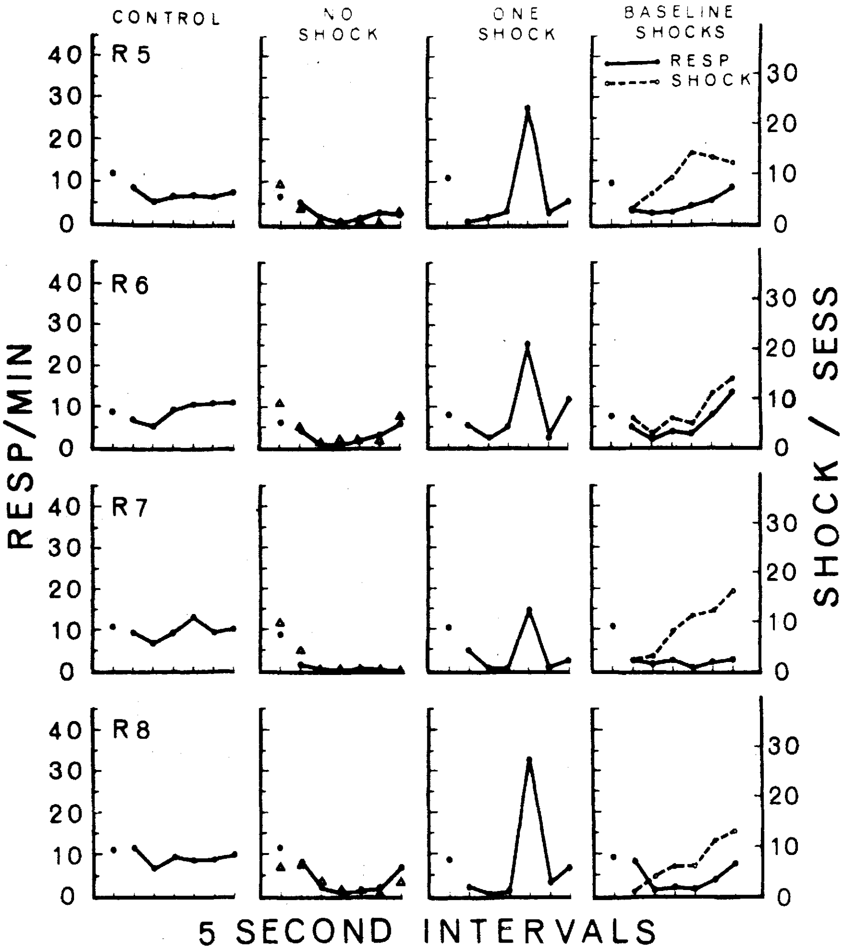

Fig. 2. Response rate of four rats under 5-sec TO baseline schedule. Each data point represents rate in successive 5-sec bins starting immediately preceding CS and continuing throughout the CS. The columns represent (from left to right) data from Phases 1, 3, 6, and 4, respectively. The data of Phase 5 is shown by open triangles superimposed on the data of Phase 3. The baseline shocks are shown in Phase 6 by the dashed line.

condition. Finally, when an additional response-independent shock was delivered in the middle of CS (Phase 6), the increase in response rate was primarily confined to the 5-sec period immediately following the mid-CS shock.

DISCUSSION

In brief, the absence of shock during a stimulus (i.e., discriminated avoidance extinction) is associated with slight or no reduction of response rate, depending on parameters of the baseline avoidance schedule. When a single response-independent shock is added at the termination of the stimulus, further response suppression is evident, but this suppression may be overcome by either baseline shocks or response-independent shock delivered during CS. The present results confirm the earlier findings of Roberts & Hurwitz (1970), and lend support to Pomerleau's (1970) contention that the presence of shocks during CS counteract the suppressive effects of CS.

However, two facts suggest that the interaction between the baseline schedule and the presence of shocks in CS may be complex. First, the postshock rates tend to be higher for the 2-sec TO group than for the 5-sec TO group under the one-shock condition of Phase 6 (only R8 has a rate approaching those of the 2-sec group). This rate difference occurs despite an equal number of intruded shocks in that phase. Second, seven of the eight Ss display an elevated rate in the final 5 sec of the CS in Phase 6 (R2 is the exception) which also occurs in Phases 3 and 5 in six of the Ss (exceptions being R4 and R7). These rate increases "anticipating" UCS suggest that, even without shocks intruding during CS, a complex waveform is generated that is more than mere "suppression" of baseline rate.

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