Operant and Pavlovian stimulus control of avoidance latencies in conditioned acceleration

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In two studies of avoidance rate increases occurring in the presence of an unreinforced light CS that had been independently paired with shock, it was shown that the time elapsing between CS onset and the next avoidance response (latency) was a function of the amount of avoidance-safe time remaining. In the first study, it was found that a formula (safe time/3) would closely predict all of the mean latencies at RS = 20 sec. In a systematic replication with RS = 30 sec, the monotonic relationship was replicated, although the formula failed to predict the data. It was further shown that the time until the next avoidance response was shortened by the light onset, so that both operant and Pavlovian variables interact to control latencies in conditioned acceleration.

A recent review of two-process learning (Rescorla & Solomon, 1967) summarizes research demonstrating that manipulation of various Pavlovian independent variables will have profound effects on operant behavior. Nearly every study referenced employs this rationale, although two-process theories contain no explicit suggestion as to why the "respondents" tend to occur as independent variables and the "operants" usually show up as dependent variables. Some exceptions to this, in the case of appetitive operants, have shown that the schedule of baseline reinforcement will influence the degree of response suppression produced by a preshock CS, while Pavlovian parameters remain constant (Brady, 1955; Lyon, 1963, 1968; Stein, Sidman, & Brady, 1958).

The present study demonstrates a further instance of operant stimulus control of a Pavlovian dependent variable (conditioned fear latencies), but employs an *aversively* maintained operant baseline.

The present effort grew out of previous research (Riess & Martin, 1969) in which avoidance-rate increases were elicited by an independently reinforced CS (conditioned acceleration). It was noted in this study that the time elapsing between the CS onset and the first avoidance response (latency) was quite variable and seemed to correlate with the amount of time remaining until the next shock due (safe time). For this reason, both latencies and Sidman safe times were recorded in two subsequent studies of conditioned acceleration to see if the suspected relationship held.

The pilot data (Experiment 1) was recorded concurrently in Ss participating in another experiment (Riess, in press) but is included here as preliminary to Experiment 2.

SUBJECTS

Experiment 1

The Ss were four male Wistar albinos participating in a study of stimulus summation described elsewhere (Riess, in press). Briefly, they had a prior history of light-shock and tone-shock pairings and experience with these unreinforced stimuli during avoidance.

Experiment 2

The Ss were three naive male Wistar albinos taken from the colony maintained by the Galesburg State Research Hospital. They were housed in individual cages and were between 89 and 98 days of age at the start of the experiment.

APPARATUS

Experiment 1

Apparatus consisted of a modified Miller-Mowrer shuttlebox, a Grason-Stadler shock generator and scrambler, an audio oscillator, a white-noise generator, and an air circulation fan described previously (Riess, in press).

Experiment 2

The apparatus was a modified Lehigh-Valley Model 52721 plastic shuttlebox. It had been rewired so that 16 separate circuits were activated and no single circuit supplied any two adjacent bars. In this way, a bolus could never straddle any one circuit, thus affording protection against shorting of the entire grid. The box was 46 x 20.5 x 20.5 cm with a 4.5-cm hurdle. The hurdle consisted of two stainless steel strips separated at the corners by four nonconducting plastic plugs with either side connected from below (to prevent wire chewing) to separate circuits. This was replaced by a 20.5 x 20.5 cm partition for classical conditioning.

The remaining equipment was identical to that of Experiment 1 except that an 87 x 43 x 54 cm wooden sound attenuation chest housed the shuttlebox. A white-noise speaker was mounted on the inside center rear of the chest and set at 82 dB. Transparent plastic doors permitted observation of S. A 7½-W white houselight at the rear of the sound chest ceiling provided illumination. Two 60-W red lights in opposite halves of the sound chest ceiling served as a CS.

PROCEDURE

The Ss were run through avoidance acquisition and classical conditioning as described previously (Riess, in press). They were tested during six sessions in a respondent-operant multiple schedule. In the first (respondent) component, eight coterminous CS-shock pairings were administered. The CS was either a 60-W white light (four reinforcements) or an 87-dB, 1,000-Hz tone (four reinforcements) in a randomized order. The CS-US interval was variable (VI 16 sec), with values of 5 sec (2), 10 sec (1), 15 sec (2), 20 sec (1), and 30 sec (2). The US was a 5-sec, 2-mA shock. The intertrial interval (ITI) was also variable (VI 90 sec) with values of 60 sec (2), 75 sec (1), 90 sec (2), 105 sec (1), and 120 sec (2). The first five shocks were given in one side and the remainder in the opposite side.

The barrier partitioning the shuttlebox was then raised, serving as the exteroceptive stimulus for the onset of the second (operant) component and allowing free responding between compartments.

The second component consisted of 30-min Sidman avoidance, with an R-S interval of 20 sec, an S-S interval of 5 sec, and 2-mA, .5-sec shocks. Six 30-sec unreinforced CS presentations occurred at the start of the 5th, 10th, 15th, 20th, 25th, and 20th minutes of the session. Two of these were CS_1 (light), two were CS_2 (tone), and two were compounded (light and tone), in variable order such that one of each occurred in each half of the session.

In Experiment 2, all Ss were run through a three-step series before CS testing was begun, consisting of:

(1) *Avoidance acquisition*, which involved 17 daily ½-h sessions, with RS = 30 sec, SS = 5 sec, and shock = .1 sec, 2.5 mA.

(2) *Adaptation*, which was identical to Step 1 except that the two red lights came on for 45 sec at the start of the 10th, 15th, 20th, 25th, and 30th minutes. A rate change ratio was computed using the 3 min before each light onset as a baseline and employing the formula 4B/(A + 4B), where A = baseline responding and B = light responding. Ss were required to have a 2-consecutive-day average of between .475 and .525 before proceeding.

(3) *Conditioned fear acquisition*, which

involved four sessions of classical conditioning (eight light and 2-sec 1-mA shock pairings) alternating with regular avoidance sessions. The CS-US interval was variable. In Session 1 all intervals were 5 sec; in Session 2, four each were used at 5 and 10 sec; in Session 3, 5 sec (3), 10 sec (2), and 20 sec (3) were used; and in Session 4, two each were used at 5, 10, 20, and 30 sec. Classical conditioning was conducted while S was confined to one side of the shuttlebox by a transparent plastic barrier, and the side of the confinement was alternated on successive sessions.

(4) *Alternating classical conditioning and testing.* The fifth and subsequent sessions of fear conditioning used the terminal schedule (VI 22.5 sec) of CS-US intervals 5 sec (2), 10 sec (1), 20 sec (2), 30 sec (1), and 45 sec (2), but were otherwise identical to Step 3. The alternating days of avoidance (testing) were identical to Step 2. At each light onset, both the Sidman safe time and the latency were recorded. This was continued until eight test sessions had been completed.

RESULTS AND DISCUSSION

All seven Ss accelerated to the light presentations, the ratios were above .500 for 55 of the 56 single sessions. The mean latencies for the longer safe times are presented in Fig. 1. Latencies were not taken for compound stimuli (Experiment 1) or if they followed a (Sidman) shock. Data for safe times of 7 sec or less (Experiment 1) or 12 sec or less (Experiment 2) were pooled because the low N for these values (some did not even occur) rendered them unrepresentative.

Included also are the plots generated by an ad hoc formula derived after Experiment 1 to predict the data. This formula is latency = safe time/3 and, as shown in Fig. 1, predicts 13 of the 14 data plots in Experiment 1 to within 1 sec of their actual length, although the data of Experiment 2 fall wide of the mark. The obvious implication of this is that the monotonicity in both studies is more sensitive, across variations in R-S intervals, to the time elapsing since the last avoidance response than it is to variations in the time until the next shock is due. For this reason, the data of both experiments are replotted together in Fig. 2 off a common abscissa of seconds elapsing since last response prior to light onset.

As can be seen here, the very large discrepancies between mean latencies in the 13- to 19-sec safe-time range for the two studies largely vanish when data for both experiments are replotted using time since last response as a measure for equating differences in R-S interval. Strictly speaking, it is the *failure* of the differences in the R-S intervals to produce commensurate differences in mean IRTs which ultimately accounts for both the large discrepancies in the 13- to 19-sec safe-time range and the seemingly erroneous prediction for Experiment 2 from the formula based on Experiment 1. In other words, if the mean IRT at RS = 30 had been 10 sec longer than the mean IRT at RS = 20 (instead of only about 1 sec longer), the formula would presumably have been more accurate for Experiment 2.

One question immediately raised by data of this type is whether the stimulus control in this situation is *exclusively* operant or if some reduction in time to next avoidance response is effected by the Pavlovian stimulus (i.e., would the data shown here be identical if no CS had ever been used but the safe times and "latencies" were simply recorded at the appropriate point in time.) One way of answering this question is to calculate when the response subsequent to the light onset would have taken place if the CS had never occurred. This can be accomplished approximately with the formula $Y = \bar{M}IRT - X$, where Y = "pseudolatency," $\bar{M}IRT$ = mean interresponse time, and X = time since last response. The result of this is plotted (light) in Fig. 2 and shows that the light onset reduces the time until the next "response due" by a relatively constant percentage across the longer safe-time values in both studies. It should be noted that the predictive power of the pseudolatency formula loses in accuracy the farther the predicted values deviate from the ordinate. This is because the formula can only predict linearly whereas actual IRT distributions decrease by progressively smaller average amounts once they have passed the modal peak. The premature intersections of the latency and pseudolatency plots in both experiments are artifacts of this inaccuracy, as is the prediction of "negative latencies" in instances where the time since last response exceeds the mean IRT. The discrepancies shown between latencies and pseudolatencies, which are accurate for the smaller values of time since last response, would probably diverge rather than converge if the pseudolatencies were calculated on a conditional probability basis rather than on the equal-interval subtractive basis used here. Unfortunately, the data required to compute such a formula (IRT distributions for all baseline responding) was not available, so the formula shown can only be considered accurate for the smaller values of time since last response in Fig. 2.

It is instructive that the measure of operant stimulus control used here (correlation between safe times and

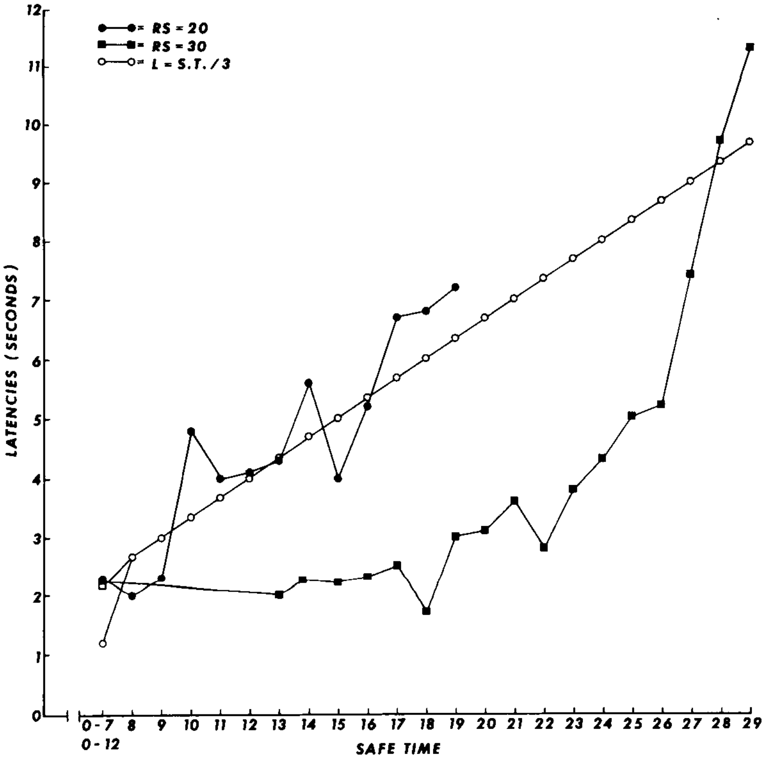

Fig. 1. Mean latencies as a function of Sidman safe time remaining at CS onset (dark) superimposed on function generated by formula safe time/3 (light).

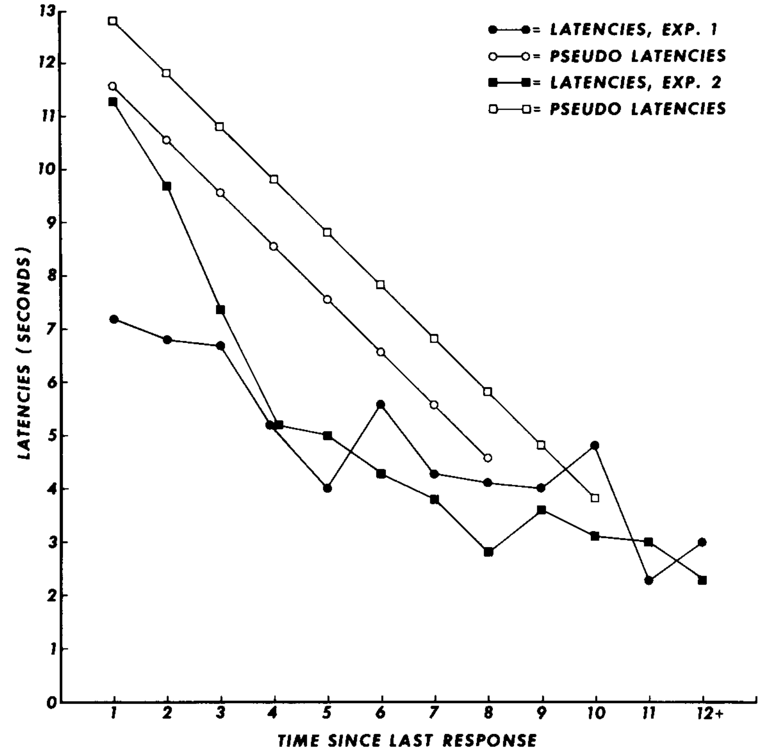

Fig. 2. Mean latencies for RS = 20 sec and RS = 30 sec replotted as a function of time elapsing since last avoidance response. The time the response would have occurred in the absence of the light (pseudolatency) is shown in open figures.

latencies) and the measure of Pavlovian stimulus control (discrepancies between latencies and pseudolatencies) both retain their sensitivity up to latency values of 2-3 sec, where they both reach asymptote. This supports the notion that increases in fear are ultimately responsible for both phenomena. However, the fear providing the motivation for the avoidance response in conditioned acceleration arises from two contingencies independently exerting stimulus control.

The present results on operant control of conditioned acceleration are considered a precise analogy of findings of Lyon (1964) and Lyon & Felton (1966) on operant control of conditioned suppression. These investigators have shown that the degree of suppression suffered by appetitive responding in the presence of a Pavlovian CS+ can be predicted on a linear basis for larger FR schedules from the simple (operant) consideration of how many responses must be executed before the next reinforcer becomes available. The linearity in conditioned suppression is due to the fact that suppression tends to become complete following the occurrence of the first post-CS reinforcer. In the case of conditioned acceleration, the linearity of the latency/safe-time relationship is due to the carryover of the normal increase in probability of an avoidance response as a function of proximity to the next shock due into the CS periods. The relationships between operant control of both conditioned acceleration and conditioned suppression coupled with related types of similar control by Pavlovian variables (e.g., shock intensity–Annau & Kamin, 1961; Riess & Martin, 1969) for these paradigms suggest that the two are reciprocal phenomena related to each other in much the same fashion as positive reinforcement and punishment.

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ERRATUM

Caul, W. F., & Miller, R. E. Effects of delay conditioning and pseudoconditioning on heart rate and suppression of drinking. Psychonomic Science, 1970, 18 (5), 284-285.–On page 285 there is a reference to Caul, W. F., Miller, R. E., & Banks, J. H., Jr. Effects on heart rate in delay conditioning and pseudoconditioning, as appearing in Psychonomic Science, 1970, 18 (5), 263-264. It, in fact, appears in Psychonomic Science, 1970, 19 (1), 15-17, although it should have appeared before the first article referenced above.