

*THE DISSOCIATION OF DISCRIMINATIVE AND
CONDITIONED REINFORCING FUNCTIONS OF
STIMULI WITH CHANGES IN DEPRIVATION¹*

KURT FISCHER AND EDMUND FANTINO

HARVARD UNIVERSITY AND UNIVERSITY OF CALIFORNIA, SAN DIEGO

Pigeons were studied in two experiments designed to explore the effects of deprivation level upon responding in each link of a two-link chained schedule. The stimulus associated with the terminal link of the chain can be both a discriminative stimulus (S^D) for responding in the presence of the stimulus and a conditioned reinforcer (S^r) for responding in the preceding link. Previous findings have indicated that the S^r function was more readily weakened by satiation than was the S^D function, *i.e.*, the rate of responding decreased more rapidly in the initial link of the chain than in the terminal link. The first of the present experiments, in which tests were conducted after a series of sessions, produced different results: rates of responding in the two links declined simultaneously. The second experiment supported the hypothesis that the effects of satiation interact with the duration of maintenance on the satiation procedure: in early sessions the S^r function was more readily disrupted, but in later sessions the rates of responding in the two links declined simultaneously. Subsequent to this extensive series of identical sessions, the pigeons' deprivation level was altered before a session by pre-feeding the pigeons up to their normal post-session weights. The rates of responding failed to reflect fully this change in deprivation in the first such session, suggesting that the pigeons' behavior had become partially independent of deprivation level.

Chained schedules of reinforcement provide a convenient means for analyzing the relation between the discriminative stimulus (S^D) and conditioned reinforcing (S^r) functions of a stimulus. In a chained schedule, responses in the presence of each of a succession of stimuli produce the next stimulus until the chain terminates with primary reinforcement. For example, in a two-link chain, responses in the presence of one stimulus produce a second stimulus, in the presence of which further responding produces food. The second stimulus exerts both discriminative and reinforcing control over behavior: it is an S^D for responding in its own presence, and it is the conditioned reinforcer maintaining responses in the initial link (Kelleher and Gollub, 1962; Fantino, 1965, 1968).

Experiments employing chained schedules have forced a reassessment of the discrimin-

ative-stimulus hypothesis of secondary reinforcement. Keller and Schoenfeld (1950) stated that "in order to act as an S^r for any response, a stimulus must have status as an S^D for some response (p. 236)." They also argued for the "equality and interchangeability of the S^D and S^r values of the stimulus (p. 237)." Gollub (1958), however, showed that a stimulus can function as an S^D without being an S^r . In his study, the S^D for responding in an early link of the chain did not maintain responding in the prior link. Fantino (1965) extinguished responding on a chain variable-interval (VI) fixed-ratio (FR) schedule and found that responding terminated on the FR while sustained responding was maintained on the VI. In other words, the stimulus associated with the terminal link was no longer an S^D for responding in its own presence but was still an S^r for responding in the initial link. Thus, the S^D and S^r values of the stimulus are not completely interdependent or interchangeable.

The present study investigated the effects of deprivation upon responding in the different links of the chain. For example, does satiation exert a selective influence upon the responding in the initial link of the chain, or is responding throughout the chain uni-

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formly reduced? Several observations in the literature indicate that responding in the initial link may be particularly sensitive to the effects of satiation. Ferster and Skinner (1957, Fig. 869) demonstrated this with chained VI schedules, and Findley (1962) and Malott (1966) with chained FR schedules. In other words, satiation affects the S^D function of the terminal-link stimulus less than it affects the S^r function. The present study examined this relationship more extensively.

EXPERIMENT 1

This study was intended as a more extensive investigation of Ferster and Skinner's finding that satiation exerted a selective influence upon responding in the initial link. They studied two pigeons in a single, long (16- to 19-hr) session. In the present study, pigeons' behavior was maintained with four different reinforcement durations. It was expected that with different reinforcement durations satiation would progress at different rates. This would be reflected by different rates of response decline for different reinforcement durations. These differential declines in rate would rule out the possibility that the length of the session *per se* might be held largely responsible for the decline in rate. Moreover, findings based on several reinforcement durations would have far greater generality than findings based on one reinforcement duration only.

For much the same reasons, the pigeons were also studied in a procedure in which deprivation level was manipulated in a different manner. The pigeons were studied in short sessions in which initial deprivation level was varied but reinforcement duration was held constant. These results would bear on the possibilities that session length is important and that the method of manipulating deprivation level is critical.

METHOD

Four male, experimentally naive, White Carneaux pigeons were maintained at approximately 80% of their free-feeding body weight except when their weights were manipulated as described below. Water was constantly available in both the home cage and the experimental chamber.

The two identical pieces of apparatus were standard experimental chambers each with two response keys (Ferster and Skinner, 1957). At the start of a session, the left response key was transilluminated by a green light mounted behind it, while the right key was dark and inoperative. Responses on the left key (in the initial link of the chain) were reinforced on a variable-interval (VI) schedule with a mean interreinforcement interval of 45 sec by the appearance of a red light on the right response key. When the right key was transilluminated, the left key became dark and inoperative. Responses on the right key (in the terminal link of the chain) were then reinforced on a VI 45-sec schedule by the presentation of food for 8 sec. After reinforcement, the left key was again transilluminated. A given session continued until the rate of responding had declined to the point where the pigeon was receiving fewer than seven reinforcements per hour. In practice, these sessions generally lasted between 4 and 15 hr. It should be added that even when the rate of responding in the initial link approached zero the chain was often completed. This resulted from the nature of VI schedules: a single response after the requisite interval had elapsed was reinforced by the production of the next link or by food. After the session the pigeon was weighed, returned to its home cage, and studied again when its weight had returned to 80%. This generally required about five days.

Each pigeon's pecking was reinforced on this procedure for at least 10 preliminary sessions. Four durations of access to food were then introduced: 2, 6, 10, and 14 sec. In a given session, only one of the four durations was administered; over four successive sessions, each pigeon was exposed to all four durations in irregular order.

Subsequently the pigeons were tested at four different deprivation levels: 67%, 72%, 81%, and 89% of their free-feeding weights in an irregular order. These were shorter sessions, with only 21 reinforcements, each of 8-sec duration. Each pigeon was tested once at each deprivation level, and the rates of responding in each link were compared across sessions.

RESULTS

Figure 1 illustrates the declining rate of responding in both links for each of the four

food durations. The decline in rate for both links occurred more swiftly the greater the duration of reinforcement. The differences in rates of decline indicate that satiation and not merely the length of the sessions was responsible for the decline. The most important finding, however, was that for every food duration, the rates of responding in both links tended to decline simultaneously and in an orderly manner. Rate of responding in the initial link was always lower than that in the terminal link, but initial link responding was not, in any obvious manner, selectively affected by satiation. Although the most salient result of the experiment is this simultaneous decline of responding in the two links, more sensitive analysis reveals that responding in

the initial link of the chain was more rapidly disrupted by satiation. This is shown by the decay rates of the smooth curves drawn in Fig. 1. These geometric curves were fitted by eye and represent a reasonable description of the data. The general equation for these curves is $f(n) = a(b)^{n-1}$ where the constant a is the initial value of the function (at $n = 1$) and b is the decay parameter. The values of b for each of the eight curves in Fig. 1 are presented in Table I. The obvious finding that greater food duration resulted in faster decay is reflected by the declining values of b for both the initial and terminal link curves as food durations increased. In addition, for each food duration, the value of b is smaller for the initial link than for the terminal link curve.

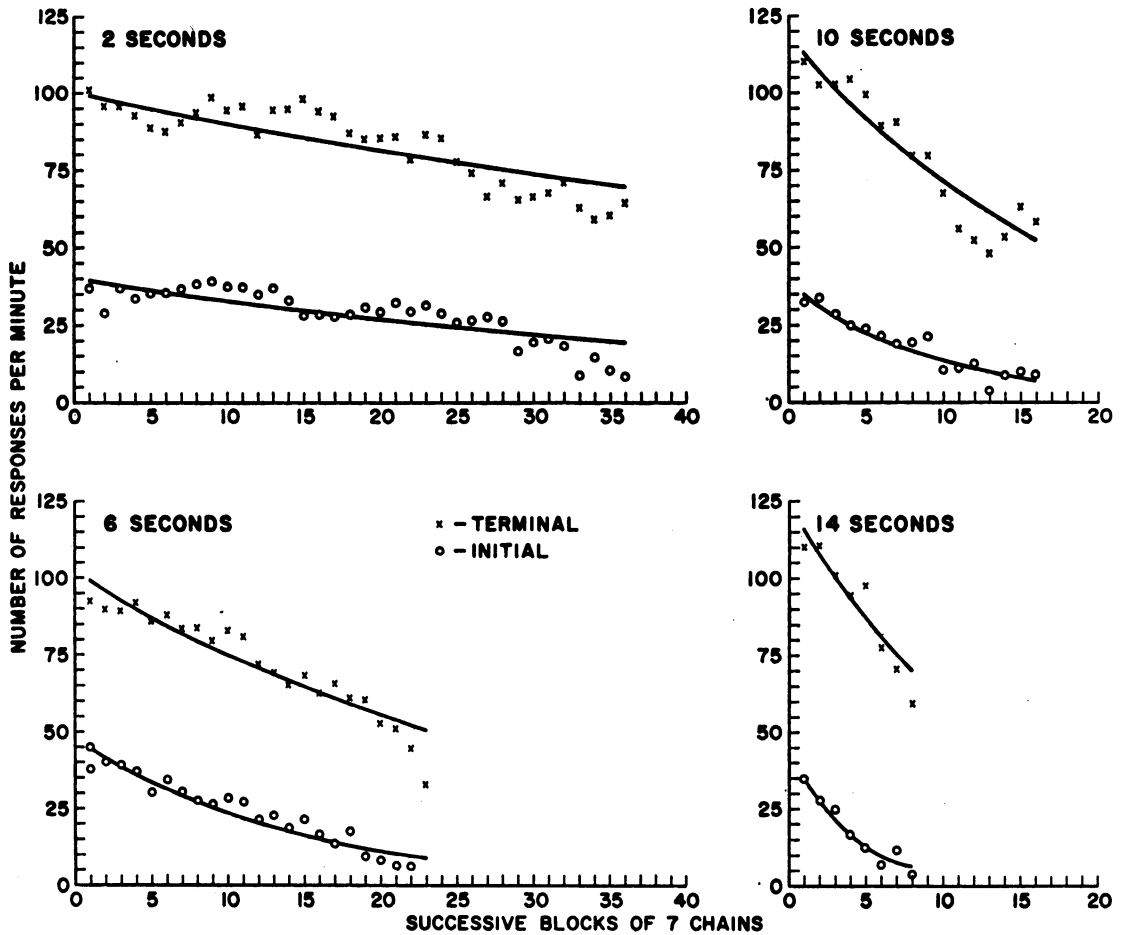


Fig. 1. Rate of responding throughout the session for each of the four durations of reinforcement. Each point represents the number of responses per minute in a block of seven chains, averaged over the animals. The geometric curves drawn through the data were fitted by eye. They are described by the equation $f(n) = a(b)^{n-1}$ where n is the abscissa value, a is the initial value of the function and b is the decay parameter. The values of b are presented in Table 1.

In other words, satiation affected responding in the initial link more rapidly than it affected responding in the terminal link.

Table 1

Decay Parameters for Geometric Curves in Fig. 1		
Food Duration	Initial Link	Terminal Link
2 sec	0.98	0.99
6 sec	0.93	0.97
10 sec	0.90	0.95
14 sec	0.78	0.93

It should be pointed out that the interpretation of which response rates decline "more rapidly" depends in part upon the method of analysis. For example, if straight lines were drawn through the data their slopes would indicate that responding in the terminal links declines more rapidly than responding in the initial links. This method of assessing rate of decline seems inappropriate, intuitively, since it measures decline in absolute units and since the response rates in the terminal links begin at higher values than those in the initial links. The decay parameters, however, describe decline relative to the response rates at the start of a session.

Similar results were obtained in the subsequent experiment in which the pigeons were tested with four deprivation levels, brief sessions, and a constant duration of reinforcement. The intersession comparisons are presented in Fig. 2. They reveal orderly declines in the rates of responding in both links across the four deprivation levels.

DISCUSSION

The results of these preliminary experiments differed from those obtained by Ferster and Skinner (1957) when they observed two pigeons in a single, long (16- to 19-hr) session on chained VI schedules. For each of their pigeons the rate of responding in the initial link decreased sharply with satiation, but there was little or no decline in the terminal link. In the present experiment, however, the effects of satiation upon responding in the two links were not dramatically different. Rather, responding in both links was affected simultaneously, although the decay parameters in Table I indicate that the decline for the initial link was indeed somewhat more rapid.

There were at least three procedural differences between Ferster and Skinner's experiment and the present one. In the first place, the means of the VI schedules were 1 min for one of Ferster and Skinner's pigeons and 3 min for the other; in the present experiment, VI 45-sec schedules were used. Secondly, Ferster and Skinner used the same key for both links of the chain while the present study used separate keys for each link. It seems unlikely that these first two differences were responsible for the different results obtained in the two experiments. Rather, the discrepancy between Ferster and Skinner's results and those of the present study (in which there were at least 10 preliminary sessions with the satiation procedure) suggested that the duration of maintenance on the satiation procedure may be critical. If so, it should be possible to obtain results similar to Ferster and Skinner's early in training and, subsequently, to obtain results similar to those of Exp. 1. If not, the other differences between the two experiments might be implicated.

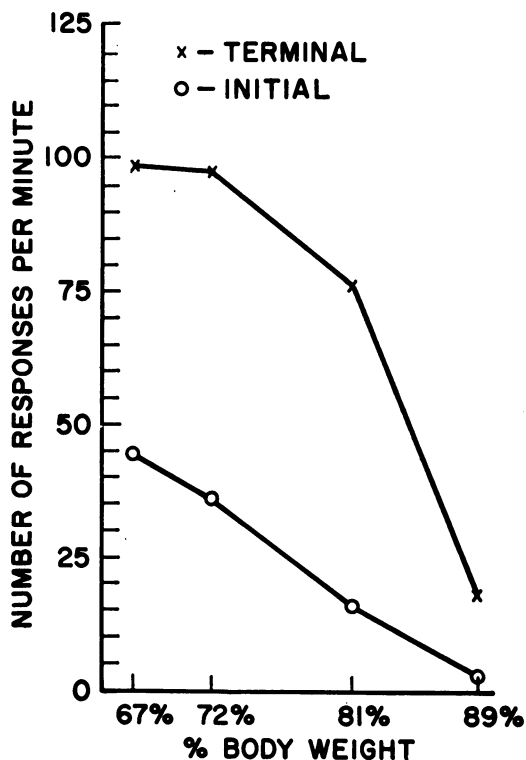


Fig. 2. Rate of responding as a function of body weight. Each point represents the number of responses per minute, in a single brief session, averaged over the animals.

EXPERIMENT 2

None of the previous experiments involving satiation (Ferster and Skinner, 1957; Findley, 1962; Malott, 1966) studied the effects of satiation over a large number of sessions. The results of Exp. 1 point to the possibility that the effects of satiation may interact with the duration of maintenance on the satiation procedure. The present study was conducted primarily to investigate systematically the effects of satiation on responding in a chain over a large number of sessions.

METHOD

Two additional naive pigeons were studied in an extensive series of sessions with chain VI 45-sec VI 45-sec in the apparatus described above. For the first nine sessions, subjects were at 80% of their free-feeding weight at the start of each session. A session consisted of 70 food reinforcements lasting 14 sec. Pigeon #5 continued to respond throughout its sessions but Pigeon #6 rarely completed sessions. Subsequently, Pigeon #6 was studied at 75% of its free-feeding weight and with reinforcements of 6-sec duration. Pigeon #5 was continued at 80% body weight with 14-sec reinforcements. For both pigeons, sessions now consisted of 84 food reinforcements. These sessions were conducted until the event-pen records and graphs of the pigeons' behavior satisfied a visual stability criterion for at least 20 consecutive sessions. For Pigeon #5 this required a total (including the original nine) of 53 sessions; for Pigeon #6, 71 sessions were required.

These pigeons were then studied in a short series of sessions in which, 1 hr before each session, they were fed an amount of grain sufficient to increase their weight to either its usual level after a satiation session or its usual level half way through a satiation session. For example, after being pre-fed to their usual post-session weight (97% body weight for Pigeon #5, 85% for Pigeon #6), they were expected to respond at the low rates characteristic of their performance at the end of a session.

Throughout Exp. 2, each session occurred on the first day in which the pigeon's weight had returned to the appropriate experimental level, which generally took about four days.

In all other respects the procedure was identical to that of Exp. 1.

RESULTS

The data for the very first satiation session are shown in Frame A of Fig. 3. In this first session the results were similar to those reported by Ferster and Skinner: responding in the initial link decreased while responding in the terminal link was maintained. In fact, for Pigeon #5 responding in the terminal link actually increased. This clear difference between the two links disappeared in four or five sessions; by the later sessions (Frame B of Fig. 3) response rates in each link fell off simultaneously and in an orderly manner, corroborating the results of Exp. 1. Geometric curves were fitted to the data in Frame B, in order to determine their decay parameters. For Pigeon #5, this decay parameter was 0.94 for the terminal link and 0.97 for the initial link, while for Pigeon #6 these values were 0.95 for the terminal link and 0.92 for the initial link. Thus, the tendency of responding in the initial link to be selectively sensitive to satiation was no longer apparent. Such a tendency had been found throughout Exp. 1 in which there were fewer sessions.

Frame C of Fig. 3 presents the results from the first sessions in which each pigeon was pre-fed (before the session) up to its normal post-session weight. The pigeons did not respond at the low rate characteristic of their performance at the end of a normal session. Instead, the rates of responding in both links were more similar to those obtained in normal satiation sessions (at 80% or 75% body weight). The pre-feeding, though not without effect, exerted surprisingly small control over the pigeons' response rates.

By the fourth pre-feeding session, both pigeons were showing greater effects of pre-feeding. Rates in both links were markedly lower than they had been at the start of regular satiation sessions. This result was most dramatic for Pigeon #5, as indicated in Frame D of Fig. 3.

For each pigeon, pre-feeding also had relatively little influence on the amount of weight gained during the initial pre-feeding sessions. In the first pre-feeding session the animals gained large amounts of weight in spite of the pre-feeding. Pigeon #5 gained

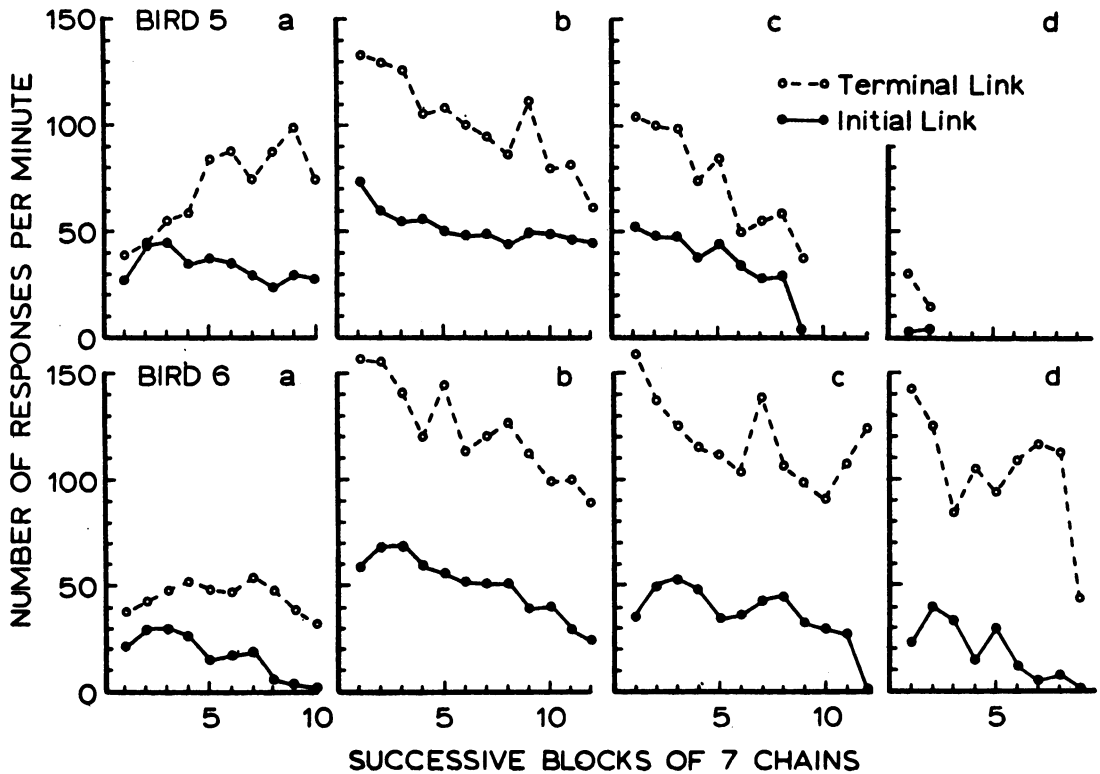


Fig. 3. Rate of responding throughout representative sessions at different stages of training for Pigeon 5 (top) and for Pigeon 6 (bottom). Panels A and B present the results for the first and last sessions of satiation training, respectively. Panels C and D present the results for the first and fourth pre-feeding sessions, respectively. For Pigeon 5 these were sessions 1, 53, 54, and 57; for Pigeon 6, sessions 1, 71, 72, and 75.

about 80 g in a standard satiation session, placing it at 97% of its free-feeding body weight. In the first pre-feeding session, Pigeon #5 gained 41 g which, combined with its pre-feeding, placed it about 20 g (4%) above its free-feeding weight. In the fourth pre-feeding session the amount of weight gained decreased to only 5 g. Pigeon #6 gained about 40 g in a standard satiation session. During the first pre-feeding session, in addition to its pre-feeding, it gained 47 g more than its usual amount, but in the fourth pre-feeding session its weight gain had decreased to only 6 g.

An interesting note is that in pre-feeding session 3, Pigeon #5 regurgitated its food in the middle of the session. In the next session, the bird finally showed a marked decrease in the amount it ate. This was the only instance of regurgitation in this study.

Earlier it was mentioned that these pigeons were given two different amounts of pre-feeding: to normal end-of-session weight and to normal mid-session weight. There was no

salient effect of the amount of pre-feeding. Perhaps the effect was masked by the stronger influence of the number of pre-feeding sessions: the rates of responding decreased with each additional pre-feeding session.

DISCUSSION

These results support the hypothesis that the effects of satiation interact with the duration of maintenance on the satiation procedure: in early sessions, responding in the initial link was more readily disrupted, but in later sessions the rates of responding in the two links declined simultaneously.

The failure of the rates of responding to reflect changes in deprivation level immediately, can be categorized under the rubrics "conditioned drive" or "externalization of drive" (Anderson, 1941), since the change in deprivation level did not have an immediate effect upon the rates of responding. In other words, the pigeons' behavior had become rel-

actively independent of deprivation level. A further example of this partial independence occurred when the pigeons were again studied in two normal satiation sessions at a high deprivation level (80%, 75%) subsequent to the pre-feeding sessions. Pigeon #6 responded as in the final pre-feeding session (as in Frame D). The rates of responding in both links were still depressed even though the pigeon was not pre-fed. By the second high deprivation session, however, each pigeon was responding as it had before pre-feeding (as in Frame B). Presumably, the important variable for obtaining the slow adjustments to changes in deprivation level was that the animals had been studied for a large number of identical sessions over a long period of time. What appears to happen is that the organisms develop a response pattern under one deprivation level that persists for some time after the deprivation level is altered.

Bolles (1967, pp 307-309) has recently reviewed studies of "conditioned hunger" and noted that the evidence is markedly against the existence of the phenomenon. The present results suggest that, if behavior is maintained for a sufficient number of sessions before altering deprivation level, positive results can be obtained. It is probably misleading, however, to describe these slow adjustments to changes in deprivation level in terms of "conditioned hunger".

GENERAL DISCUSSION AND CONCLUSIONS

These results indicate that the duration of maintenance on the satiation procedure may have profound effects upon the relationship between the extent to which a stimulus controls responding in its own presence (S^D function) and the extent to which it maintains responding in the preceding link of the chain (S^r function). Early in training, the S^D value of the stimulus associated with the terminal link is much more resistant to the effects of satiation than is the S^r value of that stimulus. This was demonstrated, for example, by the results of Exp. 2 and by those of Ferster and Skinner (1957, Fig. 869). After continued training with the satiation procedure, however, the S^D and S^r values decline simultaneously with progressive satiation. One question not answered by the present results is whether this

continued training must be with satiation procedures in order to produce these simultaneous declines. Some evidence on this question is provided when Ferster and Skinner's data is considered in conjunction with the present data. Ferster and Skinner's pigeons had received prolonged training with chained VI schedules before the single session with progressive satiation. Yet, for their pigeons, the rates of responding in the initial link decreased sharply while the rates of responding in the terminal link were largely unaffected. Apparently prolonged training with satiation procedures is the critical variable for producing simultaneous declines in the S^D and S^r functions with progressive satiation.

Our knowledge of the relationship between the S^D and S^r functions of a stimulus has become increasingly complex since Dinsmoor (1950) and Keller and Schoenfeld (1950) first suggested an equality between them. The results of both Ferster and Skinner (1957) and the present experiment, as well as those of Gollub (1958), show that a stimulus can function as an S^D without functioning as an S^r . Fantino's (1965) experiment demonstrated that with certain schedules of reinforcement these results can be reversed: a stimulus can function as an S^r without functioning as an S^D . Moreover, Fantino (1968) demonstrated in a choice situation that an S^D which occasions a high rate of responding need not be a stronger S^r than an S^D occasioning a lower rate of responding.

The present study indicated that the relationship between S^D and S^r is further dependent upon the duration of experience with, or maintenance on, a particular experimental condition. In early sessions with the satiation procedure, the S^r function is more easily disrupted than the S^D function by changes in deprivation, while after many satiation sessions the two functions are disrupted simultaneously. This gives the behavior sequence the appearance of being integrated, although generalization from this work to other research concerned with the integration of response sequences (e.g., Mandler, 1964) is only suggestive.

A stimulus becomes an S^D more readily than an S^r . This generalization is suggested by Gollub's study and by the fact that long chains of behavior are often shaped by first establishing a stimulus as an S^D and subse-

quently using it to reinforce behavior. The present results suggest that after the S^D has served as an S^r for a prolonged period with a satiation procedure the S^r function becomes more resistant to disruption than it was earlier. What is not clear from the present study is whether it is necessary for the stimulus to serve as an S^r in order for its S^r function to become resistant to disruption. In other words, if a stimulus were established as an S^D for a long period of time in a satiation procedure, and the initial link were subsequently added, would the S^r function have already become resistant to disruption, or at least, would this resistance develop more rapidly?

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