

RESISTANCE TO EXTINCTION IN THE GOLDFISH FOLLOWING SCHEDULES OF CONTINUOUS AND VARIABLE INTERVAL REINFORCEMENT¹

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Four goldfish (*Carassius auratus*, comet) were reinforced with food when they intercepted a beam of light. Each fish performed on both CRF and VI 50-sec schedules. In subsequent extinctions, the CRF schedule produced more responses on the first day than did VI, but after the first day the post-CRF rate dropped much more rapidly. These results agree with those previously obtained in birds and mammals.

In recent years, there have been many experiments investigating the behavior of fish under a variety of reinforcing conditions analogous to those used in the study of instrumental conditioning in birds and mammals. The results of these studies have suggested that the conditions under which intermittent reinforcement (IR) will produce greater resistance to extinction than continuous reinforcement (CRF) are more limited in the fish than, *e.g.*, in the pigeon or in man. Thus, these experiments find that, in the fish, IR produces an increased resistance to extinction only (a) if repeated extinctions and reconditionings are programmed, (b) if the number of reinforcements (for the CRF and IR conditions) is equated, or (c) if long runs of unreinforced trials are interspersed between reinforced trials.

Since it is an accepted experimental datum that, in birds and mammals, resistance to extinction is greater after IR than after CRF, the above-cited experimental results with fish have been interpreted, *e.g.*, Gonzales, Eskin, and Bitterman (1963), to indicate the existence of a possible class difference between the fish, and birds and mammals, with respect to the effect of these two kinds of reinforcement conditions. However, in all the experiments that have so far been reported, resistance to extinction has been measured during a sin-

gle post-reinforcement experimental session. Other investigators, *e.g.*, Keller and Schoenfeld (1950), suggest that if the results of only a single session are compared, CRF will often appear to generate a greater resistance to extinction, but that continued exposure of the animals to extinction would reveal a greater response strength after IR. As none of the fish experiments has carried extinction past the first day, it would seem that the argument for the hypothesized class difference has not been adequately tested.

In the light of Keller and Schoenfeld's discussion, the results of a single day of extinction do not provide any information upon which to base the conclusion of a class difference. The present experiment was planned to test this analysis. In this study, four fish were reinforced both on CRF and on IR. For each animal, each schedule was followed by several days of extinction. In this fashion, with each animal serving as its own control, performance after the two schedules could be compared not only during the first extinction session, but also during a more prolonged period of such a schedule.

METHOD

Subjects and Apparatus

Four goldfish (*Carassius auratus*, comet) were maintained under normal living conditions in a 5-gal (8½ by 12 by 10 in.) tank which was in turn placed inside one half of a 30-gal (20 by 26 by 14 in.) tank. In the other half of the large tank, separated by an opaque partition, was the working area which contained the response and reinforcement ap-

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paratus. This apparatus consisted of a 1-gal (10 by 4 by 9 in.) tank set in one corner of the large tank (Fig. 1).

To begin an experimental session, an *S* would be lifted by a net out of the living tank and placed in the working area. To obtain reinforcement, *S* had to swim to the surface of the working area and then into the alley formed by the outer wall of the large tank and the upward-projecting plexiglas partition. Each alley entry was recorded by a photocell. On schedule, a modified Gerbrands pellet dispenser dropped a small amount of powdered fish food (Longlife Micrograin) down a small tube into a feeding ring. If *S* did not consume all the food at once, the remaining powder sank through the mesh floor of the alley. Hence, in order to feed, *S* had to break the photocell beam and swim rapidly down the alley.

Responses were recorded on counters and a cumulative recorder. The intermittent reinforcement schedule was controlled by a tapefilm programmer. All experimental contingencies were controlled by conventional automatic switching circuits.

Procedure

All the *Ss* were initially exposed to CRF for 24 consecutive daily sessions, during which each swimming-in response produced one bit of food. Each experimental session was limited to 10 min per day for each *S*. During a session, *Ss* received about 40 reinforcements each. All *Ss* received supplementary food 1/2-hr after the day's experiment.

After the initial CRF schedule, all *Ss* were exposed for five days to extinction, during which the feeder was disconnected. During extinction, the supplementary feeding sessions were increased in length so that the day-to-day deprivation levels would be approxi-

mately the same. To accomplish this, the volume of food available during the post-extinction supplementary feedings was increased by the volume ordinarily obtained by that *S* during CRF. The sequence of conditions during initial reinforcement and the first extinction was identical for all *Ss*. This was done so that any large inter-animal differences could be noted, and also to provide some baseline information against which to compare the results of the subsequent training conditions.

Following initial CRF and extinction, *Ss* were exposed to a sequence of reconditioning and extinction periods. During reconditioning, the schedule was either CRF or VI 50 sec. The sequence of schedules for each *S* is outlined in Table 1.

Table 1
The Schedules to which each *S* was exposed.

<i>Ss</i>	Schedule Sequence	No. of Days
1, 3	CRF	24
	EXT	5
	CRF	24
	VI	24
	EXT	10
	CRF	24
	EXT	10
2, 4	CRF	24
	EXT	5
	CRF	24
	EXT	10
	CRF	24
	VI	24
	EXT	10

RESULTS

The experimental procedure was designed so that each *S* was twice exposed to CRF and once to VI 50 sec. Each reinforcement schedule was followed by several days of extinction. The results are summarized in Fig. 2, where the response rates are presented for each of the four *Ss* during the last 10 daily sessions of initial CRF performance, the five days of the first extinction, and the last 10 days of the succeeding reconditionings and extinctions. Of principal interest is the comparative course of extinction after CRF and VI.

Response rates for all *Ss* were stable during the conditioning sessions. Little difference between performance during CRF and VI appeared in the average response rates; during VI, however, there was somewhat more day-to-

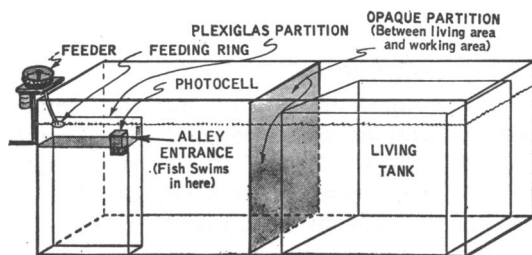


Fig. 1. Schematic diagram of apparatus to study operant behavior of goldfish.

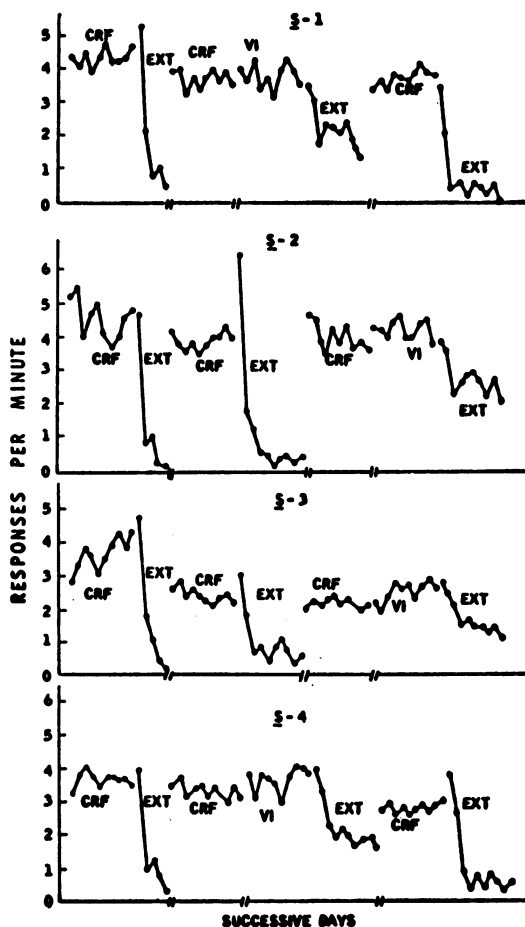


Fig. 2. Response rates for each *S* during the last few days on each reinforcement schedule.

day variability. The *Ss* all worked steadily during each day's session; the low rates were due to the fact that, to obtain another reinforcement, *Ss* had to swim a considerable distance, out of the alley and then back in up to the feeding ring.

During extinction, performances after the two reinforcement schedules differed radically. Statistical analysis revealed that on the first day of post-CRF extinction, *Ss* emitted relatively more responses than on the first day of post-VI extinction ($t = 3.35$, $.05 < t < .02$, $df = 3$). On succeeding post-CRF extinction days, the response rates dropped very rapidly to a stable low level that was clearly different from performance during the CRF training period. In comparison, on the first day of post-VI extinction the response rate was indistinguishable from that maintained during conditioning. Only on the second or third

day of VI extinction was there a clear decrease in response rate. In general, the day-to-day decline in rate in extinction was not nearly so rapid after VI as after CRF.

Representative cumulative records for one fish, *S-2* are presented in Fig. 3. Figures 3a and 3b, show the records for the last four days of the second CRF series, and the first four days of the succeeding extinction series, respectively. It is apparent that the within-session rate of responding during CRF conditioning was quite stable. During the first extinction session, this stable sequence of inter-response times was replaced by two prolonged bursts of responses, separated by a long pause. At the start of the second day of extinction, responding continued at the rate maintained at the end of the first day, but after the first 30 sec, a long pause appeared. After this, the response rate declined gradually, with the bursts becoming increasingly rare and brief, while the inter-burst pauses increased both in length and frequency.

These records are in strong contrast to those in Fig. 3c and 3d, the cumulative response curves for *S-2* during the last four days of VI conditioning and the first four days of extinction after VI. The records obtained during VI exhibit more variability than the CRF

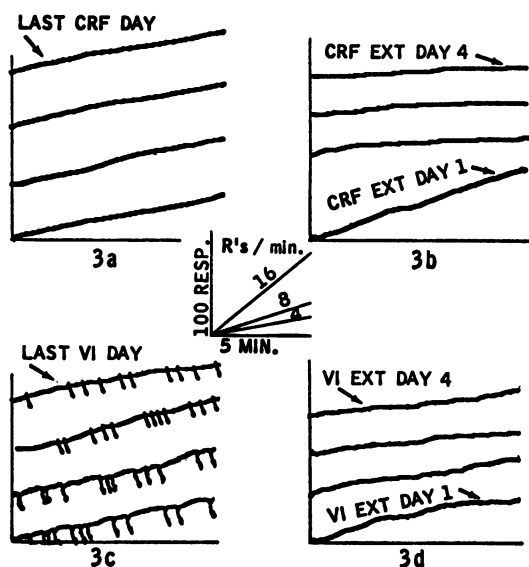


Fig. 3. Cumulative response records from one fish, *S-2*, during conditioning and extinction. Each curve is from a single 10-min session. Panels *a*, *b*, *c*, *d*, indicate performance during CRF, post-CRF extinction, VI and post-VI extinction, respectively. The slash marks in panel *c* indicate reinforcements during VI.

records. For example, after VI reinforcement there was often a long pause followed by a negatively-accelerated growth curve. This pattern of apparent "inter-reinforcement extinction" has been mentioned as a feature of the early development of intermittent reinforcement in birds and mammals (Keller and Schoenfeld, 1950; Ferster and Skinner, 1957). The records of post-VI extinction illustrate that the characteristic pattern of responding underwent only gradual changes. During the first day of extinction, the conditioning pattern of cyclic bursting and pausing continued. On the subsequent extinction days, the records exhibit a pattern of longer cycling, with the bursts decreasing in length while the pauses gradually lengthen. The characteristic features of post-CRF extinction, which included brief bursts of responses and long pauses, were not as pronounced during the first four days of extinction after VI.

DISCUSSION

Studies on the parameters of resistance to extinction in the fish by Bitterman and his co-workers have led these experimenters to conclude that the conditions under which IR produces greater resistance than CRF to extinction of an instrumental response are more limited in the fish than in higher animals. This conclusion is based on data obtained from measures of response strength during a single session of extinction.

The results of the present experiment are in agreement with those of Bitterman, *et. al.*, in that on the first day of post-CRF extinction, the fish emit relatively more responses than on the first day of post-VI extinction (*cf.*, Fig. 2). However, the performance of the fish during subsequent extinction sessions indicates a much greater resistance to extinction after VI; the response rates for all the Ss decline only gradually after VI, while the decline after the first day of post-CRF extinction is very rapid.

The present results are in no way unusual. In fact, they provide a prototypic illustration of the description by Keller and Schoenfeld (1950) of the comparative course of extinction after CRF and IR: "If we compared the two extinctions for only a brief period after rein-

forcement had ceased, regular reinforcement would appear to have generated a greater resistance to extinction than [intermittent reinforcement]. Such a conclusion, however, would be unjustified, since a continuation of extinction would reveal that the responding after [intermittent reinforcement] goes on unabated for a considerable time, whereas that after regular reinforcement soon tapers off." (*op. cit.*, p. 89)

Upon such consideration, it may be concluded that with respect to instrumental free-operant conditioning, the case for a class difference has not been proven. The description quoted above, based upon observations of the white rat, may be fittingly applied to results of the present study, especially in the comparative course of responding during successive extinction sessions, as illustrated in Fig. 2. It should also be noted that in order to demonstrate greater resistance to extinction after VI in the present study, it was not necessary to resort to the restricted set of conditions asserted by Bitterman *et. al.*, to define the supposed inter-class difference. Thus, the present results were obtained without equating the number of reinforcements in CRF and IR, without having to compare the results after many extinctions and reconditionings, and without interspersing a large number of unreinforced trials between reinforcements during intermittent reinforcement.

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