CONDITIONED SUPPRESSION IN GOLDFISH AS A FUNCTION OF SHOCK-REINFORCEMENT SCHEDULE¹

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The conditioned suppression technique (Estes and Skinner, 1941) was employed to study the effects of partial-shock reinforcement in the goldfish. Lever-pressing behavior of hungry goldfish was suppressed in the presence of a flashing light that had been previously paired with electric shocks. Fish that acquired the suppression under 50% and 100% shock-reinforcement, respectively, were subjected to repeated presentations of the flashing light alone. This procedure revealed a more rapid extinction of the suppressed behavior in the 50% than in the 100% shocked group. The finding was compared with those from other experiments and possible reasons for the differences were examined.

An extensive review of the literature dealing with the partial reinforcement phenomenon (Jenkins and Stanley, 1950) seems to support the generalization that resistance to extinction is greater after partial than after continuous reinforcement. Evidence for this derives from research extending from rats to humans. More recently, attempts to demonstrate greater resistance to extinction following partial reinforcement in fish (the African Mouthbreeder) proved to be unsuccessful (Wodinsky and Bitterman, 1960; Longo and Bitterman, 1960). In these investigations, a food-rewarded instrumental response was used. The results showed that following various experimental conditions, initial resistance to extinction of partially reinforced fish was less than that of consistently reinforced fish.

A later study of the partial reinforcement effect in goldfish revealed no differences between partial and consistently reinforced groups of animals (Gonzalez, Longo and Bitterman, 1961). These authors utilized a classical conditioning procedure and measured the generalized activity evoked by pairing a neutral stimulus with a brief shock.

The present study continued the investigation of partial reinforcement in the goldfish and employed the conditioned suppression technique (Estes and Skinner, 1941). In this classical conditioning procedure, the operant

behavior of hungry animals was suppressed in the presence of a previously neutral stimulus that had been paired repeatedly with an electric shock. The intent was to determine whether the conditioned suppression of operant behavior, acquired under partial shock reinforcement, would be more or less resistant to extinction than one acquired under 100% shock reinforcement. The term partial-shock reinforcement indicates that 50% of the CS presentations were terminated with shock as contrasted with 100% shock reinforcement where the fish was shocked following all CS presentations.

METHOD

Subjects

Ten experimentally naive goldfish, 15 to 18 cm long, were obtained from a local dealer. They were maintained individually in 2½-gal. tanks that were kept under constant aeration. Once each week, the filters were cleaned and the water was replaced with tap water drawn 24 hr previously. The water temperature was maintained at 72-76° F.

Apparatus

A plexiglass feeder (Longo and Bitterman, 1963), and an experimental chamber contained the lever and plexiglass electrodes. Lever responses were transmitted to counters by a high-gain amplifying integrating system (Longo and Bitterman, 1959). A 24 v 2 amp ac transformer served as the shock

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source. A detailed account of this apparatus has been reported previously (Geller, 1963). Programming and recording was done with switching and timing circuits, electrical impulse counters, and a cumulative recorder.

Procedure

After two weeks of food deprivation, *Ss* were trained to eat after operation of the feeder. Then, a training lever was suspended in the tank and *Ss* were trained to press it for a worm reward (weight of typical worm = 7.0 mg). In cases where *Ss* did not learn to press, a shaping procedure was employed (Skinner, 1953). In subsequent lever-pressing sessions the experimental cubicle was placed over each fish tank. After one session of lever pressing under continuous reinforcement, in which each lever response produced a worm, the schedule was changed so that reinforcements were obtainable on a 2-min VI schedule (Ferster and Skinner, 1957). The sequence of intervals has been reported (Geller, 1962). Experimental sessions were conducted at the same time each Monday, Wednesday and Friday. After an *S* had obtained 40 reinforcements, each session was terminated. When lever pressing rates on the VI schedule became relatively stable, *Ss* were divided into two groups, equated according to response rate.

The conditioned suppression was induced as follows: at 15-min intervals during the lever-pressing session, a flashing light stimulus (CS) was activated for a 3-min period. This stimulus was terminated contiguously with a 15 v electric shock of 0.3-sec duration. Each presentation of the CS constituted a trial, and *Ss* received four such trials during an experimental session. For one group of *Ss*, all trials were shock-reinforced; for the second group, trials were shock-reinforced only 50% of the time, in a mixed order. The degree of suppression during a trial was expressed as a suppression ratio (SR). It was obtained by dividing the number of responses emitted during the 3-min CS by the number of responses during the 3-min period before the CS. A value of 1.00 or higher indicates no suppression, a value of zero represents complete suppression, and intermediate degrees of suppression are expressed by values from zero to 1.00. The criterion for acquisition of the conditioned suppression was a mean SR of 0.10 or

lower, for the four successive trials of a session. After each *S* attained this degree of suppression, it was subjected to the extinction procedure, which was exactly the same as acquisition but with electric shock omitted. An SR of .90 or higher was the criterion for complete extinction.

RESULTS

Figure 1 shows the number of trials required by each *S* to attain the levels of acquisition and extinction established by the separate criteria. For the 50% shock group, more trials ($M = 17.6$) were required to reach an SR of 0.10 or lower than for the 100% group ($M = 12.8$). The 50% group, however, extinguished more rapidly than the 100% group; extinction required an average of 17.6 trials compared with an average 38.4 trials for the 100% shock group.

Variable-interval response rates for two *Ss* are shown in Table 1. Pre-conditioning rates for *S*39, the 50% shock fish, ranged from 16.0 to 20.3 resp/min. During the first set of acquisition trials, the VI response rate dropped to a level of 5.3 resp/min. Subsequent trials resulted in further reduction of VI response rate. Extinction of the conditioned suppression to the pre-determined criterion produced an incomplete recovery of the VI baselines. The data for the 100% shocked fish show a generally similar trend. During the first set of extinction trials, considerable recovery of the

Fig. 1. Acquisition and extinction of conditioned suppression under continuous and partial shock reinforcement in the goldfish. The bars represent the number of trials required for each fish to attain the criterion levels.

Table 1
VARIABLE-INTERVAL RESPONSE RATES

	Pre-Conditioning Days				Acquisition Trials				Extinction Trials				
Fish 39 (50% shock)	1	2	3	4	4	8	12	4	8	12	16	20	24
RESP/min.	20.3	18.6	16.0	17.4	5.3	4.2	2.9	2.6	7.1	8.7	7.4	9.2	
MEAN S.R.					.87	.65	.04	.16	.59	.64	.81	.97	
Fish 32 (100% shock)													
RESP/min.	18.1	18.5	18.8	15.0	7.3	4.4	9.0	8.1	9.9	10.3	10.3	12.0	
MEAN S.R.					.63	0	0	0	0	.34	.40	.94	

VI response rate occurred despite the fact that *S* remained suppressed during the CS periods (Mean SR = 0). For *S* 39, no recovery of the VI rate occurred during the first set of extinction trials, although there was some weaken-

ing of the conditioned suppression (Mean SR = .16).

Cumulative records illustrating stages in the development and extinction of the conditioned suppression are shown in Fig. 2. The

Fig. 2. Cumulative records of 10 goldfish illustrating varying degrees of suppression during acquisition and extinction phases of the experiment. The pen offsets denote the presence of the visual stimulus.

rate of acquisition for the 50% shock-reinforced fish was clearly slower. On the 12th acquisition trial, only three of the five Ss were completely suppressed, while in the 100% group, four out of five were suppressed by the seventh conditioning trial. By the sixth extinction trial, only one of the 100% shock group (#35) showed some loss of the suppression, as compared with three Ss extinguished in the partial group. By the 18th extinction trial, all of the 50% group were extinguished, while four of the 100% group were still suppressed in the presence of the light stimulus.

Figure 3 compares acquisition and extinction data for one 50% and two 100% shock-reinforced Ss. Subject 28 received the same number of shocks during acquisition as did S 30, the 50% shock-reinforced fish. Subject 33 received the same number of trials as S 30, and therefore twice the number of shocks. As the acquisition data show, all three Ss attained an SR of 0.10 or lower.

The conditioned suppression was extinguished most rapidly in the partially reinforced S by trial 17 of the extinction process. The two 100% shock-reinforced Ss were still suppressed twice as many trials later. It is of interest to note that during the early sets of extinction trials, the suppression began to ex-

tinguish in S 28 but then was strongly reinstated.

DISCUSSION

The results of this experiment are in agreement with other investigators (Longo and Bitterman, 1960; Wodinsky and Bitterman, 1960) who reported that initial resistance to extinction of partially reinforced fish was less than that of consistently reinforced fish. This is true despite the fact that in the present experiment, the common goldfish was used, rather than the African Mouthbreeder, and a different learning situation was employed.

Present results are not in agreement with those reported by Geller, Kailan, Stein and Brady (1957), who utilized the conditioned suppression technique in rats. These investigators found a more rapid extinction of conditioned suppression in 100% shock-reinforced rats than in 25% shock-reinforced rats.

Gonzalez *et al.*, using goldfish in classical conditioning, found essentially no differences between partially and consistently reinforced groups of fish. Perhaps the differences between their methodology and the present, can account for the differences in findings. In the present experiment, hungry fish working for food were given a series of light-shock pairings; in the Gonzalez experiment similar light-shock pairings were given to sated goldfish, and thus no hunger motivation was involved.

Since partial reinforcement has not been found effective in increasing resistance to extinction in goldfish or in the African Mouthbreeder, one might seek an explanation in terms of physiological or anatomical differences between fish and higher animals. The absence of this effect in fish might conceivably be related to their more primitive central nervous systems.

The author in a recent replication of the study under identical experimental conditions found that the conditioned suppression was extinguished more rapidly in 100% shock-reinforced rats than in 50% shock-reinforced rats.

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Fig. 3. A comparison of acquisition and extinction data for a 50% and two 100% shock-reinforced fish. The continuously reinforced fish are matched with the partial based on an equal number of shocks (S 28) or an equal number of trials (S 33) during acquisition training. The pen offsets denote the presence of the visual stimulus.

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