STIMULUS CONTROL IN THE GOLDFISH AFTER MASSED EXTINCTION¹

MATTHEW YARCZOWER AND RICHARD SWITALSKI

UNIVERSITY OF MARYLAND

Compared with the data of goldfish trained only with stimuli correlated with reinforcement, interspersed reinforcement-stimulus and extinction-stimulus trials resulted in sharper stimulus control and a marked reduction in the percentage of key-presses emitted in the presence of stimuli located near the extinction stimulus on the test dimension. If non-reinforced trials were not interspersed with reinforced trials, there was no sharpening of stimulus control and less reduction in key presses in the presence of stimuli near the extinction stimulus on the test dimension.

Honig, Thomas, and Guttman (1959) examined whether massed extinction trials in the presence of an exteroceptive stimulus that followed trials of positive reinforcement in the presence of a second exteroceptive stimulus would have the same effect on generalization gradients as would trials of non-reinforcement interspersed with trials of reinforcement. In that experiment, after key pecking was reinforced in the presence of a 550-nm light, pigeons were given a single session of massed trials of non-reinforcement in the presence of a 570-nm light. Relative generalization gradients after the massed extinction procedure closely resembled gradients from pigeons that had received only trials of reinforcement in the presence of the 550-nm light; the number of responses emitted during the generalization tests differed but the relative shapes of the gradients were similar. The generalization gradient after massed extinction did not resemble gradients that resulted from discriminative training procedures in which there were interspersed trials of reinforcement and non-reinforcement.

The present study used goldfish to examine the effects of massed extinction trials in a procedure that permitted an analysis of the effects

on generalization gradients and also on training performance.

METHOD

Subjects

Eighteen experimentally naive goldfish (*Carassius auratus*), about 10 to 13 cm long, were obtained from a local fish hatchery. Each fish was kept in a 2.5-gal aquarium.

Apparatus

A black Plexiglas box, to which each fish was brought in its individual aquarium, contained a response key made of translucent Plexiglas centered in an 8 by 9 cm panel of black Plexiglas. The panel was attached to the top of the enclosure and was inserted into a fish tank when the top of the enclosure was closed. A response was automatically recorded whenever a force of approximately 5 g was applied to the key (a photoelectric system was used to detect key movements). Food reinforcements were administered by automated equipment which brushed approximately 5 mg of floating fish food (BiOrell) into a feeding ring located slightly above the key. The feeding area was illuminated for 6 sec after food was delivered.

The monochromatic stimuli were produced by a Farrand visual grating monochromator.

Associated automatic scheduling and recording equipment were located in an adjacent room.

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Procedure

All fish were magazine trained and then trained to strike the response key, which was transilluminated by a 550-nm light. The fish received 20 reinforcements per session for three sessions under each of the following schedules of reinforcement: reinforcement for each response (FR 1); FR 1 and FR 3 (reinforcement for every third response) randomly alternated; FR 1 and FR 5 randomly alternated. The fish were then assigned unsystematically to one of three groups of six each.

Group 1 received daily training consisting of 20 trials under a VI 30-sec schedule of reinforcement in the presence of a 550-nm light (S+ trials). Group 2 also received each day 20 trials under VI 30-sec in the presence of a 550-nm light. In addition, they received 20 trials in which no food reinforcers were available in the presence of 590 nm (S- trials). The 20 S- trials immediately followed the 20 S+ trials. Each trial was of 30-sec duration and each was separated by a 5-sec intertrial interval, during which all lights were turned off and reinforcements were not available.

Group 3 received identical training to that of Group 2 except that each day, S+ and S- were randomly interspersed in accordance with Gellermann (1933) series.

Training for all groups continued for 25 sessions. Generalization tests were carried out during Sessions 26 to 32. During generalization, each group was exposed to the same training conditions as during the prior 25 sessions. In addition, seven test stimuli (490 nm to 610 nm in 20-nm steps) were presented for 30 sec, during which no reinforcements were available. Each test stimulus was preceded by at least one trial during which the VI 30-sec schedule was in effect in the presence of 550 nm. The presentation of 550 nm and 590 nm as test stimuli did not differ from the presentation of other test stimuli; non-reinforcement was in effect and only responses during these test trials were recorded as generalization data.

For example, a fish in the interspersed group might have received: 550 nm (S+); 580 nm (test); 550 nm (S+); 550 nm (test); 590 nm (S-); 550 nm (S+); 610 nm (test); *etc.* A fish in the separate group might have received the same sequence, except that during the test sequence, 590 nm would have been presented only if it were a test stimulus; recall that during train-

ing the separate group received 590-nm (S-) trials only after the last S+ trial.

RESULTS

Figure 1 shows the mean number of responses emitted in each block of five sessions during 25 sessions of training. Both groups given discriminative training showed differential responding, although the manner in which differential responding was achieved was quite different for the two groups. The fish given separate blocks of S- trials after S+ trials exhibited rates of responding in S+ comparable to those of fish given only S+ trials. The mean response rate in S+ for the group given interspersed S+ and S- trials appears higher, although an analysis of variance yielded marginally non-significant results ($F = 3.43$, *d.f.* 2/15, $0.05 < p < 0.10$).

A discriminative index (Hunt, Jernberg, and Brady, 1952; Pierrel and Sherman, 1960) was computed (percentage of total responses emitted in the presence of S+) in order to estimate the extent and degree of differential responding. The fish exposed to separate blocks of S+ and S- trials emitted a significantly ($p = 0.002$) higher percentage of responses in the presence of S+ than did the fish exposed to interspersed trials of S+ and S- (there was no overlap in the distribution). There is, then, a greater degree of differential responding in the group given separate (D.I. = 82.9), rather than interspersed (D.I. = 63.4), trials of S+ and S-. An analysis of the data within each session points to the manner in which differential responding developed within each session. If one compares the proportion of total responses emitted in each quarter of the 20 trials, it is clear that the major difference between the two groups given discriminative training is the proportion of S- responding in each quarter. Approximately 62% of all responses in the presence of 590 nm (S-) were emitted in the first five trials of the 20 consecutive, non-reinforced trials. In contrast, fish that received interspersed trials of S+ and S- emitted about 25% of the responses in each quarter of the 20 trials. Analysis of responding in the presence of the S+ (550 nm) indicated little difference among the three groups with respect to the proportion of responses emitted in each quarter of the 20 trials. All three groups of fish emitted a slightly greater percentage of their

Fig. 1. Mean responses per session. Mean number of responses in the presence of the S+ and S- for the fish that received interspersed (INT) and separate (SEP) trials are shown. Also shown is the mean number of responses in the presence of the S+ for the fish that received only the S+ trials (S.S., *i.e.*, single stimulus).

responses in the first than in the fourth quarter of the session.

Figure 2 shows the results of generalization tests carried out during continued training. The generalization gradient of each fish in each group is shown. A sensitive measure of the effect on generalization gradients of discriminative training procedures (if the stimuli lie on the same dimension) is the per cent of responses emitted to test stimuli on one side of the S+ (Terrace, 1966*b*; Yarczower, Gollub, and Dickson, 1968). The group given interspersed S+ and S- trials emitted a significantly ($p = 0.004$) greater percentage of re-

sponses in the presence of wavelengths shorter than 550 nm than the group given training with separate S+ and S- trials. The group that received separate S+ and S- trials differed marginally from the control group ($p = 0.042$) on this measure.

The percentage of responses emitted in the presence of the S+ during generalization tests was calculated and used as a measure of the steepness of the generalization gradient (Hiss and Thomas, 1963). Again, the group that had received interspersed S+ and S- trials showed a significantly ($p = 0.008$) steeper gradient than the control group, while the group that

Fig. 2. Generalization gradients for each fish in each of the groups are shown. The group given only S+ trials during training is labeled "S.S." The group given interspersed S+ and S- trials is labeled "INT" and the group given all non-reinforced trials after reinforced trials is labeled "SEP". Also shown are the wavelength values used as S+ and S-.

had received separate S+ and S- trials did not produce a gradient steeper than the control gradient ($p = 0.094$).

DISCUSSION

Goldfish given training in which reinforced and non-reinforced trials are interspersed show a steepening of the gradient of stimulus control and a marked reduction in the percentage of key-presses emitted in the presence of stimuli located near the S- on the test dimension (or conversely an increase in the percentage of key-presses emitted to stimuli on the side of the S+ opposite the S-). These findings support those of a previous study with goldfish using different procedures (Ames and Yarczower, 1965). Goldfish given daily training in which non-reinforced trials followed rein-

forced trials showed no steepening of the gradient of stimulus control; nor did they show as much reduction in the percentage of key-presses emitted in the presence of stimuli located near the S- on the test dimension. Why should successive, non-reinforced trials that follow reinforced trials produce effects different than interspersed trials of reinforcement and non-reinforcement?

Although a wide variety of discriminative training procedures results in an orderly modification of stimulus control (*cf.* Terrace, 1966b; Yarczower *et al.*, 1968), not all procedures which have been said to result in "discrimination learning" produce changes in stimulus control. If stimulus control of key pecking after training with a single discriminative stimulus is used as a basis of comparison, then there appear to be several "discriminative

training" procedures which produce little, if any, modification of stimulus control.

Stimulus control of key pecking is not noticeably affected (measured against the comparison gradient) by "errorless discrimination" procedures (Terrace, 1964) nor by discriminative training procedures that produce markedly different rates of key pecking in the presence of two stimuli but under which a higher frequency of reinforcement is associated with the lower rate of key pecking (Yarczower *et al.*, 1968).

The data for the goldfish in the present study given separate non-reinforcement trials resemble the data of a group of pigeons given discriminative training in which key pecks were reinforced in the presence of a 550-nm light and reinforcement in the presence of a 570-nm light was three times as frequent if they did not peck the key (Yarczower *et al.*, 1968). The pigeon's response rate in the presence of the 550-nm light was not noticeably affected during training by the addition of the schedule in effect in 570 nm. The rate of key pecking in the presence of the 570-nm light declined steadily and differential responding was maintained by this discriminative procedure. Similarly, the goldfish's response rate in S+ was not noticeably affected (compared with goldfish given only S+ training) by including the extinction component in 590 nm. The rate of key pressing in the presence of the 590-nm light declined steadily and differential responding was maintained. In both studies, stimulus control was not markedly affected by the discriminative training. In the pigeon study, it was suggested that non key-pecking behavior was under the control, not of the S- wavelength stimulus, but of other stimuli also associated with the reinforcement schedule. Perhaps in the present study, responding in the presence of the S- wavelength stimulus was also not under the control of the wavelength stimulus as much as it was under the control of other stimuli associated with the extinction schedule.

Differences in performance in the presence of two exteroceptive stimuli, each associated with different schedules of reinforcement, does not faithfully reflect stimulus control by either stimulus, as both Dickson and Thomas (1963) and Jenkins (1965*b*) have noted. If S- gains control over behavior, components of which are incompatible with the behavior under the

control of S+, and if S+ and S- are also near one another on the test dimension, then this will result in modification of a gradient which reflects only the control of behavior by S+. When S- does gain control over behavior it is referred to as "inhibitory control". If S- does not gain control over behavior, "inhibitory control" is said to be absent and the gradient of control by S+ will be less affected, if at all, by discriminative training procedures which do not produce "inhibitory control". (There may be a steepening or sharpening of the gradient but this effect does not necessarily reflect experience with a specific S- because the effect is also obtained by discriminative training involving the presence and absence of S+.) Jenkins has identified inhibitory control as control by S- of behavior other than that controlled by S+. According to Jenkins' formulation (*cf.* 1965*a*) there are at least two reasons for a demonstrated lack of inhibitory control after discriminative training: (1) removal of "... generalized excitatory effects, or to use an unpopular metaphor, ... disconnecting the (S-) stimulus from the response. Disconnection does not imply a connection to anything else" (p. 57); (2) behavior other than that controlled by the presence of S+ is under the control of a specific stimulus or stimuli but not the exteroceptive S-. The absence of inhibitory control after "errorless discrimination" (Terrace, 1964, 1966*a*) and after procedures that produce markedly different rates of responding, but under which a higher frequency of reinforcement is associated with the lower response rate (Yarczower *et al.*, 1968) may be due to either of the reasons given for lack of inhibitory control. Perhaps those discriminative training procedures that contain stimuli other than the exteroceptive stimuli, and which are relatively consistently associated with the training schedules, increase the likelihood that inhibitory control will be absent because of the control exerted by those stimuli over behavior. There is no evidence at present upon which one may rely in choosing among these alternatives, but further research may clarify the distinction or indicate an essential identity between the formulations.

It should be noted that if a stimulus other than the S- does gain control over behavior it does not necessarily explain why the exteroceptive S- does not gain control. In those cases in which more than a single stimuli is

correlated with differences in responding, it is possible (Mackintosh, 1965; Sutherland and Holgate, 1966) though not inevitable (Schade and Bitterman, 1966; Gonzalez and Bitterman, 1968) that control by one stimulus lessens the control exerted by the other stimulus. Therefore, although the behavior emitted in the presence of S— may come under the control of other stimuli, it does not necessarily follow that control by S— must be weakened. A great deal remains to be learned about the conditions responsible for the acquisition of what has been termed, "inhibitory control"

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