Classical conditioning of goldfish in the shuttlebox*

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Goldfish trained in a shuttlebox with light as CS and brief shock as US acquire the shuttling response to light whether or not an avoidance contingency is in effect. That the change in behavior produced by the classical procedure is not due merely to sensitization is demonstrated by a discriminative control. The results suggest the usefulness of the shuttlebox for the study of classical conditioning in goldfish and call into question the instrumental interpretation of the change in behavior produced by the avoidance procedure.

The shuttlebox designed for the study of avoidance conditioning in fishes (Horner, Longo, & Bitterman, 1961) can be used also for the study of classical conditioning. Brief shock tends to produce shuttling in the goldfish, and stimuli paired with shock come to increase the probability of shuttling even when the shock is unavoidable. The phenomenon appeared unexpectedly in an experiment on the role of the avoidance contingency in the maintenance of avoidance responding. One group of goldfish had conventional avoidance training in the shuttlebox, a second group was yoked with the first, and a third served as an activity control (unstimulated, its crossing was monitored in blank trials). When the performance of the avoidance group had stabilized, an attempt at extinction was made, not by the traditional method of omitting shock entirely, but—following the suggestion of Davenport and Olson (1968)—by suspending the avoidance contingency; that is, all groups were trained by the classical procedure, the CS paired with shock on every trial. Unlike Davenport and Olson's rats, the goldfish which had been given avoidance training continued to respond to the CS, and the performance of the other two groups soon reached the same level.

EXPERIMENT 1

Method

The Ss were 36 goldfish selected for uniformity of length, which averaged 6 cm. The apparatus was a set of six Plexiglas shuttleboxes like those described earlier (Horner, Longo, & Bitterman, 1961). Filtered and aerated water was circulated through the boxes from a common tank to which all were connected. The end compartments of each box were filled to a depth of 7 cm, and the depth of the water over the hurdle was 2 cm.

The CS was provided by red Christmas-tree lamps which simultaneously illuminated the two end compartments through the translucent end walls. The US was a single 0.65-V/cm, 0.4-sec ac shock delivered through the long walls of the shuttlebox which were coated with a conductive (carbon) paint. The CS-US interval was 10 sec, and the CS terminated with the US unless (under avoidance conditions) it was terminated earlier by response. Response was defined as swimming from one end compartment into the other. Photodetectors were positioned at either side of the hurdle, and a crossing was registered only when the fish had passed completely through the near beam and had intercepted the far beam. All events of the experiment were programmed automatically, with responses recorded on paper tape.

In the first stage of the experiment (Days 1-4), activity was monitored in blank trials, and the animals were divided into three groups matched for performance on those trials. In the second stage of the experiment

(Days 5-17), Group A had 10 avoidance trials (response in the CS-US interval terminating the CS and avoiding the US) each day at a mean intertrial interval of 208 sec. Group A-Y served as a yoked control. For each A animal in an odd-numbered shuttlebox, there was an A-Y animal in an even-numbered shuttlebox. The responses of the two animals were recorded separately, but the duration of the CS and the occurrence of the US for both animals were determined by the behavior of the A animal. Group ACT continued to have only blank trials. In the third stage of the experiment (Days 18-29), all three groups were trained by the classical procedure (response in the CS-US interval neither terminating the CS nor avoiding the US). In the fourth stage of the experiment (Days 30-34), all three groups were extinguished by the classical procedure (no termination of the CS by response and no US).

Results

The performance of the three groups is plotted in Fig. 1, the score for each animal being the number of each day's trials on which it made at least one response in the CS-US interval. The curves for Groups A and A-Y are based only on data from 8 of the original 12 animals in each group, because the loss of 4 animals made it necessary to discard also the 4 animals paired with them.

The first portion of Fig. 1 shows the initial level of activity. The second portion shows increasing probability of response to the CS in the avoidance animals and to some extent also in the yoked controls. Analysis of variance yields a significant groups effect [$F(2,25) = 12.37, p < .001$], with the

Fig. 1. The performance of the three groups in the various stages of Experiment 1.

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Fig. 2. Differential conditioning in the shuttlebox.

level of response significantly greater in A than in A-Y ($t = 3.78$, $p < .001$) and greater in A-Y than in ACT ($t = 2.49$, $p < .01$). The third portion of Fig. 1 shows that when all groups were classically trained, there was no extinction in Group A, but acquisition in the two control groups, whose performance soon equaled that of Group A. The fourth portion of Fig. 1 shows that all three groups extinguished at the same rate when tested with unreinforced presentations of the CS. Analysis of variance yields a significant days effect in the final stage of the experiment [$F(4,88) = 7.50$, $p < .01$] but a negligible groups effect and a negligible Groups by Days interaction.

Before the results obtained in the third stage of this experiment can be attributed to classical conditioning, the possibility of sensitization must be eliminated. Our first approach to the problem was to use an unpaired control group, which showed no sign of acquisition, but many Ss were injured during the training. On the suspicion that the low level of responding may have been due to the deleterious effect of unheralded shock, we went over to a discrimination design. Two CSs were used, of which only one was paired with shock.

EXPERIMENT 2

Method

The Ss were 18 goldfish drawn from the same population as before. The apparatus and procedure also were the same, with the following exceptions: there were 3 days of activity measurement, after which training was begun with two CSs (red and green light), each presented (in Gellermann orders) on 10 of each day's 20 trials. The intertrial interval averaged 104 sec. For half the animals, red light

was paired with shock; for the rest, green was paired with shock. The procedure was purely classical, response to the CS neither terminating the CS nor preventing shock when shock was programmed.

Results

The response of the animals on blank trials in the first three sessions and to each CS in the subsequent conditioning sessions is plotted in Fig. 2. The probability of response to both stimuli, which was very low to begin with, increased in the course of training, but much more markedly for CS+ than for CS-. Analysis of variance yields a significant stimulus effect [$F(1,16) = 71.00$, $p < .001$], a significant days effect [$F(21,336) = 14.40$, $p < .001$], and a significant Stimulus by Days interaction [$F(21,336) = 7.84$, $p < .001$].

An analysis also was made in this experiment of responses to the US. The probability of at least one crossing in the 10 sec following shock was about 0.5, while the probability of at least one crossing in the 10 sec following the unreinforced CS was about 0.1. The two probabilities, which remained very much the same in the course of training ($F < 1$), differ significantly [$F(1,16) = 116.17$, $p < .001$].

DISCUSSION

Goldfish trained in the shuttlebox under conditions in which response neither terminates the CS nor avoids shock show an increase in the probability of shuttling, just as do goldfish trained under conventional avoidance conditions. Although unanticipated, the result is not difficult to understand. When a goldfish confined in a small compartment is subjected to paired stimulation with light and shock, the light comes increasingly to activate the animal (Horner, Longo, & Bitterman, 1960), and it seems reasonable to assume that the same process operates in the shuttlebox: activated by the CS, the animal is more likely to swim across the hurdle. It has, in fact, been demonstrated that certain quantitative features of the shuttlebox performance of goldfish can be deduced directly from measurements of conditioned activation (Bitterman, 1965).

The new finding is of interest for several reasons. For one thing, we now have another technique for studying the classical conditioning of skeletal

behavior in fishes, and one which is considerably simpler than the general-activity technique, although whether it is as sensitive remains to be determined. Furthermore, the new finding raises the question of whether instrumental learning plays any part at all in the shuttlebox performance of goldfish trained by the avoidance procedure. Where, as in experiments with other animals in other situations (Broden, Lipman, & Culler, 1938; Davenport & Olson, 1968), it is found that patterns of behavior produced by avoidance training can neither be established nor maintained by classical training, a process of response selection as well as a process of activation must be assumed, but a simpler interpretation may be sufficient where the two training procedures produce comparable results. The different performance of avoidance and yoked animals in the second stage of Experiment 1 demonstrates the effectiveness of the avoidance contingency but does not mean necessarily that instrumental learning has taken place. As Gormezano (1965) has suggested, for example, the same outcome might be expected also on the assumption that the reinforcing effect of the US on any trial is an inverse function of preexisting associative strength. Some parametric comparisons of classical and avoidance training in the shuttlebox might help to determine whether or not different mechanisms are involved.

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