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Spatially located visual CS effects on conditioned avoidance shuttle response (CASR) acquisition in goldfish (*Carassius auratus*): Training over days

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Goldfish (*Carassius auratus*) were run for 4 days at 20 trials a day with either CS onset or CS offset conditions. In each condition, the CS was located on the same, the opposite, or both ends as the subject. Conditioned avoidance shuttle rate (CASR) was found to be a function of the magnitude of CS change for both CS onset and CS offset conditions, specifically from maximum to minimum CASR performance, both, same, opposite. The differences in this order of CASR performance vs. that where subjects are trained in a single day are interpreted as being a function of a negative phototaxis for the CS onset and a confusion reaction for the CS offset conditions, both of which affect acquisition rates in the single-day paradigm, but which acquire cue functions and augment acquisition in the multiday paradigm.

Recent results from Gallon (1974), which were confirmed by Zerbolio and Wickstra (1976), indicate the acquisition of a conditioned avoidance shuttle response (CASR) in goldfish is a function of type of CS stimulus change (lamp onset or offset) and location of CS stimulus change (CS occurring on the same, opposite, or both ends of the shuttle tank relative to the subject's position). For CS onset, both Gallon (1974) and Zerbolio and Wickstra (1976) found same end locations yielded highest avoidance rates, opposite end locations lowest rates, with both intermediate. In contrast, for CS offset conditions, Zerbolio and Wickstra (1976) found equivalent avoidance performance for all three locations, while Gallon (1974) found equivalent avoidance rates for same and opposite locations, but no acquisition for the CS both location. These results for CS onset conditions are consistent with Gallon's (1974) hypothesis that, for CS onset, the CS light acquires aversive characteristics (conditioned aversion) in addition to a generalized shuttle response, which facilitates performance for the same location, as the aversion response and generalized shuttle response are compatible. Under CS opposite conditions, the aversion and generalized shuttle responses are incompatible, which interferes with acquisition. Results for the offset condition from Zerbolio and Wickstra (1976) confirm Gallon's (1974) suggestion that aversive properties cannot be attached to a localized area of darkness.

The above effects were obtained under conditions of massed practice (100 trials in a single-day session). The purpose of the present study is to determine if conditioned aversion to the CS develops when training is carried out over the course of 4 days.

METHOD

Subjects

Sixty goldfish, 5-8 cm long, obtained from Ozark Fisheries, Stoutland, Missouri, were used. All subjects were housed in 30-gal aquaria until 48 h prior to use, when they were transferred to 10-gal aquaria in the experimental chamber. Twenty-four hours prior to the first day of running, the subjects were again transferred to individual 7.5 x 11.5 x 12.5 cm deep holding tanks. All tanks were well aerated and filtered throughout the experiment, and fish were fed daily.

Apparatus

Two identical 29.2 x 11.4 x 11.4 cm shuttle tanks, separated into two compartments by a center hurdle 6.35 cm high, were used. Water clearance over the hurdle was 2.5 cm. Photocells located at hurdle ends monitored all shuttling activity. Blue 7-W 110 ac lamps, affixed to the tank ends, served as the CS. Plastic plates were mounted on the tank ends and served to diffuse illumination within the tank. The US was delivered via 28 x 10.2 cm 22-g stainless steel plates attached to the interior sides of the tank. The US was generated by isolated variable transformers, individually monitored and metered at 7.5 V ac. Temperature (21.1°C) and pH (7.00 ± .1) were held constant. All events were programmed and all responses recorded via appropriate circuitry.

Procedure

Six groups of 10 fish each were run in a factorial design of 2 CS conditions (onset and offset) by 3 CS locations (CS located on the same, the opposite, or both ends relative to the subject at trial onset). Each subject was run 20 trials a day for 4 consecutive days. A trial consisted of a 10-sec CS period followed by a 2.2-sec US period if the subject did not respond. The US was a series of 200-msec-on/300-msec-off shocks. A maximum of five shocks occurred on any one trial. Any initial shuttle response occurring in the CS-US period was recorded as an avoidance; any initial shuttle response occurring during the US period was recorded as an escape; and either an avoidance or escape response terminated further stimulation. The ITI was a VI 60 sec. Total shuttle rate and ITI shuttle rates were recorded.

RESULTS

A 2 CS condition by 3 CS location by 4 days of Training ANOVA (Winer, 1971) indicated significant differences between CS locations, $F(2,54) = 10.150$, $p < .01$, but no effect for Onset/Offset conditions or their interaction. Additionally, there was a significant

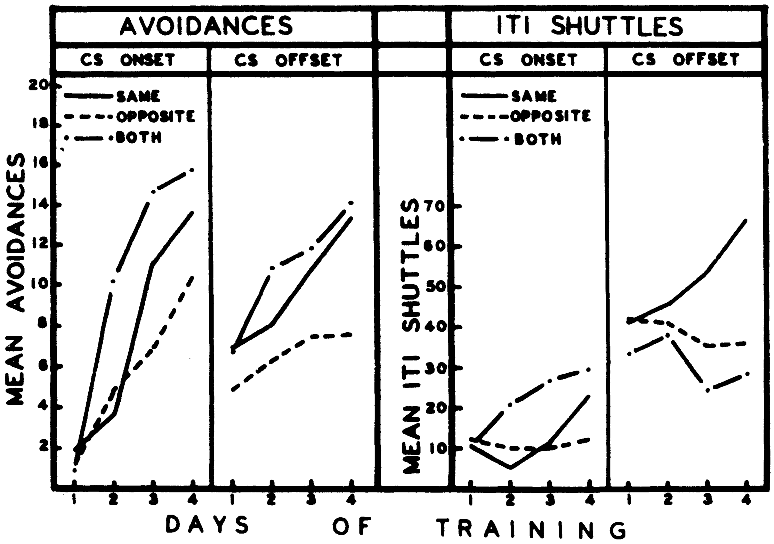

Figure 1. The mean CASR rates and mean ITI shuttle rates for the CS onset and CS offset conditions, with the three CS locations, same, opposite, and both, under each condition.

Training effect, $F(3,162) = 82.296$, $p < .01$, and Onset/Offset by Training interaction, $F(3,162) = 12.178$, $p < .01$, and a CS Location by Training interaction, $F(6,162) = 4.555$, $p < .05$. All repeated measures tests are reported using a Geisser-Greenhouse conservative F test (Kirk, 1968). These results are shown in Figure 1. Individual comparisons of overall group means for CS location found the both CS location superior to the same CS location [$q(3,54) = 5.729$, $p < .01$] and the same CS location superior to the opposite CS location [$q(3,54) = 6.959$, $p < .01$].

A similar 2 by 3 by 4 ANOVA for ITI response rate was also calculated. Differences between Onset and Offset conditions, $F(1,54) = 29.74$, $p < .01$, and an interaction between Onset/Offset by CS Location, $F(2,54) = 3.50$, $p < .05$, were found. All other comparisons did not meet statistical criterion. These data also appear in Figure 1.

DISCUSSION

The present data show that, for the CS onset condition, the order of acquisition by CS location is both maximum, same intermediate, and opposite minimum. Basically, the same order is present for the CS offset data. These results strongly suggest that the magnitude of CS change controls CASR acquisition performance and do not confirm the conditioned aversion response found in earlier work by Gallon (1974) and Zerbolio and Wickstra (1976). In comparing the acquisition rates in the present study against those reported by Zerbolio and Wickstra (1976), where the only difference is training in 1 day vs. the present multiday technique, one finds that CASR acquisition performance is comparable for CS onset same and CS offset opposite, but all other groups (CS onset both and opposite and CS offset same and both) show substantially higher acquisition rates in the present study than were obtained with training in 1 day. One way to approach the differences in CASR order by CS location between the present multiday and the 1-day training paradigms is to assume that the subject must learn to locate the salient stimulus change (a magnitude function) but that, in the 1-day paradigm, especially in the CS onset condition, the subject's reaction to a sudden light onset is a negative phototaxis which, depending on the location, yields a reaction which may retard acquisition. Over days, the negative phototaxis reaction acquires a cue function and augments acquisition. Thus, for the CS onset same condition, the negative phototaxis reaction and cue function for the 1-day and multiday training paradigms move the subject in the same direction and CASR rates are comparable. In the CS onset both condition, for the 1-day training paradigm, the subject reacts to the onset but must approach an onset, a double-negative phototaxis condition. This facilitates leaving the CS side but retards approaching the safe side of the shuttle tank on any given trial. For the CS onset opposite condition, the subject, reacting via the negative phototaxis, shows low CASR acquisition. But over days, the CS onset both and opposite learn to use the negative phototaxis reaction as a cue, and, as a function of cue magnitude, CASR acquisition is markedly augmented for both groups along the CS magnitude dimension.

For the CS offset conditions, the termination of illumination may be confusing, as Gallon (1974) suggests. Certainly the ITI shuttle rate differences between CS onset and CS offset data support this interpretation, as subjects respond less in the dark than in the light. For the CS offset conditions, the present study finds higher CASR rates for the offset same and offset both conditions than Zerbolio and Wickstra (1976), but comparable offset opposite rates. Thus, in the 1-day paradigm, the confusion reaction governs CASR rate, but, with training over days, this acquires a cue function. The important difference is that the confusion reaction to light offset in the 1-day paradigm does not have a negative response bias as light onset does, and therefore produces relatively equivalent CASR performance (Zerbolio & Wickstra, 1976). Over days, the cue function is acquired and CASR acquisition proceeds along the dimension of stimulus magnitude.

In sum, then, the present data do not find support in the multiday training paradigm for the acquisition of "conditioned aversion" postulated by Gallon (1974). The difference in CASR performance by CS location in the 1-day vs. multiday paradigms can be explained by assuming that the CS onset condition produces a negative phototaxis and CS offset produces a confusion reaction in the first day of training; but both of these reactions, although they produce different behavioral effects in regard to CASR performance, acquire cue functions over days. Over days, CASR performance is mainly affected by the magnitude of CS change, as it is in rats (Kish, 1955). Further work to confirm the characteristic of these reactions, which are hypothesized to occur in the single-day training paradigm but which acquire cue functions with training over days, is indicated.

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