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Spatially located visual CS effects on conditioned shuttlebox avoidance in goldfish (*Carassius auratus*): Further analysis

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The present study investigates shuttlebox avoidance acquisition in goldfish as a function of type of stimulus change (onset of offset of light) and CS location (CS occurring on the same, opposite, or both sides relative to the fish). For the onset conditions, the CS-same produced superior acquisition to the CS-both location, which in turn was superior to the CS-opposite condition. For the offset conditions, the three CS locations yielded comparable avoidance rates. These data indicate that, in addition to activation by the stimulus change, when the CS is the onset of a localized light, aversive properties are conditioned to the CS which facilitate acquisition for the CS-same location and depress acquisition for the CS-opposite location. The offset data indicate that these directional properties are not conditioned to a localized area of darkness.

Recently, Gallon (1974) reported that goldfish (*Carassius auratus*) acquire a conditioned shuttle avoidance response differentially as a function of a light CS onset or offset and as a function of the spatial location of the CS. In the CS onset condition, a CS occurring on the same end as the subject facilitated, while a CS occurring on the end opposite the subject debilitated, acquisition. When the CS onset occurred on both ends, acquisition was intermediate. In the CS offset condition, subjects showed equivalent acquisition rates for the same and opposite CS offset locations, and no acquisition when the CS offset occurred on both ends. To account for these results, Gallon (1974) postulated that the CS stimulus change has activation characteristics which tend to move the CS across the hurdle. In addition, via CS-US pairing, the localized light CS acquires aversive properties which tend to direct responding primarily away from the CS. When this additional directional response is compatible with the activation response, it facilitates acquisition (CS onset same) and when it competes with the activation response, it debilitates acquisition (CS onset opposite). If the experimental situation does not provide a localized CS, this directional component does not develop and performance is basically activation only (CS onset both).

However, the CS offset conditions, which experimentally should provide the subject with the same information as the CS onset conditions, do not produce the same results. The CS offset same and CS offset opposite conditions produced comparable acquisition rates but the CS offset both produced no acquisition at all. To account for this discrepancy, Gallon (1974) postulated that the "aversive properties of a localized light CS cannot be attached to a spatially localized area of darkness." This explains the CS offset same and CS offset opposite equivalence, but does not explain the failure of the CS offset both group to learn. The last finding is puzzling, since the stimulus change ought to

produce an activation effect and support acquisition at least at the rates of the CS offset same and opposite groups. The present study is essentially a replication of Gallon's (1974) work to further examine the role of the CS in conditioned shuttle avoidance in goldfish.

METHOD

Subjects

One hundred and twenty goldfish, 5-6 cm long, obtained from Ozark Fisheries, Stoutland, Missouri, were used. All fish were housed in 30-gal aquaria until 48 h prior to use, when they were transferred to 10-gal aquaria in the experimental chamber.

Apparatus

Subjects were run in two identical 29.2 x 11.4 x 11.4 cm shuttle tanks, separated by a center hurdle 6.35 cm high. Water clearance over the top of the hurdle was maintained at 2.5 cm. Photocells located at the ends of the center hurdle monitored all shuttling activity. Blue 7-W 110 ac lamps at the ends of the tank served as the CS. Diffusing plates were affixed to each end of the tank between the tank end and the CS lamp. The US was delivered via 28 x 10.2 cm 22-g stainless steel plates affixed to the sides of both tanks. The US was generated by variable isolated transformers, individually monitored and metered at 7.5 V ac. All tanks were filtered and aerated, and fish were fed daily throughout the experiment. All events were programmed, controlled, and recorded by appropriate circuitry.

Procedure

Six groups of 20 subjects each, in a factorial arrangement of two CS conditions (onset vs. offset) by three CS locations (same, opposite, or both) were run. In the CS onset condition, the blue end lamps, off during the ITI, were illuminated appropriately during the CS. For the CS offset condition, the blue end lamps, illuminated during the ITI, were extinguished appropriately during the CS. All subjects were run 100 trials in a single session on a VI 60 sec. 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 7.5-V ac shocks for a maximum of five shocks. Any initial shuttle response occurring in the CS-US period was recorded as an avoidance, and any initial response in the US period was recorded as an escape. Avoidance or escape responses terminated further stimulation. Any shuttle response occurring from the offset

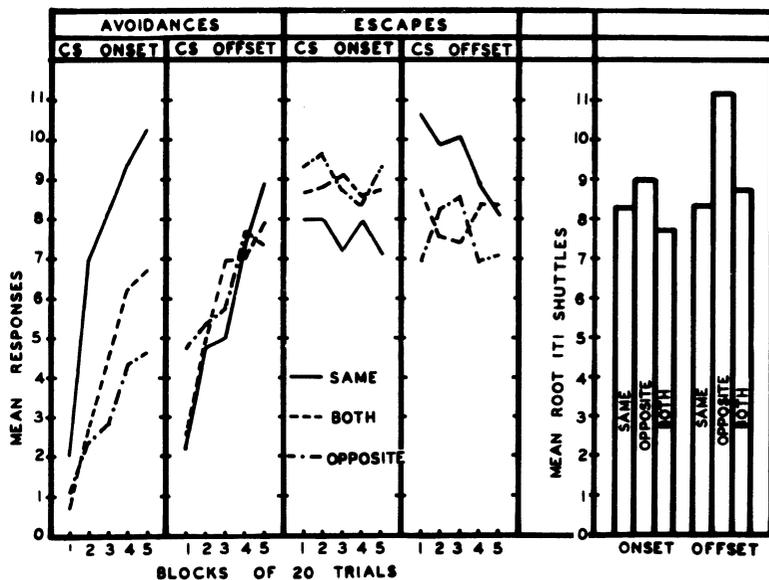


Figure 1. The avoidance and escape rate by blocks of 20 trials and ITI shuttle rate for all 100 trials for CS location (same, opposite, and both) and CS condition (onset and offset).

of the US to the onset of the next CS was recorded as an ITI response. A record of avoidance and escape responses by trial was kept on paper tape.

RESULTS

A three-way repeated measure ANOVA (Winer, 1971) for 2 CS conditions by 3 CS locations by 5 blocks of 20 trials was performed on both the avoidance and escape data. For avoidances, neither CS condition, [$F(1/114) = 1.986$] nor CS location [$F(2/114) = 2.492$] was statistically reliable, but their interaction was significant [$F(2/114) = 4.025$, $p < .05$]. A partition of this interaction by CS condition found no location differences for the CS offset conditions [$F(1/114) = 1.002$], but significant differences between CS locations for the CS onset condition [$F(1/114) = 32.08$, $p < .01$]. A highly significant training effect for blocks of trials was also found, [$F(4/456) = 55.23$, $p < .01$]. These results are shown in Figure 1.

Individual comparisons for overall avoidance using the Studentized Range Test (Winer, 1971) found no difference between the CS offset means, but found the CS offset both and the CS onset opposite means significantly higher than the CS onset both mean, [$q(1/114) = 4.33$, $p < .05$] and [$q(1/114) = 5.092$, $p < .01$], respectively. A comparable analysis for the escape rate data was performed. There were no statistically reliable results found for CS location, CS condition, or training. These data also appear in Figure 1. A third 2 CS condition by 3 CS location ANOVA on the ITI shuttle rate, which was square root transformed to reduce mean/variance correlation, was also completed. Significant effects for CS condition, [$F(1/114) = 4.457$, $p < .05$] and CS location [$F(2/114) = 5.514$, $p < .01$], were found. These data also appear in Figure 1.

DISCUSSION

The present study shows that, for a CS onset condition, avoidance acquisition is facilitated by a localized same-end CS and debilitated by a localized opposite-end CS, as compared to a nonlocalized both-end CS presentation paradigm. For the CS offset condition, the localized CS conditions (same and opposite end) and the nonlocalized CS condition (both ends) produce equivalent avoidance acquisition. The present finding, which shows no difference in escape rates for location or onset/offset, strongly suggests that the effects are primarily on avoidance behavior alone. The analysis of these data strongly supports Gallon's (1974) explanation. The CS produces a generalized activity, and the CS onset condition, when experimentally localized, also produces an additional aversive directional component which can be compatible with the activation component (CS onset same) or compete with the activation component (CS onset opposite). Present evidence confirms the hypothesis that goldfish do not seem to attach a directional aversive component to a localized area of darkness. Thus the CS offset groups, all responding on the basis of activation alone, are equivalent. But comparisons in overall avoidance rates for the groups that theoretically should be responding via activation alone (CS onset both, CS offset same, opposite, and both) show that the CS onset both avoidance rate is significantly below the CS offset opposite and CS offset both conditions, and below the CS offset same level, although this latter comparison does not reach reliable levels. This finding suggests that there is some aversive component in the CS onset both condition, but not to the same extent as in the CS onset opposite condition. The lower overall ITI shuttle rate of the CS onset both group supports this interpretation.

The major discrepancy between the present data and Gallon's (1974) is that the prior work found no acquisition for the CS offset both condition, whereas our results show acquisition rates similar to the other CS offset groups. A possible explanation for this difference may be in the differing modes of US delivery. The US was at comparable intensity and duration per unit pulse, but Gallon (1974) allowed the US to run for a maximum of 15 sec (or 30 pulses), whereas the present work allowed a maximum of 2.2 sec (or five pulses). Earlier work has shown that acquisition rates for goldfish are sensitive to US power, or intensity times duration (Zerbolio & Wickstra, 1975), and it seems reasonable to construe the 30 allowable US pulses as a higher US level than the 5 allowable US pulses in the present

study. If this assumption is made, then the discrepancy between the present and earlier findings for the CS offset both condition can be explained by Kish (1955), who found, for rats, very low avoidance acquisition rates for CS offset high-shock conditions and substantially higher acquisition rates for CS offset low-shock conditions. The high/low-shock conditions did not affect the CS onset acquisition rates. Further work examining the effect of US frequency and avoidance rate, especially for the CS offset condition, seems warranted.

In sum, the present work confirms that goldfish, in a CS onset situation, learn a directional response when the CS is localized, but a comparable response does not seem to be conditioned to a similar localized area of darkness. But all CS stimulus energy changes, either onset or offset, do produce generalized activation which is sufficient to support at least moderate avoidance acquisition performance.

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