CS-US interval and conditioned fear facilitation of shuttlebox avoidance learning in the goldfish¹

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Goldfish were given 40 Pavlovian fear conditioning trials and then were trained on a shuttlebox avoidance task under either a 10-sec or a 30-sec CS-US interval. When compared with unstimulated control Ss, fear-conditioned fish showed facilitation of avoidance responding for the 30-sec, but not for the 10-sec, interstimulus interval.

In its simplest form, two factor learning theory (Rescorla & Solomon, 1967) predicts that Pavlovian fear conditioning should improve later avoidance responding to the same CS. Evidence exists, however, which indicates that conditioned fear training may have both interfering and facilitating effects on subsequent avoidance learning in rats (cf. de Toledo & Black, 1967; Weiss, Kriekhaus, & Conte, 1968) and in fish (Frumkin & Brookshire, 1969; Pinckney, 1967).

It has been suggested (Dinsmoor & Campbell, 1956; Weiss et al, 1968) that interference with avoidance responding by prior fear conditioning may depend upon the extent to which competing responses (such as freezing in the rat) tend to interfere with the required avoidance response. Weiss et al (1968) found that fear conditioning did produce extensive freezing in rats, and that this behavior interfered with subsequent shuttlebox avoidance conditioning. When Ss were pretrained on the shuttle avoidance task, however, Pavlovian fear conditioning improved later avoidance responding (Rescorla, 1967; Weiss et al, 1968). It may be argued that pretraining served to make the conditioned avoidance response (CAR) more readily available during later training and thus decreased the likelihood of interference by competing responses.

While classical fear conditioning is sufficient to motivate fish to learn an instrumental response to escape a previously neutral CS (Brookshire & Hognander, 1968), such training has been shown to produce interference with subsequent shuttlebox avoidance learning, at least with fish who are "poor performers" (Pinckney, 1967). Even if competing responses acquired during fear conditioning do interfere with later avoidance learning to the same CS, it is possible to assume that the

proactive facilitation effects of conditioned fear predicted by two-process theory might still occur if sufficient opportunity were provided for the S to both make the competing response and avoid the fear-producing CS. Therefore, the CS-US interval during shuttle avoidance testing was varied on the hypothesis that a longer CS-US interval would allow facilitatory effects of conditioned fear to emerge in spite of the presence of competing responses. The CS-US interval during fear conditioning also was varied, in order to assess possible correlative transfer effects based on the degree of similarity of the two interstimulus intervals.

METHOD

The Ss were 64 goldfish (*Carassius auratus*), averaging 2-3 in. in length, obtained from a local supplier and housed initially in a communal tank at 72-74 deg F. During the experiment each S was kept in a separate compartment of a larger tank.

The apparatus was a Plexiglas, two-compartment shuttlebox (12 x 4 x 4 in.), painted gray. The two sides were separated by a gray Plexiglas guillotine door resting on a hurdle which was 1 1/4 in. below the water level. The CS was a 6-V light centered above each compartment. The US was a 12-V pulsed (.05 sec on, 0.25 sec off) dc shock applied through metal plates on the sides of each compartment. Photocells directed through the center of the box detected movement from one side to another.

For conditioned fear training, Ss were randomly assigned to one of four treatment groups (N = 16). All Ss were removed from the communal tank and placed in one side of the shuttlebox for a 7-min adaptation period. Following this, Ss in three groups received 40 CS (light)-US (shock) pairings (ITI = 2 min) with a delayed conditioning procedure at a CS-US interval of either 5, 10, or 30 sec. The US duration was always 5 sec. Control Ss spent 100 min in the apparatus but experienced neither the CS nor the US.

Twenty-four hours later avoidance testing was begun. Each of the four treatment groups was divided into two subgroups (N = 8) and tested with either a 10-sec or 30-sec CS-US interval (delayed conditioning procedure). The Ss received 7 min of adaptation followed by 10 avoidance trials (ITI = 2 min) per day until reaching a criterion of nine avoidances in 10 successive trials. A trial was started with the lifting of the guillotine door. At the same time the CS

came on, followed 10 or 30 sec later by the onset of the US.

Interrupting the photocell beams between the two compartments terminated the CS (avoidance) or CS and US (escape). If no escape occurred after 2 min, the trial was terminated by E.

RESULTS

The mean number of trials to criterion for each group is presented in Table 1. Analysis of variance indicated that, overall, Ss tested on the 10-sec avoidance task required significantly more trials to meet the learning criterion than did those tested on the 30-sec avoidance task ($F = 4.01$, $df = 1$, $p < .05$). The interaction also was significant ($F = 2.95$, $df = 3$, $p < .05$). Scheffé post hoc comparisons demonstrated that among the groups tested with a 10-sec CS-US interval, control and experimental Ss did not differ significantly in terms of trials to criterion. For the 30-sec test interval, however, control Ss required a significantly greater number of trials to reach criterion than did fear conditioned Ss. For each row, no reliable differences appeared between any of the experimental groups. Moreover, the two control groups did not differ significantly from each other. A median split for each experimental group was used to define "good performers" and "poor performers" (after Pinckney, 1967). Separate analyses of variance on these two sets of data yielded results identical with those of the overall analysis.

Table 2 contains the mean number of trials required to make the first avoidance response for each of the eight groups. Analysis of variance showed that groups receiving a 30-sec CS-US interval during avoidance conditioning made their first CAR significantly earlier in training than did Ss tested with a 10-sec CS-US interval ($F = 12.06$, $df = 1$, $p < .01$). However, the difference between the two control groups did not approach statistical significance ($t = 0.09$, $df = 14$, $p > .45$); fear conditioning interval ($F = .79$, $df = 3$) and the interaction ($F = 1.48$, $df = 3$) also were not significant.

Table 3 shows the mean latency of the first avoidance response for experimental groups. By analysis of variance both primary sources were statistically significant (fear conditioning interval: $F = 5.49$, $df = 3, 56$, $p < .01$; avoidance interval: $F = 69.86$, $df = 1, 56$, $p < .01$), as well as the interaction term ($F = 4.05$, $df = 3, 56$, $p < .025$). Scheffé tests showed that experimental Ss differed from the control group under the 30-sec CS-US avoidance test interval, but not under the 10-sec avoidance interval.

DISCUSSION

In this study Pavlovian fear conditioning (regardless of the CS-US interval employed) was shown to facilitate subsequent CAR

Table 1
Mean Number of Trials to Criterion

		Fear Conditioning CS-US Interval (sec)			
		Control	5	10	30
CS-US Interval During Avoidance Training (sec)	10	27.9	35.5	31.4	27.6
	30	35.8	20.2	16.0	17.5

Table 2
Mean Number of Trials until the First Avoidance Response

		Fear Conditioning CS-US Interval (sec)			
		Control	5	10	30
CS-US Interval During Avoidance Training (sec)	10	3.75	7.25	8.25	6.00
	30	3.88	2.25	3.25	2.00

Table 3
Mean Latency of the First Avoidance Response

		Fear Conditioning CS-US Interval (sec)			
		Control	5	10	30
CS-US Interval During Avoidance Training (sec)	10	5.28	6.81	4.45	6.63
	30	10.94	14.29	16.34	23.64

acquisition in fish when the CS-US interval during avoidance training was 30 sec. No effect of fear conditioning appeared with a 10-sec CS-US test interval. For fish which had received prior fear conditioning, the 30-sec avoidance task produced more efficient learning than the 10-sec task (measured in terms of trials to criterion and emergence of the first CAR). However, control groups (which had received no fear conditioning) tested at either 10 or 30 sec did not differ from each other on either of these two measures.

Previously, CAR facilitation by conditioned fear had been observed in the rat either when pretraining had made the required avoidance response readily available to the S (Rescorla, 1967; Weiss et al, 1968) or when the avoidance task was a relatively easy one, such as ledge-jumping (Baum, 1969) or one-way avoidance (de Toledo & Black, 1967), as compared with the more difficult (Theios & Dunaway, 1964) shuttlebox avoidance problem. It appears that neither of these conditions (earlier availability of the CAR, more easily learned task) was present to account for the shuttlebox avoidance facilitation observed at a CS-US interval of 30 sec in the present study: the control group data showed that the first avoidance response did not occur any earlier in training for the 30-sec group (Table 2), nor was the 30-sec avoidance task learned more quickly (Table 1).

One possible explanation for the disjunctive effects with different CS-US avoidance intervals observed in this study is that competing responses acquired during fear conditioning (which are assumed to interfere with later shuttlebox avoidance learning; Pinckney, 1967) are relatively short-lived and are not maintained over the 30-sec interval employed in the present study. Therefore, competing responses may manifest themselves early in the CS-US interval and still allow time for conditioned fear to precipitate an avoidance response. This interpretation is supported in the present study by the observation that the latency of the first CAR by fear-conditioned fish was longer than for control Ss (Table 3) even though the fear-conditioned animals were, overall, better learners.

The data for the 10-sec test condition, which showed no group differences in CAR performance, failed to support the results reported by Pinckney (1967), in which he found *interference* with avoidance responding by conditioned fear in "poor performers." It should be noted, however, that Ss in the present study were tested 24 h after fear conditioning, 10 trials per day, to a criterion, whereas Pinckney's test consisted of 40 trials of avoidance training commencing 3 min after fear conditioning.

The fact that CAR acquisition did not vary as a function of the CS-US interval during fear conditioning supports the

findings of Behrend & Bitterman (1962), also from goldfish, which suggest that a wide range of CS-US intervals are equally efficient for Pavlovian fear conditioning. However, there appears to be a direct relationship between latency of the first avoidance response and fear conditioning CS-US interval when CAR facilitation is observed. Therefore, in the present study, conditioned fear and its effects may be thought of as independent of the CS-US interval during fear conditioning, while competing responses or their latency may be a function of this variable. This might be taken to mean that the two hypothesized effects of fear conditioning (the development of fear and the development of competing responses) are sensitive to different experimental variables.

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NOTE

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