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Heart rate conditioning of goldfish, *Carassius auratus*, with intermittent vs. continuous CS

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Within a respondent conditioning paradigm, the heart rate response (CHR) for goldfish was compared with CS, US, and pseudoconditioning controls with intermittent or constant CS (light). Goldfish showed a differential CHR (bradycardia) in the experimental condition, in contrast to the controls, and a greater level of CHR occurred under the intermittent CS condition.

Pavlov (1927/1960) made extensive use of various intermittent CSs in his research with dogs. However, Pavlov did not concern himself with the dynamics of CS. Comparing an intermittent and a continuous CS in conditioning the nictitating membrane response of the rabbit, Papsdorf, Fishbien, and Gormezano (1964) report that higher levels of conditioning were obtained in the intermittent CS condition as compared to the continuous CS. The present experiment was designed to replicate, in part, the Papsdorf et al. experiment with goldfish.

METHOD

Subjects

The subjects were 21 goldfish, *Carassius auratus*, acquired from Santian Aquarium, Brownsville, Oregon. The fish (15-20 cm long) were housed in a 300-l aquarium measuring 120 x 120 x 120 cm for 1-4 days prior to experimentation. The aquarium temperature was approximately 12°C. Subjects were maintained on a photoperiod that approximated the normal seasonal environment, illumination occurred from 7:00 a.m. to 6:00 p.m.

Apparatus

A fish was placed in a clear plastic tank 27 cm long x 6 cm wide x 14 cm deep. The plastic tank was located inside a 45 cm long x 14 cm wide x 17 cm deep electrically shielded compartment. A constant .5-l/min flow of charcoal-filtered water was circulated through the tank to provide an adequate supply of oxygenated water. Six 24-V dc lamps, three located on either side of the shielded compartment, served as the CS. The US was a 1.5-sec .050-mA dc electric shock delivered through alligator clip electrodes. This intensity of shock resulted in a reliable flinch or startle response in both species of fish. A polygraph was used to record the heart rate.

Procedure

The active electrode was fastened to the pectoral fin, the indifferent electrode to the tail fin, and the ground electrode to the dorsal fin. The fish was placed in the plastic tank and allowed to habituate for a period of 5 min. The 35 trials for each treatment condition were divided into seven blocks of five trials each. A variable intertrial interval of 70 sec was used for all treatment conditions except pseudoconditioning. Mean values were computed for three periods [last 10 sec of the baseline (BS), CS, and the first 10 sec immediately following the CS (P-US)] of each of the seven trial blocks.

Treatment Conditions

(1) Treatment 1 was a 20-sec presentation of a constant CS with a US during the last 1.5 sec. (2) Treatment 2 was a US control where the US was presented without the CS. (3) Treatment 3 was a CS control that was identical to Treatment 1 except no US was presented. (4) Treatment 4 was a pseudoconditioning control. The CSs and USs were presented such that one CS and one US occurred within each of 35 segments of time (trials) that were equivalent to the amount of time required for the three periods (BS, CS, and P-US) plus 70 sec. There was no temporal relationship between the CS and US; they occurred randomly within the trial. (5) Treatment 5 was a flashing experimental condition [CS-US(FL)] with the presentation of a 20-sec CS that flashed at a rate of .5 sec "on" to .5 sec "off," with a US during the last 1.5 sec. (6) Treatment 6 was a flashing CS control that was identical to the CS-US(FL) except no US was presented. (7) Treatment 7 was a pseudoconditioning control that was identical to Treatment 4 except a flashing CS was substituted for the constant CS.

RESULTS AND DISCUSSION

The analysis showed no significant changes in heart rate between periods (BS, CS, P-US) within trial blocks across trial blocks for all treatment conditions except the CS-US and the CS-US(FL). These comparisons suggest that the CS and CS(FL) were neutral stimuli,

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and there was no evidence of differential heart rate for the controls.

The CS period heart rate for the continuous CS condition was not different from the BS in Trial Blocks 1 and 2. However, it was significantly lower in the other trial blocks ($p < .01$). Comparing the heart rate during the CS period across trial blocks revealed significant heart rate deceleration ($p < .01$) from Trial Block 2 to Block 5 with an increase during Trial Blocks 6 and 7; Trial Blocks 3, 4, and 7 were approximately equal.

The CS(FL) condition revealed that the heart rate during the CS(FL) was not different from the BS on Trial Block 1. However, the heart rates on Trial Blocks 2-7 were significantly lower ($p < .01$). Comparing the heart rate across trials, all trial blocks differed from Trial Block 1, and Trial Block 3 was significantly lower than all other trial blocks ($p < .01$).

Heart rate during the CS(FL) period was significantly lower ($p < .01$) than the constant CS in Trial Blocks 2-7. This suggests that the magnitude of the conditioned heart rate to the flashing CS was greater than the magnitude of response to the constant CS.

This experiment further confirmed the findings of previous investigators concerning conditioning of heart rate in goldfish (Bernstein, 1961, 1962; McCleary, 1960; McCleary & Bernstein, 1959; Otis, Cerf, & Thomas, 1957). Furthermore, while conditioning was observed with both the continuous and intermittent CSs, the intermittent or flashing CS was found to be a more significant elicitor of the conditioned heart rate.

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