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AUTOMATED TRAINING AND RECORDING OF A LIGHT-TRACKING RESPONSE IN FISH[1]

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Fish placed in a circular trough and rotated past a stationary stimulus light can learn in one session to swim almost continuously in the light. Recording of time spent in the light and electric shock termination are accomplished with a photoelectric circuit controlled by the stimulus light (Fig. 1). This apparatus is suitable for experiments requiring continuous responding, as compared to phasic responding in Sidman avoidance demonstrated in fish by Behrend and Bitterman (1964).

The circular trough (O.D. = 48 cm) in Fig. 1 was vacuum-formed from one piece of clear tenite (Lus-Trus Corporation, Ypsilanti, Michigan). The trough is 5 cm wide, 10 cm deep, and filled with water to a depth of 5 cm. The trough is rotated 2 rpm on a turntable in a darkened chamber. The alternative of rotating the stimulus light, photoconductors, and electrodes around the stationary trough seemed less convenient. The stimulus light is a divergent, horizontal beam given by a photoenlarger fitted with a rectangular slit on the negative holder and a 25-w incandescent bulb. The beam is projected through the trough onto four photoconductors (Clarex Cl-2) in a rectangular array. They are connected in series to a conventional thyratron circuit. A baffle blocks the light from the rest of the chamber. In the water, the beam is approximately 5 cm wide and 3 cm high. Fish turned off the shock when they occluded even a small part of the beam. A repetitive shock stimulus is given through two platinum wire electrodes suspended in the water near the outer wall of the trough. The cathode is 45° clockwise and the anode 45° counterclockwise from the stimulus light. The shock consists of 0.2-sec, 100-v pulses discharged from a 2-mfd capacitor 84 times per minute. When the subject enters the stimulus light, the photoelectric circuit turns off the shock and starts a clutch-controlled 1-rps cam which actuates a digital print counter (Texas Instrument Corp., model S/N 334-143). When the subject leaves the light, the recording cam stops immediately but the onset of the shock is delayed for 3.5 sec. The delay interval was determined to be optimum for naive subjects. A different interval might improve performance of experienced subjects. Naive subjects ordinarily

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Table 1
Light-Tracking in the Goldfish

	Mean Number of Seconds in Light During a 15-Min Session					
	Day 1			*Day 3*		
	1-5	*6-10*	*11-15 (min)*	*1-5*	*6-10*	*11-15 (min)*
50 subjects with shock	52	104	153	97	180	213
F ratios	$F = 27.53$, $df = 2/147$, $p < .01$			$F = 23.47$, $df = 2/147$, $p < .01$		
24 subjects no shock	47	42	43	51	47	41
F ratios	$F < 1$, ns			$F < 1$, ns		

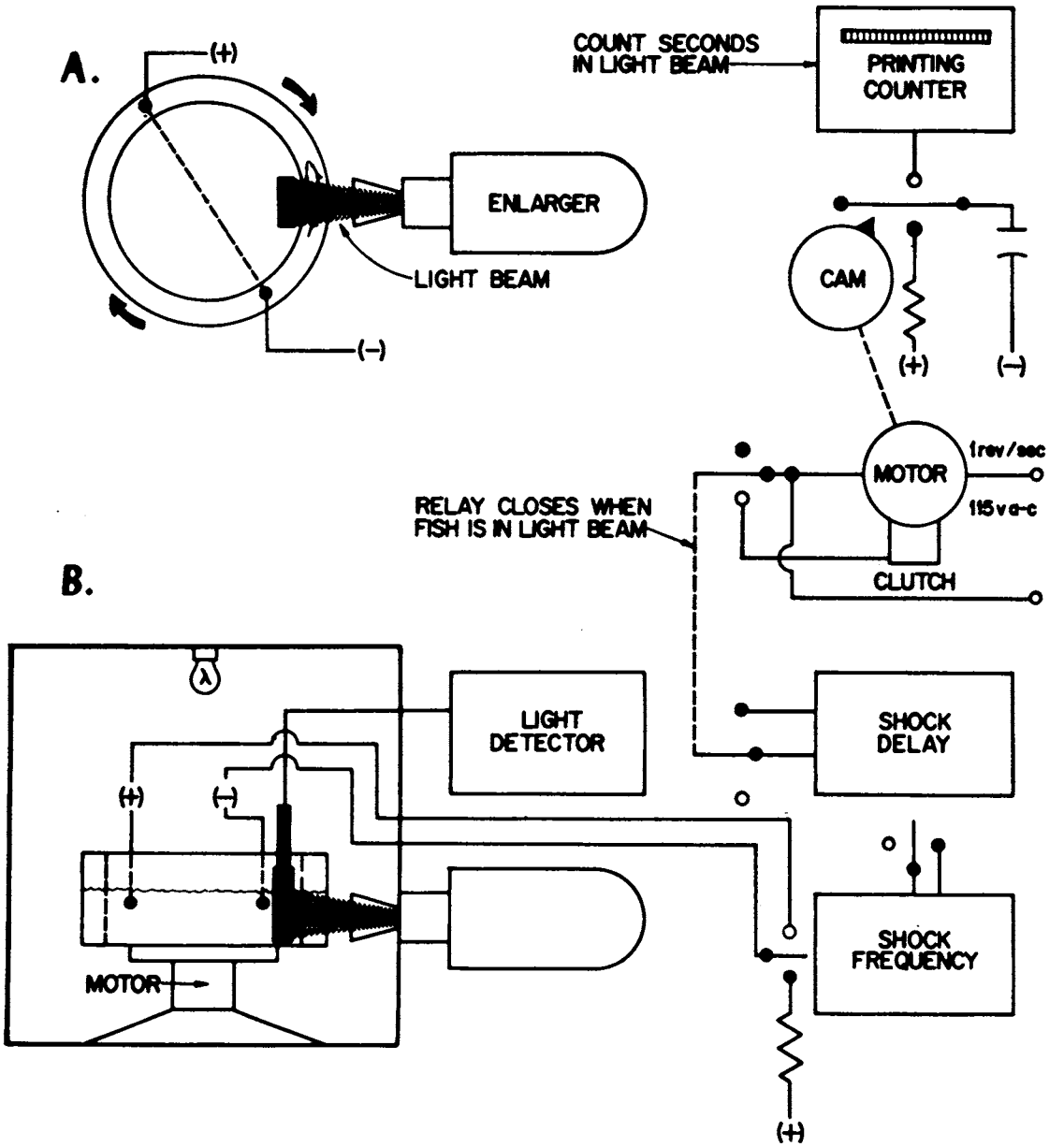

Fig. 1. The light-tracking apparatus. (A) Plan view of rotating trough showing alignment of the light beam and shock electrodes. (B) Elevation view of the trough and turntable in the chamber. The electrical components which start and stop the shock, and record the time fish spend in the light, are described in the text.

do not linger in or near the stimulus light, and for them the shock delay is nearly equivalent to the interval of shock termination. A delay substantially shorter than 3.5 sec is apparently less readily perceived as an end to the repetitive shock. With a delay much longer than 3.5 sec, the subject might not associate shock termination with having been in the stimulus light. The shock-delay is timed by a model 12012, CK Timer (Farmer Electric Co.). Preliminary studies suggest that the shock intensity, reinforcement schedule, speed of rotation, and area of the light beam influence the rate of response acquisition.

This technique has been used successfully with the giant danio, *Danio malibaricus*, but the goldfish, *Carassius auratus* was mainly used. As seen in Table 1, goldfish improve

performance with time in the first 15-min session and further improve in a second 15-min session two days later. If the electric shock is withheld, no detectable change in performance is shown in two 15-min sessions. The number of shocks received decreases with time in a session (Fig. 2). Experienced subjects typically receive a few shocks at the start of a session and then begin tracking continuously. Individuals have tracked perfectly for more than 1 hr.

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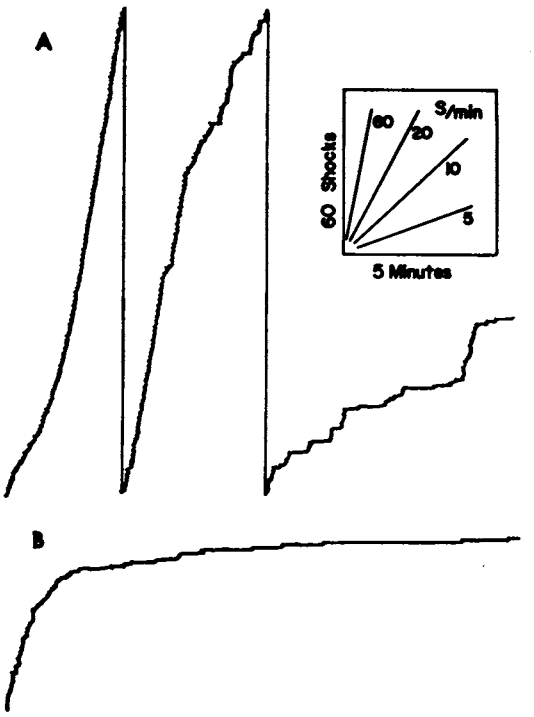

Fig. 2. Tracings of cumulative records of shocks received by goldfish A and B during their first training session. These data are from a preliminary experiment with shock frequency of 60 per min. The record of A is typical for naive subjects. B shows unusually fast learning.