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Alarm Pheromone and Avoidance Conditioning in Goldfish, *Carassius auratus*

WHILE the alarm reaction in fish is believed to be produced by a chemical substance (pheromone) secreted by specialized cells in the epidermis and released by epidermal damage, relatively little systematic research has been devoted to the extent, nature or essence of the reaction and its relationship to the relevant chemical substance[1]. Our investigation represents an exploration of the effect of alarm pheromone on avoidance conditioning. Fifteen 2 inch goldfish, *Carassius auratus*, were kept in a thirty gallon aquarium divided into thirds by wire barriers. In accordance with other reports, the fish were deliberately well fed[2]. Massed avoidance conditioning (all trials on one day) was studied in a Lafayette Instrument aquatic conditioning unit (volume of approximately one gallon; inside dimensions, $3{\cdot}5 \times 6 \times 9$ inches). Lights at each end of the conditioning tank served as the conditional stimuli (CS) and electric shock as the unconditional stimulus (US). Shock was adjusted for each fish and varied from 5 to 7 a.c.

A successful avoidance response involved swimming out of the lighted side of the tank into the dark side within the CS–US interval of 7 s. Following the 7 s CS, the CS remained on and shock was delivered through electrodes at the top and bottom of the tank on the lighted side only for 23 s. The next trial started 30 s after shock offset. Thus the intertrial interval was a constant 1 min. The experimenter manually switched the apparatus so that, regardless of the fish's position (if, for example, it swam through the divider during the intertrial interval), the CS (light) would be presented on the side of the tank that the fish was occupying at the start of each trial. In other words, this is a two-way shuttle avoidance paradigm.

Thus a typical avoidance paradigm was followed (delay procedure, CS–US interval of 7 s, 1 min intertrial interval) with trials continuing until a criterion of twelve successful avoidances out of fifteen consecutive trials was attained. Six of the fish received training trials in aquarium water, four were conditioned in aquarium water into which 50 ml. of pheromone solution had been thoroughly mixed, and five were left undisturbed in one end section of the aquarium. The alarm pheromone was prepared by scaling a freshly decapitated goldfish into 50 ml. of aquarium water.

Fish conditioned in plain water reached criterion in an average of 65·5 trials (range 49–84). Fish conditioned in water containing pheromone reached criterion in an average of 45·5 trials (range 12–94). Using the Wald–Wolfowitz Runs test, this was found to be a significant difference ($P < 0{\cdot}05$). It should be pointed out that the extreme case in the pheromone group (ninety-four trials) was operating "near" criterion throughout, and all the other pheromone fish reached criterion in thirty-eight trials or less. To assess the effects of pheromone on activity and to observe the "fright" or alarm reaction more carefully (with video tape), 100 ml. of pheromone solution was prepared by scaling two freshly killed goldfish into 100 ml. of aquarium water. The solution was dumped into one corner of the section of the aquarium containing the five previously undisturbed fish. As soon as several of the fish happened to swim into the area in which the solution had been dumped, they displayed agitated, non-directional, jerky movements with fins fully erected. Soon afterwards, all the fish began doing this and within seconds all sank to the bottom of the tank in the corner farthest removed from the one into which the pheromone solution had been dumped. The form of the reaction agrees with other reports[2]. The fish remained clumped together in this fashion and did not resume their normal free-swimming patterns for several hours.

The pheromone's effect on avoidance conditioning cannot be explained from this brief experiment. It is probably not the result of an increase in general activity or reactiveness to stimuli in general as shown by the large tank experiment. Observation did not reveal any differential sensitivity to electric shock in the two groups. As shown by the large tank experiment, alarm pheromone seems to produce not only "fright" and "alarm" behaviour but also flight or withdrawal. In our apparatus, avoidance involved swimming from a lighted chamber on presentation of the CS into a dark one. Even though this is a somewhat unnatural situation for a fish to be in, it is probably similar enough to swimming into dark recesses and crevices, as many kinds of fish do when frightened or threatened. So perhaps the increased "fearfulness" resulting from the alarm pheromone in the water interacts with the CS–US pairing to result in an enhancement of avoidance conditioning.

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Serum Lipids and the Death of Spawning Pacific Salmon

DURING a recent expedition of the R/V Alpha Helix (1968), we had the opportunity to compare blood serum lipids of pink salmon (*Oncorhynchus gorbuscha*) collected at two points in their spawning migration. Fish were sampled from commercial purse seines near Namu, which is located on the British Columbia coast at the entrance to the Burke Channel; and again 60 miles from the sea in a small freshwater stream (a tributary of Thornsons Creek) near Bella Coola, at the head of the same channel. The fish were spawning at this latter site and were obtained by dip net. The principal difference between the Namu and Thornsons Creek fish was that the latter had undertaken a migration