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More on Seasonal Variations in Goldfish Learning

Goldfish obtained in weekly shipments from Ozark Fisheries, Stoutland, Missouri, demonstrate a seasonal fluctuation in ability to learn a shock-avoidance shuttle box task (*1*). High acquisition and retention scores are seen in February, with lowest ones in July. Shashoua reported a similar distribution of scores in a "float training" experiment in which animals adapt to a polystyrene float sutured to the ventral surface (*2*). He also confirmed the seasonal variation in shock-avoidance shuttle box performance (*3*). Fjerdingstad (*4*), however, saw no seasonal variability in a shock-avoidance task with goldfish obtained from Ozark or from another source. He suggested that the fish used by us and by Shashoua may be weak during the hot summer months as a result of the stress of shipping and starvation in the laboratory, and stated that we use the fish 1 or 2 days after arrival.

Fjerdingstad's last point is an incorrect assumption; we keep the fish in group tanks for at least 2 weeks before setting them out in individual home tanks the day before a behavioral experiment. We do not feed them unless they are kept longer. Furthermore, while fish fare better under cooler conditions of shipment than warm ones, it is not likely that temperature during shipment is the key to the problem of seasonal variation in avoidance conditioning. We have been receiving goldfish weekly for 10 years. Since 1970 we have discontinued using rail shipment in favor of air freight, without noticeable alteration in the seasonal pattern. If we kept summer fish at 8°C for several weeks before training, the performance typical of winter fish was not restored. Winter fish maintained in the laboratory at 19°C, under constant light and with daily feeding, did not show a decline in performance with the change in season.

Fjerdingstad's failure to see seasonal variation is probably due to other factors. Acquisition scores for goldfish in shuttle boxes vary according to stimulus parameters and to the apparatus (*5*). In the case of goldfish, the height of water over the barrier is especially important. In our experiments trials are massed in a single session, while Fjerdingstad trains fish over a period of days. If less effort and skill is involved in Fjerdingstad's task than in ours, one might expect less difference between groups of fish in varying states of vigor.

We conclude that the seasonal variation in behavior is a result of changes in the goldfish we receive. The origin of the variation is uncertain. Ozark Fisheries ships us fish 6 to 7 cm in body length throughout the year. The goldfish breeds annually in early summer, so the average age of their fish population must increase and then decrease annually. Fish are raised in about 400 ponds that are separated by levees and drained periodically, and the new generation is usually shipped beginning in September, so fish 6 to 7 cm long are rarely more than 2 years or less than 5 months old. We propose that, beginning in May or June, an increasing number of the fish we receive are the slower-growing individuals of the previous year (*6*). Beginning in the fall, we obtain the most vigorous individuals of the new generation. The resulting selection as a function of season could account for behavioral differences.

It is also possible that annual variations in the physiological state of the individual contribute to the seasonal changes in avoidance conditioning. Annual changes in photoperiod and temperature may be important. There are many precedents in biology. If Otto Loewi had searched for slowing of the frog heart in the summer, he might not have succeeded in discovering acetylcholine, since the inhibitory response of the frog heart is weak in the summer (*7*). Ovarian function is correlated with goldfish learning, as Shashoua notes (*2*), but the relevance of this observation to behavior is not clear for several reasons: (i) a large portion of 7- to 8-g female fish used by Shashoua may not be sexually mature; (ii) we have seen 8- to 11-g gravid females, some of which spawned abortively during training, perform well in the shuttle box; and (iii) presumably half of the fish are males. A correlate of ovarian but not of testicular function would result in a bimodal distribution of performance in summer fish. The standard error of the mean for a mixed sex population should thus increase during the summer. Examination of published data suggests that this is not the case (*1, 2*).

Whatever the explanations are for the seasonal variation, storing winter fish in the laboratory may be a solution to the practical problem. Winter fish can be inexpensively fed and maintained in a limited space, and they appear to be suitable experimental subjects in the following summer.

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