

and some may originate from neurones in the accumbens¹⁰. The reduction of GABA in the pallidus following accumbens lesions suggests a possible role as the inhibitory transmitter in the pathway. That no significant changes in substantia nigra GABA were observed suggests that accumbens lesions were selective and did not damage the caudato-nigral GABA pathway⁵. The lack of biochemical changes in the nigra may also reflect the sparse projection from the accumbens or indicate that GABA is not involved in the pathway.

The nucleus accumbens thus appears to send inhibitory and excitatory projections to the pallidus and nigra. The identification of the neurotransmitters concerned requires further study. However since the accumbens is an important site for self stimulation¹¹ and for the

actions of locomotor stimulants¹²⁻¹⁵ it is reasonable to consider that such behaviour may be mediated in part through the pallidal and nigral projections.

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Temperature acclimation and learning in fish

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Summary. Control fish acclimated at 21°C learned to swim upright following the attachment of floats to their ventral surfaces, while fish acclimated at both 5°C and 33°C failed to learn the swimming skill. Fish previously acclimated at 5°C and then transferred to 21°C 48 h before the task, learnt the swimming skill better than the control fish, but fish acclimated at 33°C and transferred to 21°C failed to acquire the new skill. Acclimation temperature, therefore, significantly modifies the learning behaviour of fish.

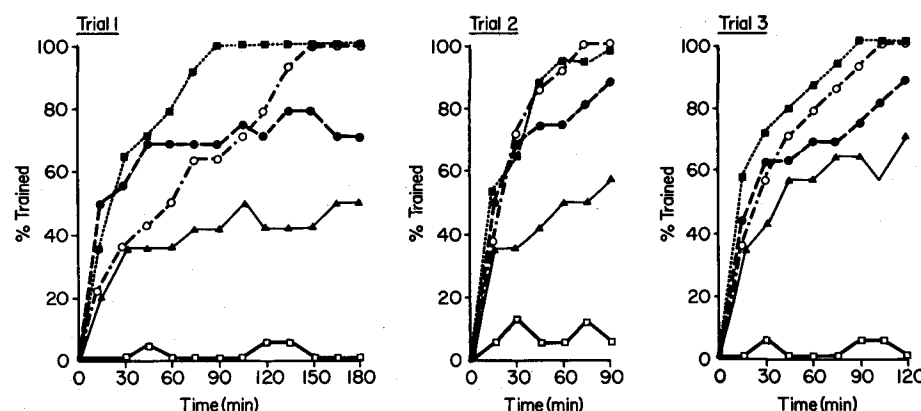
Fish have the ability to learn to swim in the upright position after polystyrene floats are attached to their ventral surfaces¹⁻⁵. Shashoua³ has shown that goldfish exhibit cyclic changes, with an annual rhythm, in their capacity to learn this swimming skill. Fish learned better during the winter months than during the summer months; the lowest levels of learning coincided with the onset of spawning³. These changes in learning patterns were thought to be due to cyclic hormonal and biogenic amine level changes⁴. The direct effect of temperature on learning was not, however, investigated.

We have investigated the effect of different acclimation temperatures on learning in fish using the same learning task as that used by Shashoua¹.

Materials and methods. *Cyprinus carpio* (L.) fingerlings weighing 14-18 g were used in all experiments. All experiments were performed during the autumn (May-June) and at the same time of day (evening). Groups of fish were acclimatized to 33, 21 and 5°C for 3 weeks. They were kept in 40-l aquaria equipped with aerators, and

the animals were fed regularly at fixed times. The fish were divided into 5 groups of 8 each for training. 3 groups were trained in their respective acclimation temperatures. The other 2 groups were removed from 5 or 33°C and placed in a tank initially at the same temperature, which was then allowed to equilibrate to room temperature (21°C). This transfer took place 48 h before training.

Polystyrene floats 8.75% of the mass of the fish in 600 ml of water were made. The method of attaching these floats, as well as the method used for calculating the percentage trained, was the same as that used by Kaplan et al.⁵. The fish were assigned 3 stages of learning. During stage I the



Acquisition (trial 1) and retention (trials 2 and 3) of a learning task for fish acclimated to 21°C (○—○), to 5°C (□—□) and to 33°C (●—●) for a period of 3 weeks. The results of fish transferred from 5°C (■—■) and from 33°C (▲—▲) after the same acclimation period to 21°C 48 h before being subjected to the learning task in trial 1 are also shown. Each point represents the mean percentage trained for 8 fish at 15-min-intervals.

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fish were upside down or pulled to the surface; stage II was reached when the fish swam continuously at an angle of 45° to the horizontal; and stage III was reached when the fish swam normally. The fish were subjected to 3 trials: Trial 1 (day 1) for 180 min, trial 2 (day 2) for 90 min, and trial 3 (day 6) for 120 min. The percentage trained was plotted against time for each 15-min-period during the training period for each trial.

Results. The effect of acclimation on learning and retention scores on the 5 groups of fish is shown in the figure. Fish acclimated at 21°C all reached 100% trained after 150 min in trial 1, 75 min in trial 2 and 105 min in trial 3. The fact that the fish learned best on trial 2 and reached 100% trained on trial 3 in a time intermediate between trials 1 and 2, indicates a memory component.

The cold acclimated fish failed to learn the task. The fish remained floating upside down, but occasionally swam upside down. Fish that had previously been acclimated to 5°C for 3 weeks and then placed in water at 21°C, 48 h before the first trial, learned the task in 90 min on day 1. The scores for this group of fish were similar to the fish acclimated at 21°C during trial 2 and slightly better at trial 3.

Fish acclimated at 33°C failed to learn the task during any one of the 3 trials, and those transferred from 33°C to 21°C still failed to learn the task even 1 week after being transferred from the warm temperature. These results agree with those previously reported by Shashoua for summer fish³.

Discussion. Shashoua³ found that goldfish learn the task used in this experiment better in winter than in summer. The previous water temperature at which the fish were kept a few days before the experiments was not mentioned. Our results have shown that fish taken from a warm water environment and trained at room temperature still fail to learn the swimming skill 8 days after the transfer. Changes in biogenic amine levels⁴, as well as

changes in steroid levels with the onset of the spawning season⁵, have been cited by Shashoua as reasons for these seasonal variations in learning. Control for the direct temperature effects was not, however, carried out.

French⁶ has tested the effect of the acclimation temperature on the retention of a learned maze performance in goldfish. All the fish were tested at 16°C. Fish acclimated at low temperatures exhibited increased retention of the maze habit. These results, which involved transferring fish from cold to warmer water are in agreement with our findings that learning is improved when fish are transferred from 5°C to 21°C. Furthermore, French also found that significantly more errors were made by fish kept at 28°C than fish at 16 or 4°C¹⁰, which is also in agreement with the results we have found for warm acclimated groups of fish.

The poor results of cold acclimated (5°C) fish when they were not transferred to 21°C are probably due to the low temperature slowing down metabolic reactions and altering neural and muscle function.

The present paper, in which sexually immature carp fingerlings were used, indicates that temperature acclimation is a significant factor in learning and memory. Although temperature is known to affect ionic composition⁷, amino acid levels⁸, oxygen consumption⁹, biogenic amine levels⁴, hormonal levels and nervous system functions¹⁰, the exact manner in which memory and learning are affected by these changes is not quite clear.

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Positive after-image, PAI:

Early erasure by saccadic eye movement or Jendrassik manoeuvre¹

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Summary. Positive after-images (PAIs) evoked by low intensity stroboscopic flash are erased by voluntary large amplitude saccadic eye movements. The duration of the PAI is shortened by a Jendrassik manoeuvre. The results suggest that muscle spindle afferent impulses conducted centrally are involved in the erasure phenomenon. The duration of the PAI is modifiable by drugs. The social implications of PAI are considered briefly.

A flash of stroboscopic light evokes a series of images that can be examined subjectively. The real image observed during the flash fades rapidly, disappears and is replaced by a highly-detailed positive after-image, PAI, the onset and duration of which is dependent upon the intensity of the stimulating light. This image fades to a uniform neutral PAI in which the detail is absent, and is followed by a more durable negative after-image²⁻⁴. This communication reports that the PAI is erased by a large amplitude saccadic eye movement. This striking phenomenon can be produced easily by simply flashing a strobe light, photostimulator or electronic flashgun of low intensity while observing targets containing detailed images. It is suggested that the phenomenon of erasure is initiated by afferent impulses from activated muscle spindle receptors on the extraocular muscles which are processed centrally.

Methods. The subject, head in a fixed position, seated comfortably and allowed to adapt for 15 min to a completely darkened room, faces a target surrounded by a black nonreflecting surface. The target consists of a series of black and white concentric rings which subtend a solid angle of 10° at a distance of 35 cm.

A Grass Photostimulator, Model PS22, placed out of view of the subject at a height of 75 cm above the target which is tilted at an angle of 45° from the horizontal toward the subject, is triggered every 15 sec by a Grass

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