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A conditioned response overrides social attraction in common carp: A possibility for low stress sorting strongly schooling fish?

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A B S T R A C T

In this study we investigated whether a conditioned response to a light cue can override the strong schooling tendency of common carp, with a view to identifying a possible system for low stress control of movement for captive fish. Carp were trained in groups of three to approach and bite a trigger to obtain food, the trigger being located next to a coloured light. In an initial pre-training period, fish were trained to approach and feed from a single trigger, identified by either a red, a green or a blue light; six groups were pre-trained with each colour. During 10 pre-training trials, 11 of the 18 groups learned to feed efficiently in this set up. These groups were then given further training with triggers at three potential feeding locations, again identified by red, green and blue lights, food being delivered from the trigger signalled by the colour on which the fish had been pre-trained. The position of the rewarded trigger was changed randomly between trials, which numbered 15 in all. All 11 groups learned to approach the rewarded trigger preferentially, though some sampling of unrewarded triggers continued. The learned response was strongest for fish trained to approach the red light. New groups were then constructed comprising one fish trained to each of the three colours. When released simultaneously in a position equidistant from a red, a green and a blue light, all unrewarded, the three fish swam independently towards the colour on which they had been trained. Besides confirming the ability of common carp to use a demand-feeding system and to associate a coloured light with the presence of food, these results show that individual fish can be induced to move away from a small group towards a coloured light as a result of differential training. The potential for using this capacity to control movement of common carp held in captivity, for whatever reason, is discussed.

1. Introduction

Given the adverse effects of stress on growth, health and welfare in captive fish (Huntingford et al., 2012), it is important to minimise stress in fish-husbandry systems. Rearing fish in captivity for whatever purpose often involves periodic sorting into categories, for example, on the basis of size, gender or reproductive condition. It is also sometimes necessary to separate specific individuals from within a group. A number of techniques have been proposed for reducing handling stress during such processes (Lines and Frost, 1999; Zion, 2012), some based on innate responses to directional cues. For example, innate positive phototactic and rheotactic responses of guppies

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(*Poecilia reticulata*) can be used to stimulate fish to move through a narrow channel in which they can be sorted by gender using a computer vision system (Karplus et al., 2005). Positive phototaxis can be used to move farmed Atlantic salmon (*Salmo salar*) between cages (Lekang and Fjæra, 1995). Learned responses can also be used to control the movement of fish; for example, movement of Atlantic salmon through a sub-surface grid can be facilitated by a conditioned response to visual stimuli previously associated with the presentation of food (Fjæra and Skogesal, 1993).

The present study was designed to explore the possibility of using a conditioned response to control the movement of common carp (*Cyprinus carpio*), a species commonly reared for research and for the aquarium trade, as well as for restocking and for food. That such an approach might be feasible is demonstrated by the fact that learned responses to an acoustic signal can be used for hands-off recapture of carp following release into a large water body (Zion et al., 2012). Cyprinid fish readily learn to associate visual cues with the presence of food (e.g. Warburton, 1990) and our specific aim was to exploit this ability by determining whether learned responses to a coloured light could be used to separate individual members of small groups. We expected this to be challenging, since carp are strongly schooling fish and so might be expected to follow other fish rather than to base decisions on their own recent experience.

2. Material and methods

2.1. Subjects and husbandry

54 mirror carp (mean/min/max length = 8.98 cm, 7.4 cm, 10.6 cm; mean/min/max weight = 12.83 g, 7.65 g, 19.82 g) were transferred from VS Fisheries, Sparsholt, Hampshire, UK, to the Experimental Aquaria, Institute of Biodiversity, Animal Health and Comparative Medicine, University of Glasgow. The fish were housed in groups of six in glass tanks (100 × 38 × 31.5 cm), each with a re-circulating filter and airstones, at a temperature of 12 °C. Carp were marked using a Panjet inoculator (Hart and Pitcher, 1969) with Alcian blue dye (under UK HO Licence number 60/3679) and photographed for future identification on the basis of dye marks, together with scale pattern (Huntingford et al., 2013b). They were fed daily to satiation with commercial pellets, supplemented with frozen chironomid larvae. All procedures were in accordance with national and international guidelines for the use of animals in research.

2.2. Training

The carp were subjected to a training procedure during which they learned to feed on demand at a specific location signalled by a coloured light. This was achieved by placing one or three triggers projecting 20 cm below the water surface at specified points in a glass training tank (100 × 38 × 32 cm, Fig. 1) and delivering a single pellet next to the trigger whenever a fish approached and touched a trigger. The triggers were made of a narrow plastic rod (ca 2 mm diameter, 3 cm long) with a small piece of red rubber

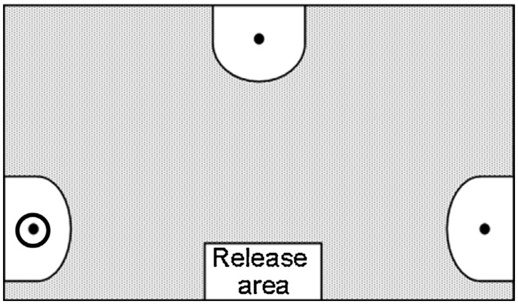

Fig. 1. Schematic diagram of the training tank. ●, potential position of the triggers; ⊙, position of single trigger (see text); White, area into which fish had to enter for a pellet to be delivered.

(1 cm long) covering the tip of the rod. Each trigger was identified by a small coloured light located underwater about 5 cm from its tip. Fish were trained in groups of three (size matched as far as possible), since carp are highly stressed by isolation.

2.3. Initial training with a single trigger

Initially, the carp were trained to use the demand-feeding system with just one feeder and just one colour of light. Groups of three fish were netted from their holding tank and released into a small area at the side of the training tank (Fig. 1). The fish were observed continuously for 20 min, during which, to attract the fish to the trigger, initially a pellet was released into the water (manually) each time a fish approached the light and subsequently only when they entered the feeding area and touched the sensor. The time that elapsed before the first fish in the group entered the feeding area and touched the trigger (touch latency) was recorded. At the end of each trial the fish were netted back to their holding tank. Fish were tested in this way once per day for 10 days, in the same groups and with the same light colour, the order in which groups were tested on any given day being randomised. Most fish ate some food during a given trial and at the end of each trial a few pellets were delivered to ensure that all fish had received sufficient food for carp held at a temperature of 12 °C. Other than this, the fish were only feed during the training sessions. Six groups were trained using a red light, six with green and six with blue, these colours being chosen because they are clearly distinct and known to lie within the visual range of carp.

2.4. Training with three triggers

Those groups that learned to use the demand-feeding set-up effectively (see Section 3.1) were used in the next phase of the study, in which they were presented with three potential feeding stations, each with a different coloured light, in different positions in the tank, only one of which delivered food. The fish were trained by the delivery of pellets to approach and touch the trigger with the same colour of light as that on which they were initially trained (the rewarded trigger). Now however, there were three triggers and three colours of light in the tank, two