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Selective attention in dairy cattle

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ABSTRACT

In a replication of Reynolds (1961), two cows learned to discriminate between compound stimuli in a forced choice procedure where pushing through a one-way gate marked with a red cross (S+) gave access to food. Pushing through a one-way gate marked with a yellow triangle (S−) gave no access to food. To investigate whether shape or colour was controlling behaviour, probe tests varied either the shape or the colour of the stimuli (e.g., a red vs. a yellow cross, and a red cross vs. a red triangle). Results suggested control by colour rather than shape, as the gate marked with the red stimulus was chosen more than the gate marked with the yellow stimulus regardless of stimulus shape, and when two shapes of the same colour (either red or yellow) were presented, cows chose both equally. Further probe tests with painted red, white, and yellow stimuli showed that the cows had learned to avoid yellow rather than to approach red, suggesting discriminative behaviour was controlled by the colour of the negative stimulus and not by either aspect of the positive stimulus. It is not clear why the negative stimulus was more salient, but it may reflect a tendency for cows to learn to avoid farm handling practices which involve mainly negative stimuli.

1. Introduction

Visual cues utilising distinctive shapes and colours are used extensively to guide humans, but their potential is unexplored in cattle. Yet the modern dairy cow is required to behave independently of humans and correctly discriminate on-farm stimuli. Automatic milking systems (AMS) require that cows move voluntarily from barn or field to the AMS for milking (Jago et al., 2002; Lind et al., 2000). New Zealand dairy farms are predominantly pasture-based; therefore to reach the dairy, cows must identify and operate a variety of different walk-through gates. With AMS a relatively emerging technology in New Zealand, it is relevant to investigate whether the provision of visual stimuli might aid dairy cows in learning an automated system.

Cattle are dichromats and can perceive some colours (Jacobs et al., 1998), and it appears that yellow and medium-long-wavelength colours are most easily discriminated (e.g., Dabrowska et al., 1981; Phillips and Lomas, 2001; Riol et al., 1989; Soffie et al., 1980; Thines and Soffie 1977). Cattle can also learn simple (e.g., Entsu et al., 1992; Neave et al., 2013; Rehkamper and Gorlach, 1997; Rehkamper et al., 2000; Schaeffer and Sikes, 1971; Wieckert et al., 1966), and complex (Baldwin, 1981) visual discriminations and can discriminate familiar herd members (Coulon et al., 2011; Coulon et al., 2009; Hagen and Broom, 2003), different handlers (Taylor and Davis, 1998), handlers wearing red and yellow overalls (Munksgaard et al., 2001; Munksgaard et al., 1997; Rushen et al., 1999) and handlers on the basis of facial features and height (Rybarczyk et al., 2003).

Discriminations between stimuli may be learned faster when physical differences between stimuli are large (Teng et al., 2015), thus using stimuli that differ along more than one dimension could aid learning. In a classic study, Reynolds (1961) showed that when both stimulus shape and colour differed, either could come to control behaviour. In his experiment, two pigeons learnt to peck a white triangle on a red background (S+) and not to peck a white circle on a green background (S−), but when elements of both stimuli were presented separately, one pigeon pecked the red background only, and the other responded to the white triangle only. Each attended to a single aspect of S+ and neither responded to either aspect of S−. Recently, with squirrel monkeys, Ploog (2011) showed that inhibitory control by the form and colour of S− was less than the excitatory control from these aspects of S+. Thus, with compound stimuli, one aspect of the stimuli might come to have more control over behaviour than others, with an aspect of S+ possibly having more control than any aspect of S-.

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Reynolds (1961) described his results as showing selective attention, and this term is also used to refer to the processes underlying such findings. The traditional view of the development of such selective attention to the elements of stimuli focused on relational learning (e.g., MacKintosh, 1975), but, as Zentall (2005) pointed out, there are more recent cognitive theories, in addition to 'attentional' accounts. In reviewing these theories, Zentall (2005) concluded that none accounted for all the data, that when behaviour comes under selective control by one or more elements of the compound stimuli attentional processes are involved. Configural-cue theories, such as that described by Pearce (1994) suggest discrimination training with a compound stimulus will lead to a configural representation of the entire stimulus and it is this representation that is associated with the outcome of a trial.

The current experiment sought to determine if cattle would learn to use two different shaped and coloured stimuli to select the appropriate gate to move through, and, if so, whether one aspect (colour and shape) would have come to have more control over behaviour. Based on the work of Baldwin (1981), a cross and a triangle were chosen as shapes, and based on the colour research summarised above; red and yellow were chosen as colours. A red cross (S+) signaled food was available once the cow had pushed through the associated one-way gate and a yellow triangle (S−) signaled no food was available through that gate. Given such training, cows should learn to select the gate associated with S+ and avoid or not select the gate associated with S−.

2. Materials and methods

2.1. Subjects

Two non-milking Friesian cows were kept in a fenced holding area located adjacent to the experimental yards. In addition to food received within a session, cows were walked to a grassed field every afternoon and fed a ration of grass before being returned to the holding area where they remained overnight (to ensure a mild level of food deprivation). The animals had full access to water at all locations and full access to grass Friday to Sunday afternoon.

2.2. Apparatus

The experiment was conducted in modified out-door animal holding yards. Two adjacent holding pens (termed runs) were situated on one side of the yard area (see Fig. 1). At the end of each run were two pairs of one-way gates, with feeding areas beyond that contained trays and food bowls. A small plastic container containing food sat behind each feed bowl to control for olfactory cues.

Stimuli were mounted on four grey wooden boards that were attached to one half of the gate. A red acrylic plastic cross and yellow acrylic plastic equilateral triangle were attached to the middle of the boards (Fig. 1). For the probe tests, the same sized acrylic crosses and triangles (yellow and red) and crosses (red) and triangles (yellow and white) were cut from painted plastic signboard.

2.3. Procedure

Sessions were conducted starting at 8:30 am Monday to Friday and lasted approximately 50 min. One experimenter set up each trial, changing the stimuli and replacing the food reinforcer (125 ml of a mixture of barley, chaff and molasses) if a correct choice had resulted in food being consumed. They also brushed away any food particles that were visible on the top or sides of the feed bowls between trials to control for any visual cues. If an incorrect choice had previously been made, the reinforcer was left in the bowl and the location was changed, if required, for the following trial. A second experimenter timed and recorded all responses. To start a trial, a cow was let into Run 1 (Fig. 1), where timing started once her shoulder passed a point on a marker gate positioned approximately 156 cm from the end of Run 1 and Run 2 (Fig. 1, points A and B respectively). Timing ended when the cow's shoulder pushed through the one-way gate at the end of the run. Once the cow had moved through a one-way gate the second person called out the position (i.e. left or right) of the stimuli for the next trial, so as one trial was being completed, the next trial was set up. Once stimuli for the next trial were in position, food had been put into the appropriate bowl and, if food had been delivered, once the cow had finished eating, a new trial was started by releasing the cow into Run 2. This process was repeated so that a cow systematically moved from Run 1 to Run 2 until all trials were completed.

2.4. Experimental procedure

Two grey boards, one with a red acrylic cross (S+) attached and the other with a yellow acrylic triangle (S−) attached were presented on each set of gates. The side of S+ and S− presentation (left/right) was determined quasi-randomly with no more than three consecutive presentations on the same side. Cows had to achieve a criterion of 90% correct over five consecutive sessions before a probe session took place. This criterion was decreased to 80% correct over five consecutive sessions because Cow 2 did not achieve 90% and time constraints were in place due to calving.

2.5. Probe sessions

Twenty probe trials were randomly interspersed in an experimental session, with responses to either option gaining access to reinforcement. In probe sessions 1–4 either the shape or the colour of both acrylic stimuli was the same (i.e., red cross vs yellow cross, red cross vs red triangle, red triangle vs yellow triangle, yellow cross vs. yellow triangle). Only Cow 1 completed probe session 4. In probe sessions 5 and 6, a red acrylic cross (S+) and then a yellow acrylic triangle (S−) were presented opposite a grey panel. Only Cow 1 completed probe session 7, with painted versions of S+ and S− (i.e., a painted red cross and yellow triangle), and probe session 8, with painted white and yellow triangles. These two sessions changed the relative brightness of the stimuli (i.e., the original acrylic red cross was darker than the acrylic yellow triangle, the painted red cross was lighter than the painted yellow triangle, and the painted white triangle lighter than painted yellow triangle).

All experiments were carried out with approval from The University of Waikato Animal Ethics Committee.

3. Results

Cow 1 completed 45 sessions. Accuracy, calculated as percentage of correct responses, was consistently high (above 80%) over the last 24 sessions. Cow 2 completed 64 sessions. Accuracy fluctuated but was always above 80% over the last 10 sessions.

Fig. 2 shows the number of times each probe stimulus was selected over the 20 probe trials. The data for sessions in which one stimulus was selected on most trials are plotted first, followed by those where the differences were less. A two-tailed binomial test was used to test for significance of the different numbers of choices of each stimulus over the 20 trials. In probes 1 and 3, Cow 1 chose the red stimulus on 19/20 trials, $p < 0.0001$, over the yellow cross and yellow triangle. In probe 7, the painted red cross was always chosen over the painted version of S-, $p < 0.0001$. In session 6, the grey panel was chosen over the original S- every time, $p < 0.0001$. In session 8, this cow chose the white triangle over the painted version of S- on 16/20 trials, $p = 0.01$. All these results were significant at the 0.05 level. In sessions 4, 5 and 2 the results were not sig-