Animal Behaviour 84 (2012) 219–223

Contents lists available at SciVerse ScienceDirect

Animal Behaviour

journal homepage: www.elsevier.com/locate/anbehav

Optical flow, flock behaviour and chicken welfare

Marian Stamp Dawkins [a,*], Russell Cain [a], Stephen J. Roberts [b]

[a] Department of Zoology, University of Oxford, Oxford, U.K

[b] Department of Engineering Science, University of Oxford, Oxford, U.K

ARTICLE INFO

Article history:
Received 6 September 2011
Initial acceptance 9 January 2012
Final acceptance 17 April 2012
Available online 4 June 2012
MS. number: 11-00700R

Keywords:
animal welfare
broiler chicken
collective behaviour
contact dermatitis
gait
Gallus gallus
optical flow
welfare assessment

We used a combination of inexpensive camera equipment and statistical analysis of optical flow patterns to analyse the behaviour of 24 commercial broiler (meat) chicken flocks, *Gallus gallus*. Individual birds were not tracked or marked but the skew and kurtosis of flow patterns produced by the collective movements of the flocks were significantly correlated with key welfare measures such as % mortality, numbers of birds with hockburn (damaged leg skin) and abnormal walking behaviour (poor gaits) in individual birds. These correlations were already apparent in birds as young as 15–20 days. Optical flow patterns provided an information-rich link between flock and individual that could be important in the development of new ways of assessing the welfare of, and managing, broiler chickens. It could also have wider application to the study of other animal groups as an alternative to more invasive or intrusive methods.

There is now an array of inexpensive camera/video systems for observing and recording animal behaviour, from tiny cameras that can be put onto flying birds to video surveillance that enable constant monitoring of whole groups. But collecting data is only the first step. Without the ability to sift and analyse the vast quantities of data that can now be collected, the information revolution that the new technology promises is incomplete. The question still remains: having collected the data, what should we now do with them?

We here address this question in the context of a rapidly growing area of ethology: the study of the collective behaviour of large groups of animals (Sumpter 2010). We show that the combination of inexpensive technology and relatively simple statistical analysis of group behaviour can give valuable information quickly and easily from a large and otherwise unwieldy data set. The particular example we use, extracting information about animal welfare from month-long video recordings of flocks of commercial broiler (meat) chickens, *Gallus gallus*, raises many of the same problems that are widely encountered in the study of other animal groups: there were very large numbers of animals (35 000 in each house), they were homogeneous in appearance (making individual tracking computationally very difficult), they could not be visually marked (as it would interfere with behaviour) and they could not be pit-tagged or fitted with loggers (as these could have ended up in the food chain). Some or all of these problems are common to studying animal groups on farms, in zoos or in the wild so that the noninvasive, nonintrusive 'optical flow' approach we describe here has the potential to be widely used in other ethological studies.

Optical flow analysis works by detecting the rate of change of brightness in different parts of a moving visual image (Beauchemin & Barron 1995; Sonka et al. 1999; Fleet & Weiss 2005). It is used in a variety of different applications including traffic flow (Bellomo et al. 2009), movement of glaciers (Giles et al. 2009), cell and sperm motility (Shi et al. 2008; Weissleder & Pitter 2008; Cheng et al. 2009) and the study of human crowds (Courty & Corpetti 2007; Ma & Cisar 2008), but has so far been relatively little used for studying groups of nonhuman animals (Bremond et al. 2006). Its great advantage is that whole frames or sections of frames, containing tens or hundreds of individuals can be assessed together and the basic statistical properties of these flow patterns can be derived automatically and continuously (Sonka et al. 1999) using algorithms that are simple enough to deliver results continuously in real time. A key step in using optical flow successfully is, therefore, to establish which statistical properties are most appropriate for a given situation.

* Correspondence: M. S. Dawkins, University of Oxford, Department of Zoology, South Parks Road, Oxford OX1 3PS, U.K.
E-mail address: marian.dawkins@zoo.ox.ac.uk (M. S. Dawkins).

0003-3472/$38.00
doi:10.1016/j.anbehav.2012.04.036

The most obvious statistic to use is the mean flow rate, which indicates the overall level of movement over time in whatever sequence is being looked at. In broiler chickens, flocks with a high percentage of individuals with abnormal walking behaviour have been shown to have a lower mean flow rate than flocks made up of normally walking individuals (Dawkins et al. 2009), a finding confirmed experimentally by Aydin et al. (2010). However, the mean flow rate can also be affected by other factors such as size of individuals, light levels and distance to camera (Fleet & Weiss 2005), which are likely to be common problems in many animal behaviour studies and are difficult to control. Relying on the mean flow rate alone could therefore give misleading results and additional measures from optical flow data may be needed to guard against this. In pursuit of alternative measures, we found that flocks with large numbers of abnormally walking birds also showed higher variance in movement, higher positive skew (movement mode displaced from the mean in the direction of slower movement) and higher kurtosis ('fat-tails', indicating unusual movement; Dawkins et al. 2009). One explanation of this result is that healthy birds all tend to walk in the same way, whereas flocks with a high percentage of lame birds are 'mixed-ability' flocks, with some individuals walking normally and others walking with varying degrees of difficulty and this is reflected in their higher variance, skew and kurtosis of movement.

Whatever statistic is used, the next step is to validate it and to make sure that it is actually delivering something of biological interest, either instead of an observer being present or as a supplement to direct observation. In the case of broiler chickens, abnormal walking is a key indicator of reduced welfare (Bessei 2006; Renema et al. 2007; Knowles et al. 2008) and is currently measured by the time-consuming method of people 'gait scoring' birds by eye (Kestin et al. 1992). If optical flow could be validated as an automated way of monitoring chicken walking ability, this would have important implications for the assessment of their welfare.

The aim of this study was to see whether our preliminary findings on the use of optical flow patterns of flock movement were sufficiently robust to be useful as a practical way of assessing chicken welfare on commercial farms. We collected optical flow data on 24 commercial flocks of broilers and predicted that reduced welfare (as measured by higher mortality, abnormal walking and higher incidence of leg and foot damage) would be correlated with lower mean optical flow and higher variance, skew and kurtosis. To test its sensitivity and make it maximally difficult for the optical flow system to pick out differences between the flocks, we chose flocks that were as similar to each other as possible in size, stocking density and housing. To test its ability to provide useful information at different stages of the birds' lives, we collected optical flow data continuously every 15 min throughout the entire lives of the flocks, from day-old to 35 days when they were taken to slaughter.

METHODS

Twenty-four commercial broiler flocks were used for this study, which was conducted on a single site in the U.K. Four identical houses were studied simultaneously, with six replications over time, between October 2010 and June 2011.

Animals and Husbandry

Broiler chickens of mixed sexes and of one of two commercial broiler breeds were placed in the houses as day-olds (33 000–35 000/house) and grown to 35 days old with a target final stocking density of 38 kg/m^2. Each house was 1670 m^2 and contained 488 feed pans and 1735 water nipples. Ventilation was standard roof extraction. There was no thinning (early removal of a proportion of the flock) or changes to floor space at different ages. Lighting, feeding, temperature and other husbandry regimes were in accordance with practice recommended by the breeder companies (Cobb 2008; Aviagen 2009).

Production Data

The production company supplied the following information: total mortality (% of flock dead before slaughter); total culls (% total mortality from culling); daily mortality and culls (recorded on a daily basis by the farm manager); growth rate (average daily bird growth weight calculated from daily recording with automatic weighers in each house and additional weekly weighing by hand); hockburn (% of birds with any permanent discoloration to the hocks, assessed at the slaughter plant post mortem and after cleaning and defeathering); pododermatitis (% of birds with any lesion to the foot pad, assessed at the slaughter plant post mortem and after cleaning and defeathering). In addition, the company supplied information on gas consumption per house, water consumption per house, age at which the birds were sold, total weight sold and the farm manager's recordings of relative humidity (rH) measured with a hand-held rH meter. Company data were validated as far as possible; for example, the totals of the mortality and cull data as they were recorded on the daily house sheets were checked against the final flock mortality and culls as given by the company and the company provided data before being told optical flow results for that flock. Systematic bias in the collection of post mortem data was controlled for by collecting data from the slaughterhouse 'blind' (i.e. the staff assessing hockburn and pododermatitis at the slaughter plant operated to standard company procedures and did not know which flocks they were assessing).

Welfare Measures

In addition to information about the mortality, hockburn and pododermatitis, birds were assessed for their walking ability. Gait scores were collected by the farm manager who had been trained to use the 6-point Bristol Gait Score (Kestin et al. 1992) and gait scored 60 birds/house on day 28. The results were expressed as a mean gait score for that flock. As a validation of these data, a second observer used a 3-point score (Dawkins et al. 2004; Webster et al. 2008) and gait scored a total of 100 individuals on days 32–34. On the first half of the data, the two scores were significantly positively correlated (Spearman rank correlation: $r_S = 0.71$, $N = 12$, $P < 0.01$), which was taken as validation of the observer.

Recording Equipment

The behaviour of the broiler flocks was recorded using waterproof and custom-built C120 web cameras (Logitech International S.A. Plc., Romanel-sur-Morges, Switzerland), connected (two cameras/unit) to a small form-factor (115 × 101 × 27 mm) industrial PC (Fit-PC2, Anders Electronics Plc., London, U.K.) enclosed in a protective waterproof casing. In each chicken house, two units (four cameras) were installed on each side of a house at a height of 200 cm (±10 cm), and connected to a domestic power supply. Machines were programmed to operate the optical flow package between 0800 and 1900 hours and were left running from day 1 to day 35.

Optical Flow

Optical flow analysis involves detecting the rate of change of brightness in each area of an image frame both through time and