

**Movement change detected by optical flow precedes, but does not predict, tail-biting in
pigs**

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Abstract

Videos of pigs were analysed using an optical flow algorithm to measure group movement in the four days leading up to and including an outbreak of tail-biting. 8 pens in which tail-biting occurred (Outbreak) were retrospectively matched with 8 similar pens in which no tail-biting occurred over the lifetime of the pigs (NoOutbreak) and videos analysed for the same four days. Results showed an increase in movement over the four days in both groups and no difference between Outbreak pens and their matched NoOutbreak pens. On the contrary, Outbreak and NoOutbreak matched pens showed similar changes in behaviour, suggesting that the pigs were influencing each other or responding to common external circumstances. Such a tendency to “match” the behaviour of pigs in neighbouring pens makes it difficult to identify which pens will show tail biting.

Key words

Tail biting; pigs; optical flow; animal welfare

Introduction

Tail-biting is a serious welfare issue in modern pig production (Taylor et al., 2010; Valros and Heinonen, 2015) and the main method of reducing its impact – docking the tails of all pigs in a group – is itself a welfare issue (Sutherland and Tucker, 2011; Di Giminiani et al., 2017; Sandercock et al., 2019). There is therefore considerable public and commercial pressure to find ways of controlling tail-biting without tail docking (D’Eath et al., 2014). Known risk factors for outbreaks of tail-biting include keeping pigs on partially or completely slatted floors, high stocking densities and feeding systems in which pigs have to compete for the same trough space (Moinard et al., 2003; Scollo et al., 2017). Attempts to eliminate or

at least reduce tail biting have emphasized the importance of providing straw or objects that the pigs can manipulate (Zonderland et al., 2008; D'Eath et al., 2014; Lahrmann et al., 2019; Wallgren et al., 2019a; Godyn et al., 2019). In Sweden and Finland, where tail docking has been banned, a combination of lower stocking densities, sufficient feeding space, no fully slatted floors, controlled levels of noxious gases and manipulable litter material has resulted in tail biting amongst undocked pigs being much less of a problem than in the rest of the European Union (Valros et al., 2016; Wallgren et al., 2019b). However, in many parts of the world, such standards have not been adopted in full and, despite attempts to provide some elements such as an enriched environment with objects and substrates designed to interest the pigs, tail-biting remain a major welfare and commercial problem (Gruempel et al., 2019; Nalon and DeBriyne, 2019; Hoy et al., 2020).

In the absence of a reliable way of preventing tail-biting, a useful substitute would be a method of detecting the early warning signs of tail-biting before it resulted in injury, allowing interventions such as correction of environmental inadequacies, provision of additional enrichment or temporary removal of individuals doing the biting (Lahrman et al., 2018; Chou et al., 2019). For example, changes in temperature and in the amount of water pigs drink have been shown to occur in the days leading up to an outbreak of tail-biting although these are not entirely reliable predictors (Larsen et al., 2019a). Pigs also show an increase in activity and in object manipulation suggesting that behaviour might be used as an early warning of tail-biting (D'Eath et al., 2014; Larsen et al., 2016; 2019b). Lowered tail posture with reduced curliness of the tail appears to be an advance indicator of a tail-biting outbreak, giving at least 7 days early warning (Zonderland et al., 2009; Wedin et al., 2018; Larsen et al., 2018b; Wallgren et al., 2019c). Tail posture has the advantage that it could be

easily incorporated into routine inspection by farmers (Wedon et al., 2018) and can also be detected automatically using 3D cameras (D'Eath et al., 2018).

In this study, we investigated whether a simpler method involving automated monitoring of group movement might also be able to predict tail-biting and thus provide an additional precision farming tool for farmers. Automated analysis of the optical flow patterns made by the movement of groups of chickens has already been shown to predict welfare problems and *Campylobacter* infection in broilers (Dawkins et al., 2012; 2017; Colles et al., 2016) and to contribute to prediction of which flocks of laying hens will subsequently show later feather damage (Lee et al., 2011). Optical flow measures rate of change of image brightness in different parts of a moving image (Beauchemin and Barron, 1995) and is particularly suited for analysing the behaviour, and changes in behaviour, of whole groups of animals. It has the potential to detect changes indicative of tail-biting (Li et al., 2020) but this has so far not been fully tested. To validate the use of optical flow as a predictor of tail-biting outbreaks, we tested two hypotheses:

(i) that there would be an increase in mean optical flow in pigs before an outbreak of tail-biting, corresponding to the reported increase in activity in pigs in the days leading up to tail-biting (Zonderland et al., 2011)

(ii) that groups in which tail-biting was about to occur would show higher mean optical flow than groups that did not tail bite.

Methods

The data used were taken from video recordings of 32 pens of finisher pigs on an experimental unit at the Department of Animal Science, Aarhus University, Denmark. The videos were recorded in June and July 2015. The experiment was conducted in accordance

96 with a protocol approved by the Danish Animal Experiments Inspectorate (Journal no. 2015-
97 15-0201- 00593).

98 *Animals Housing and Management*

99 The animals included in the experiment were finisher pigs from 30 kg until slaughter,
100 bred from dams of Danbreed Yorkshire × Danbreed Landrace, all inseminated with
101 Danbreed Duroc semen. The pigs were born at a Danish commercial farm and arrived at the
102 experimental unit as weaners.

103 The pens were all in the same building **which was approximately 5m high** and
104 divided into two sections with two concrete walls and a hallway between them. All pens
105 were identical with dimensions of 5.45 x 2.48 m and with the flooring equally divided
106 between solid, drained and slatted areas. **The wall of the building constituted the back wall**
107 **of each pen, with the other three walls being approximately 1 m high.** The pigs were fed
108 *ad libitum* with a commercial dry feed and the feeders were filled three times a day at 0300,
109 1000 and 1830 h. Lights were switched on between 05.30 and 18.30. The general
110 management was performed by the trained stock people. Between 10.00 and 12.00 h, the
111 general routine in the sections was performed including cleaning, straw provision (see
112 below) and a general health check.

113 The experiment was part of a larger study on risk factors for tail biting including
114 multiple batches of finisher pigs and is described in detail in Larsen et al. (2018a). The larger
115 study was a 3x2 factorial experiment, meaning that each pen was assigned to one level of
116 three treatments: (1) pigs with docked tails v. pigs with undocked tails, (2) provision of 150g
117 of straw per pig and day v. no provision of straw and (3) stocking density of 1.21 m²/pig (11
118 pigs, 2 feeding spaces) v. 0.73 m²/pig (18 pigs, 3 feeding spaces). The tail-docked pigs had
119 their tails shortened to half their original length, in accordance with Danish legislation.

120 *Definition of 'tail biting'*

121 A pen was classified as an Outbreak pen when at least one pig in the pen was
122 observed to have a bleeding tail. Trained observers scored the tails in detail every Monday,
123 Wednesday and Friday from within the pen and stock people scored them daily from
124 outside the pen.

125 *Matching of Outbreak and NoOutbreak Pens*

126 Outbreaks of tail biting occurred in 19 pens. Each Outbreak pen was retrospectively
127 matched with another pen of the same age pigs in which tail-biting did not occur during the
128 entire lifetime of the pigs (NoOutbreak). A requirement for matching was that the matched
129 pens had to be videoed on the same dates, so that a direct comparison would be possible,
130 and that the matched pens had the same level of each of the three treatments. There were
131 more pens with tail-biting than without, so it was not possible to match all the Outbreak
132 pens with a different NoOutbreak pen. Four of the NoOutbreak pens were therefore
133 matched with more than Outbreak pen but the matching was done on different dates,
134 depending on when tail-biting occurred, so in practice different video sequences were used
135 for the matching. Where there was a choice of NoOutbreak pen, the physically nearest pen
136 to the Outbreak pen was chosen.

137 *Cameras and videos*

138 A camera (Monacor, TYPE-TVCCD-1705, Bremen Germany) was positioned at a
139 height of about 3m **on the wall of the building at the back of each pen**, giving a view of the
140 entire pen. Videos were initially stored on the herd computer and transferred on a weekly
141 basis to hard drives for back-up. Data used in the current study were copied to a single hard
142 drive and sent to Oxford for analysis. The videos were of a non-standard format Videoswitch
143 (.vdm) and of variable frame rate in which the cameras switched off if nothing was moving.

As optical flow measures amount of movement (rate of change of image brightness between frames), this has to include all sequences, even where there is no movement. Before the optical flow analysis could take place the video sequences therefore had to be 'reconstructed' by inserting zero movement for the missing frames. Missing sequences were recognized by reading the timestamps in the bottom right hand corner of frames with Optical Character Recognition.

Optical Flow Analysis

Optical flow analysis works by detecting the rate of change of image brightness ('flow') in each part of successive image frames and summing over both space and time (Beauchemin and Barron, 1995). For this analysis, each image frame in a video was divided into 1200 (40 x 30) 8-by-8 pixel blocks and the rate of change of image brightness within each block was measured. The pigs appeared as pale patches against a darker background. If pigs remained stationary over time, the pale blocks remained pale and darker blocks remained dark and there was no change in image brightness. However, if the pigs started to move, some of the previously pale blocks would become dark and dark blocks would become lighter. Movement was thus picked up as the rate of change in image brightness ('optical flow') summed over all blocks and delivered as a summary of the mean amount of movement every 15 minutes. This method only recorded the gross amount of movement within a pen and did not recognize either individual animals or pick up on small movements such as nosing. Its advantages are that it works with relatively poor image quality, gives a summary of the movements of whole groups of pigs, does not **require detailed object recognition against different backgrounds** and is computationally simple, making it potentially suitable for use on commercial farms if its value as a predictive tool could be

shown. The method has been successfully used to describe movement patterns in flocks of broiler chickens on commercial farms (Dawkins et al. 2009, 2012, 2017).

The results were initially in the form of median values for every second of the videos. Median values were used to eliminate spuriously large numbers that occasionally occurred in the optical flow records when the cameras switched off and then on again during periods when there was no movement from the pigs. The results from each second were then averaged to give a single value for each day for each pen. This was then used for the statistical analysis.

Statistical analysis

Days included in the statistical analysis were day-3, day-2, day-1 and day-0 relative to the outbreaks of tail biting, where day-0 was the day of outbreak, with the same exact dates for the matched pairs of Outbreak and NoOutbreak pens. Only 8 matched pairs of Outbreak and NoOutbreak pens were included in the analysis as only these had complete data for all four days.

The data were analysed as a matched pairs 2-way ANOVA with repeated measures on 'day' using Kaleidograph 4.5.2 software.

Results

There was no significant difference between the daily mean optical flow of tail-biting Outbreak pens and their non-tail biting NoOutbreak matched pens (Table 1). There was, however, an increase in mean optical flow in both groups in the three days leading up to an outbreak of tail biting (Table 1, Figure 1). Furthermore, there was a highly significant effect of subjects or matched pairs, indicating a high correlation between the Outbreak pen and its matched NoOutbreak pen.

Table 1. The results of the comparison between 8 matched pairs of Outbreak and NoOutbreak pens, using a two-way ANOVA with repeated measures on the 3 days leading up to an outbreak of tail-biting (day 0).

| Source | df | MS | F | P |
|----------------------|----|-------|-------|---------|
| Total | 63 | 5.92 | | |
| Outbreak/No Outbreak | 1 | 6.55 | 0.37 | 0.55 |
| Day | 3 | 6.58 | 2.94 | 0.04 |
| Interaction | 3 | 0.57 | 0.25 | 0.86 |
| Matched Pairs | 14 | 17.93 | 8.011 | <0.0001 |
| Error | 42 | | | |

<Figure 1 near here>

Discussion

As predicted from hypothesis (i), mean optical flow increased in the days before an outbreak of tail-biting, confirming results from behavioural studies that have reported an increase in general activity before an outbreak (D'Eath et al., 2014; Larsen et al., 2016; 2019b). However, hypothesis (ii) that mean optical flow would be higher over this period in pens that developed tail-biting than in matched non-tail biting pens was not fulfilled. There was no difference or interaction over time in mean optical flow between Outbreak pens and matched NoOutbreak pens.

The results thus show that optical flow can be used to detect more activity among pigs in the days leading up to an outbreak but not to predict which pens will show actual

tail-biting. However, although activity as revealed by optical flow is not, on its own, an accurate predictor of which pens will develop tail-biting, it may nevertheless be a useful indicator that pigs are at increased risk and that precautionary measures should be taken. In this, it is similar to other measures such as water use that is associated with tail-biting but has too many false positives to be relied on as a sole predictor (Larsen et al., 2019a). One reason for false positives is that tail-biting may have a variety of precursors and that a single one may be important and often present but still not sufficient to predict tail biting on its own.

The highly significant effect of the matched pairs shows that there was a striking correlation *between* the Outbreak pens and matched NoOutbreak pens in the three days leading up to an outbreak. This could be due to the fact that the matched pairs were observed on the same dates and were therefore exposed to the same environmental factors such as weather events, visitors etc. Alternatively, it could be due to pigs in one pen influencing and being influenced by the behaviour of pigs in other pens. From the evidence available, it is impossible to distinguish these two hypotheses. In this study, all pens were all within one house, with matched pairs chosen to be close to each other and pigs were potentially able to see or at least hear each other. This means that the pigs in a NoOutbreak pen could have been stimulated into activity by its tail-biting neighbours or *vice versa*. The matched pairs design of this study was a statistically valid way (Grafen and Hails, 2002) of ensuring that Outbreak and NoOutbreak pens were exposed to the same environment, and videoed on the same day but it could also have had the effect of eliminating any potential differences that might become apparent in pens that could not see or hear one another. Validating the optical flow approach on pigs that are completely isolated from one another was beyond the scope of this study but these results provide a clear demonstration of yet

another difficulty in identifying ‘predictors’ of tail-biting: even pigs that are not tail biting may show some of the early warning signs of tail-biting because of social stimulation by other animals but these may never be followed by actual tail-biting.

Tail-biting is caused by many different factors (D’Eath et al., 2014) and predicting when an outbreak is going to occur without an unacceptable number of false positives will need input from many different sources about both the environment (e.g. Larsen et al., 2019) and pig behaviour (e.g. D’Eath et al., 2018; Diana et al., 2019) as well as a multifactorial modelling approach. It could also be informative to look much further back in time beyond the three days looked at in the present study and to record the behaviour of pigs many days or even weeks before an outbreak of tail-biting. It is possible, given indications from the above studies for behavioural changes as early as 7 days prior to a tail-biting outbreak, that the difference of movement between Outbreak and NoOutbreak pens would have been visible earlier, and that activity of the NoOutbreak pigs was then entrained by the Outbreak pigs. The optical flow approach described here, with its ability to automate analysis of movement, would be particularly well suited to handling the very large video records that would be generated by a long term study.

Conclusions

Continuous monitoring of pig behaviour with optical flow has shown that although there was an increase in movement in the days leading up to tail-biting, this increase was not specific to tail-biting as it was also shown simultaneously in neighbouring pens in which no tail-biting occurred. Increased movement therefore indicated an increased risk of tail-biting but could not predict in which pen it would occur.

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Figure captions

Figure 1. Mean optical flow for Outbreak (solid line) and NoOutbreak (dashed line) matched pairs of pens. The vertical lines are standard errors. Day 0 was the day on which tail biting occurred in the Outbreak pen.