The search for positive welfare indicators – precision poultry farming tracking activity in pullets

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Abstract

Activity is considered one of the most promising animal-based measures (ABM) of animal welfare and health. However, tracking activity is a challenge in the barn. To date, different techniques have been considered. Video technology can detect pixel-based activity via various algorithms, but is costly to install. Passive infrared sensors (PID) could provide a simple and practical alternative supporting the farmer. To validate these techniques, 9 pens of pullets were observed 24/7 for 33 days. The sensors were placed so that they each focused on a pen of 56 animals in 9.2 m² area. Pens differed in genotype and treatment (flicker frequency of the LED light). Data were measured continuously at 1-min intervals. Values were tested in empty pens and recorded afterwards in occupied pens, and the readings represented the entire range of 100% output during animal observation. The PID sensors showed a mean activity during the light phase of 21.74% and during the dark phase of 4.73%. Measurements from the PID sensors, video-based analyses, and ethological scan sampling observations have been analyzed. The correlation of PID and ethological data ranges between $r = 0.512$ to 0.845 ($P \leq 0.001$) reflecting a strong correlation throughout the data set. Video-based validation reveals lower correlation coefficients within the six focal days based on one pen ($r = 0.37$ to 0.684, with 3 other days $P \geq 0.3$). Further data cleaning should be applied. The measurement of activity in the pen offers simple approaches of the PPF to improve animal welfare, such as the derivation of activity for the enhancement of animal health or in relation to the adequate occupation of the animals with enrichment materials.

Keywords: infrared sensors, activity, chicken, welfare

Introduction

In the search for positive animal welfare indicators, the focus is increasingly on dynamic behavior, i.e., the activity of the animals. In this context, it is not only of interest to measure activity, but also to use these data to promote higher levels of active behavior. It is known from broilers that increased activity supports bone health and leads to a general improvement in mobility (Riber et al., 2021). In addition to the activity of the individual animal, the movement behavior of the flock, in particular, is often used as an indicator. There are various approaches to this, including, for example, the optical flow method by Dawkins et al. (2013). This method shows that the movement behavior of a broiler flock can indicate how good the health status of the animals is. However, video-based methods are often complex and have only been established in practice to a limited extent because, among other things, the technology can be expensive.

In this project, in addition to video technology for pixel-based and ethological scan sampling evaluation, passive infrared detectors (PID) were also used. These may offer a cheaper and more robust alternative to previous techniques. The sensors themselves must be modified to give a scaled output instead of a binary one. The technique has already been successfully tested in pigs (von Jasmund et al., 2020) and is currently being validated in other animal species.

It has already been used in chickens, for example by Nielsen (2003). However, the correlation with behaviorally collected data shown at that time was very low. In a subsequent publication (Nielsen et al., 2004), however, it was shown that the daily rhythm of broilers can be reflected by the PID technique. On the other hand, increased activity is not always associated with increased animal welfare. Dynamic behavior, such as feather pecking in laying hens, or disturbances of resting animals reduce animal welfare (Forslind et al., 2021). The renewed interest in appropriate sensor technology may be due to the fact that animal welfare is becoming more important, animal welfare is increasingly associated with unrestricted animal activity, and the level of animal welfare achieved during the production period should also be demonstrated by farmers in the future.

Activity index was proposed to quantify poultry activity through image processing by Bloemen et al., 2010. Activity index is the measure of movement activity through image processing. This method has been widely used to quantify broiler activity for many years and was selected as a good validation method for the objective of this study (Kristensen et al., 2010; Neves et al., 2015).

Here the PID technique is used to measure the activity of pullets in different housing environments. The animals experience different flicker frequencies in the lighting, which may influence animal welfare. In general, however, the validation of the technique was in the foreground. Can infrared be used to measure the activity of pullets, and are the infrared data correlated with video-based activity analysis or ethological scan sampling procedures?

Materials and methods

Animals

The present study was part of a larger study focusing on the effects of LED flicker frequencies on the welfare, health and behavior of pullets during the rearing phase. In total, six pens of Lohmann Selected Leghorn Lite (n = 331) and three pens of Lohmann Brown Lite (n = 165, both Clark's Hatchery, Brandon, MB, Canada) pullets were observed. The average number of birds per pen was 54, resulting in an average stocking density of 55.86 birds per m^2. Average pullet weights were 680g for LSL Lite and 730g for LB Lite at 59 days (8 weeks) of life.

The chickens were housed in the Poultry Research and Teaching Unit's Poultry Centre of the Department of Animal and Poultry Science, University of Saskatchewan, in three rooms with 6 pens (3 pens/strain/room) each. Each pen measured 2.3 x 4 m with 1-2 solid walls and wire panels on the other sides. Floor-housing pens were offered perches on one side, a hanging standard nipple drinker line and two hanging tube feeders. Regular management was applied to the birds resulting in a minimum of two health checks per day. The photoperiod was set at 8L:16D. Light intensity was kept at 30 lux, and temperature was maintained at 18-20°C.

Materials

The PIR sensors are typically used for motion detection outdoors (Renkforce 1362922, surface-mount PIR motion detector 360 ° Relay White IP55 (Conrad Electronic SE, Hirschau, Germany). PIR sensors were modified in the scientific workshop of the Institute of Agricultural Engineering of the Agricultural Faculty, University of Bonn, Germany. The electrical signal, ranging from 1V (idle mode) to 10V (max. output), was transferred into a percentage ranging from 1 to 100%. A small signal light enables a quick check whether the sensor is reacting to motion. The PIR sensors were installed in at 3.00 m height, with the lens being at 2.82 m. All sensors were connected via cables to a reading and recording advice (datalogger ALMEMO® 710, Ahlborn Mess- und Regelungstechnik GmbH, Holzkirchen, Germany) outside the rooms. As the PIR has a range of 16 m to either side, and 10 m and 16 m to the front and back (assumed height 2.5 m), respectively, the lens was shielded to three sides (no shield facing the wall of the pen) with an paper-covered aluminum sheet. The sheet was manually adjusted to that all movements within a pen were measured but non from outside the pen.

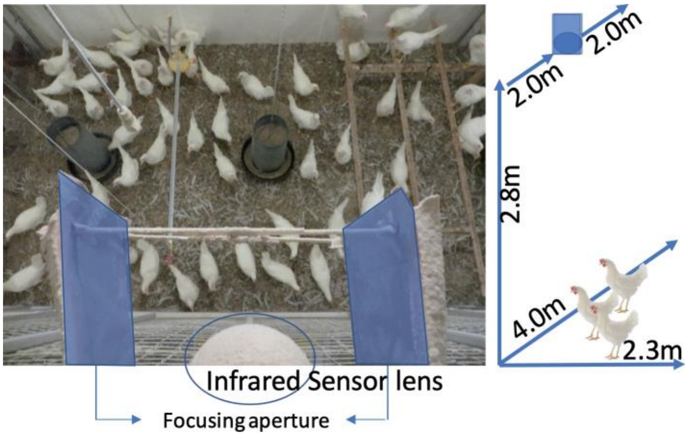

Figure 1: Top view from the PID sensor on the chicken pen. To focus the PID on the chicken's behavior within a single pen, the lens was shielded with a prototype from the neighboring pen. Dimensions are given on the right.

Data collection

The PIDs sensors monitored the chickens from the 53 day (7 weeks) of life to the 87 day (week 12) of life. PIDs were validated before recordings started by taking all birds out of the pen. Data were monitored 5 min testing whether values are constant below 5% which was then applied to all of the nine sensors. Each sensor was then challenged by the experimenter going in the pen and walking up and down near the side panels which increased values accordingly. This was to ensure that the shielding excluded the birds of the adjacent pen but included all movements within the pen. Afterwards chickens were returned to the pen.

One pen per genotype per room was video observed using infrared dome cameras (Bosch WZ45 Integrated IR Dome; Bosch Security Systems Inc., Fairport, New York, USA). Videos were recorded three times (Monday, Wednesday, Friday) per week starting on day 56 of life until day 86 of life. Each recording started with the lighting phase at 8:00 am and continued for 24h. Of these, six focal days were scan sampled for ethological data. The ethogram included all active behaviours including locomotion, comfort behaviour, perching behaviour, exploratory behaviour as well as aggressive behavior. Therefore, the value measured by the sensor is rather unspecific, but it covers all main category of welfare-related behaviours as the PIR sensors measure the shift of temperature of the animal's body and the temperature of the background (wall/floor) in correlation to the size of the moving body (also as a function of distance) and the intensity of the movement.

In addition, one pen was used for video-based validation. First images were extracted from the videos at a rate of every 2 seconds. A color threshold was the set based on the bird pixel values in the rgb (red, grey, blue) image. Images were then converted to black and white and binarized, in which white pixels (the birds) are assigned a value of 1 and all other pixel values are assigned a value of 0. The binarized images were then subtracted sequentially by each other i.e. image1, image2, image3, The total representative bird pixels were also gathered from each binarized image by returning the number of nonzero pixel values present in the image. Total number of non-zero pixels (nnz) was calculated as the difference between the two consecutive images due to the activity of broilers. The total number of broiler representative pixels (bird_area) was calculated. The activity index (AI) was calculated as the fraction of the number of non-zero pixels in the resulting binarized image.

$$AI = \frac{\text{??ç}}{\text{é!YW\_ZYVZ}} \quad (1)$$

Data analyses

To parallel PID and ethological data, the proportion of birds showing a specific behavior was multiplied with factors (1 to 4) reflecting the planimetric equivalent of the behavior and the bird's surface. Data of the PIR sensors were pooled to focal intervals (5min), e.g., at the onset of light, and general intervals (1h) e.g., during night.

Data were visualized using Sigma Plot 14 (Systat Software Inc., Chicago, USA) based on descriptive statistics (Excel). A Pearson Product Moment Correlation was calculated, and *P*-values are given based on $\alpha = 0.05$. For bilateral comparison, a One-Way Repeated Measures Analysis of Variance was used due to the Normality Test (Shapiro-Wilk) failed.

Results and discussion

PID sensor data were in line with ethological scan sampling. Although there is an overestimation of activity based on the weighed behaviors, the course of the curve of the diurnal rhythm is strongly correlated to the PID sensor data ($r = 0.881$, $P \leq 0.001$, Figure 2). Bird activity strongly increased with the onset of light, and, in addition, birds appeared to expect the onset of light indicated by an increase of activity during the scotopic phase just before 08:00h. Bird activity strongly decreased after the end of the photoperiod, although, there was a slight activity in PID sensor data and the ethological data, which is remarkable since chickens are thought to have an impaired scotopic vision (Gover et al., 2009). Data did show that pullets left the perches, and ate and drank during the night.

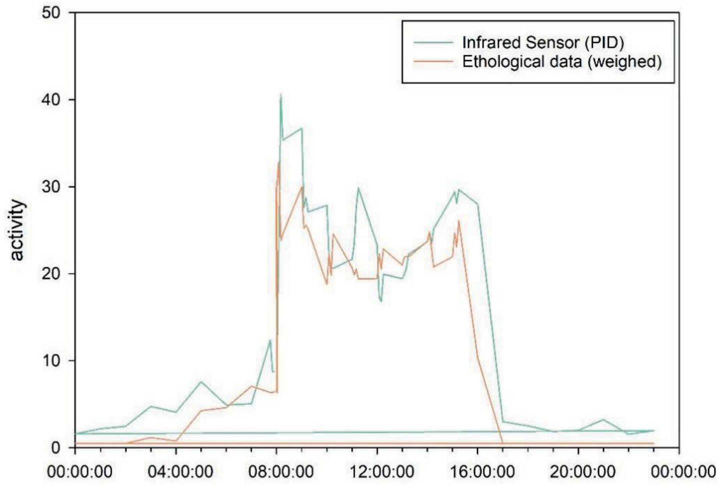

Figure 2: Diurnal rhythm of activity based on PID sensor data and behavioral scan sampling data of pullets. Behaviors are weighed according to the planimetric change of the chicken's surface, taking dynamics (categorical velocity ranging from 0-4, and animals' weight into account. Initiation of the photoperiod was 08:00h, and the scotoperiod began at 16:00h. Given are average data of six focal days of three treatment groups and two different layer lines.

Planimetric data were used to specify the space covered by the animals' body (Spindler et al., 2016). . The space covered by a laying hen varies between behavior from 505cm² for a standing hen up to 2388cm² for a wing-flapping hen (EFSA AHAW Panel, 2023). Planimetric data were extrapolated to all behaviors assessed. In addition, as the dynamics of the animals' movement trigger the infrared sensor response, behaviors were categorized based on their velocity/intensity ranging from 0-3. A refinement here would be conceivable and desirable as soon as more behavior-specific planimetric/velocity data are available.

For each focal day, treatment group and layer line, a separate correlation was calculated for PID sensor data (n = 1440) and ethological scan sampling data (n = 1,632 per day; 51 time points x 32 behaviors assessed). The range of correlation coefficient *r* is reported in Table 1.

Table 1: Correlation coefficients *r* among PID sensor data and ethological data for the three treatment groups and two layer lines. Calculations are based on six focal days. All correlations have been shown highly significant ($P \leq 0.001$).

Treatment / layer line	30Hz	90Hz	250Hz
LSL	0.603 – 0.800	0.512 – 0.835	0.561 – 0.837
LB	0.565 – 0.801	0.603 – 0.828	0.570 – 0.845

Correlation coefficients were not affected by treatment or layer line indicating a robust and strong correlation between PID sensor data and ethological data.

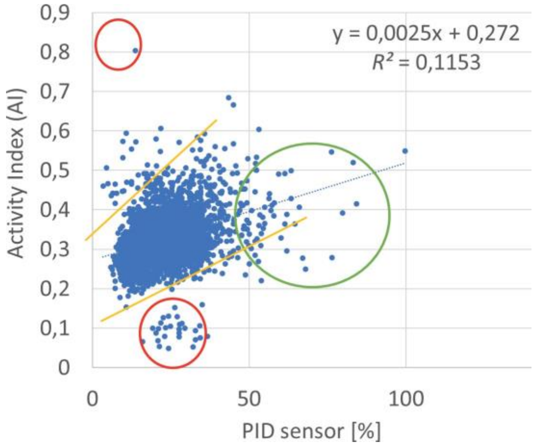

Figure 3: Correlation of Activity data retrieved in the video-based validation with PID sensor data. Blue line indicates linear regression, yellow lines show aimed distribution, red circles indicate outliers, green circle might result from difference between techniques (AI vs IR, i.e., relative vs absolute activity).

PID sensor data as well as weighed ethological data were also correlated to video-based activity data (Figure 3 and 4). The correlation of both data sets was calculated on 1-min. intervals, taking the average video-based activity (2 sec intervals) in the minute before the data point of the PID sensor into account. This presumption is based on the (slow) response speed of the PID sensors. The correlation coefficient is comparable low. Further refinement might include the reduction of outliers and refinement of the video-based intervals to optimizing the time interval used. Another possible reason for the subpar correlation could be the placement of cameras and PID sensors. The cameras used for AI calculations were placed at the corners of the pens, while the PID sensors were placed in the middle of the side walls. This difference in placement could have caused variations in occlusion and affected the accuracy of bird activity detection and agreement between these two sensors.

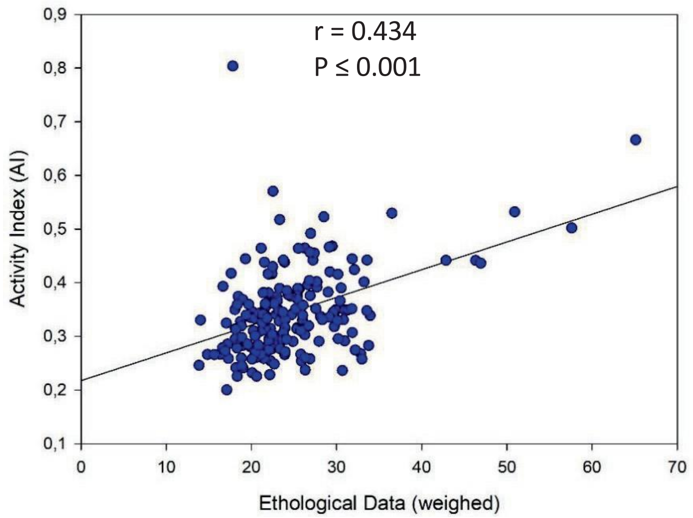

Figure 4: Correlation of Activity data retrieved in the video-based validation with weighed ethological data. Black line indicates linear regression.

PID sensor data reflect the diurnal rhythm of the chickens (Figure 5). This rhythm is influence by the genetic background of the chicken ($P \leq 0.001$) with LSL showing higher activity rates than LB. Our data showed a mean activity during the photoperiod of 22.74 % (± SD 4.57 %) and 4.73 % (±SD 2.02) in the scotopic phase.

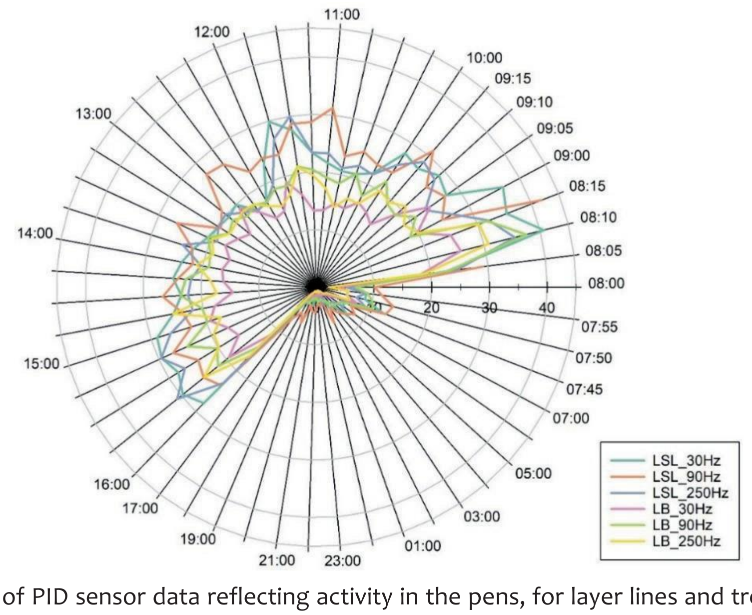

Figure 5: Radar plot of PID sensor data reflecting activity in the pens, for layer lines and treatment groups. Note that chickens get active just before onset of light, and LSL being more active than LB. Averaged are six focal days per pen.

Treatment groups do not differ in LSL sensor data (P = 0.308) nor in LSL ethological data (P = 0.189). Interestingly, LB show differences between treatment groups in sensor data (P = 0.021), but not in weighed ethological data (P = 0.275). Differences between these layer lines regarding their response to different light intensities have been reported recently (Chew et al., 2021). Further analysis based on pairwise comparisons of the 32 behaviors of LB scanned under the three flicker frequencies should be conducted.

Conclusions

PID sensor are capable to measure chicken activity. Strong correlations indicate that sensor data and ethological data reflect the same pattern of dynamic behaviors. Which behaviors contribute to the infrared measurement in detail, must be recalculated when behavior-specific planimetric data are available. This recalculation would also be the prerequisite to align sensor data with positive welfare indicators.

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