Understanding anomalies in animal behaviour: data on cow activity in relation to health and welfare

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ABSTRACT

We collected data on the behaviour of dairy cows in barns, clinical signs of diseases as well as events that may stress or agitate the cows. A Real-Time Locating System gives the position of individual cows every second. The position of the cow is determined by triangulation based on radio waves emitted by a tag fixed on each cow neck collar and captured by antennas in the barn. The cow's activity is inferred from its position: 'eating' if the cow is positioned at the feeding table, 'resting' if the cow is in a resting area (typically cubicles), else 'in alleys'. We aggregated this information to get the time spent in each activity per hour. We also calculated the activity level of the cow for each hour of the day by attributing a weight to the time spent in each activity. For each cow and day, we collected information on health events or other events that may affect behaviour. There were 11 types of events. Six events were linked to health: lameness; mastitis; LPS (i.e. administration of lipopolysaccharide (**LPS**) in the mammary gland, an experimental treatment to induce udder inflammation); subacute ruminal acidosis; other diseases (such as colic, diarrhoea, ketosis, milk fever or other infectious diseases); and accidents (such as retained placenta or vaginal laceration). Two events were linked to reproduction: oestrus and calving. Three events were stress events: animal mixing, disturbance (i.e. mild intervention on animals such as late feeding, alarm test) and marginal management changes (ration changes, fill bed). In addition, a Boolean sums up whether this hour was considered as normal or not. Data contain four datasets. It consists of univariate time series. Each time series corresponds to the hourly activity level of a cow. Datasets 1 and 2 are from the INRAE Herbipôle experimental farm and include data from experiments; datasets 3 and 4 are from commercial farms. They contain data on respectively 28, 28, 30 and 300 cows monitored for 6 months, 2 months, 40 days and one year. The data can be used to study the links between health, reproduction events and stress on the one hand and cow behaviour on the other hand. More specifically, it can be used to build and test tools for an earlier detection of health and disturbances, with a view to inform caretakers so that corrective actions can be rapidly put in place.

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Specification table

Subject	Behaviour and Health Management
Specific subject area	Cow behaviour through hourly cow activity data and associated event labels (e.g. oestrus, diseases, lameness, …)
Type of data	Table
How data were acquired	We collected data from the CowView system (GEA Farm Technology, Bönen, Germany), which is a Real-Time Locating System (**RTLS**) that gives the position of each cow in a barn every second. The cow's activity is inferred from its position: 'eating' if the cow is positioned at the feeding table, 'resting' if the cow is in a resting area (typically cubicles), else 'in alleys'. We also calculated the level of activity of the cow for each hour of the day. For each cow and day, we collected information on health events or other events that may affect behaviour. Event data were collected from logbooks or from sanitary information system (SICPA sanitaire, https://doi.org/10.15454/A1UV8Q). The caretakers logged any event as soon as it was observed (oestrus [ATOL_0005321], calving [ATOL_0000877], lameness [AHOL_0003029], mastitis [AHOL_0003088], clinical signs of other diseases, accident-related health problems, disturbances such as handling for vaccination, change of pen, mixing of animals) in a logbook, together with the treatment applied to the animal. In addition, data for datasets 1, 2 and 3 provide a labelling of days where udder inflammation induced by lipopolysaccharide (**LPS**) (dataset 1), acidosis [AHOL_0003154] (dataset 2) or oestrus (dataset 3) was checked or detected via additional measures. In dataset 1, cow body temperature was monitored to check that they reacted to LPS. All cows were of Holstein breed [LBO:0000132].
Data format	Aggregated data at hourly scale and expressed as activities.
Parameters for data collection	Datasets 1 and 2 were obtained in an experimental farm, datasets 3 and 4 were obtained in commercial farms (i.e. real-world field conditions).
Description of data collection	Data from different sources were aggregated into one file per farm.
Data source location	Datasets 1 and 2 are from INRAE Herbipôle experimental farm, Marcenat, France (https://doi.org/10.15454/1.5572318050509348E12).| Datasets 3 and 4 are European commercial farms.
Data accessibility	Repository name: Data INRAE https://data.inrae.fr/ Direct URL to data: https://data.inrae.fr/privateurl.xhtml?token=7e2f5c12-400b-45c4-b543-b512688da799
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Value of the data

- These data are unique because of their scale/size and the fact that they combine behavioural measures with health observations.
- The data, made publicly available, are a unique resource of interest to data scientists, biologists (in particular specialised in animal health and behaviour), and engineers developing Precision Livestock Farming solutions.
- The data offer opportunities to data scientists to develop and test algorithms to detect anomalies in time series
- Biologists can explore the data to analyse behavioural alterations due to health disorders (so-called sickness behaviour) or reproductive events. The nature of the modifications can be investigated, e.g. variations of the time spent in specific activities, variations of the level of activity, alteration of the circadian rhythm of activity. More importantly, the evolution of the behavioural alterations over time can be studied.
- The data can support the development of Precision Livestock Farming tools based on the detection of behavioural anomalies in relation to health and disturbances, with a view to inform caretakers so that corrective actions can be rapidly put in place.
- Even though data on activity can be obtained by different sensors, the results obtained are likely to be valid on datasets of animal activity obtained by other means (other sensors or observation) (Buller et al., 2020).

Data description

Data are composed of four datasets and one table (Table 1). The datasets are structured as follows:

- cow working id (3 or 5 digits); No cow belongs to several datasets; therefore, there are 386 unique cows.
- date;
- hour (integer). The time spent in each activity is aggregated at hourly scale because lower scales contain too much variability; the hourly scale allows to study variations during the day and results in datasets which can be processed easily by softwares such as R. The agreement between INRAE and GEA Farm Technologies was thus established on the basis of activity data collected per hour;
- the time(s) spent 'walking' during one hour (the cow is positioned 'in alleys');
- the time(s) spent 'resting' during one hour (the cow is in a resting area (typically cubicles));

- the time(s) spent 'eating' during one hour (the cow is positioned at the feeding table);
- the activity level (unitless), which is the weighted sum of the time spent in each activity (with the following weights: −0.23 for resting, +0.16 for in alleys, and +0.42 for eating, (Wagner et al., 2021)). Due to the weights, the hourly activity level can range from −828 (i.e. −0.23 × 3 600) to 1512 (i.e. 0.42 × 3 600). To attribute a weight to each activity, a Factorial Analysis of Correspondence was run with observations being the hours of the day and variables being the time spent in each activity (Veissier et al., 2017). The weights attributed to each activity to calculate the activity level are those obtained on the first component which expressed at most the variability between hours of the day and is thus likely to reveal the circadian cycle. This analysis was performed on each dataset. Although the datasets were obtained in farms managed under varying conditions (e.g. conventional vs. automatic milking, mixed diet vs. roughage and concentrate distributed separately), the weights obtained showed good closeness (mean absolute variation of coefficient was 6.7% ±. 11.0%). We thus calculated averaged weights across the four datasets, that we think generic enough to be applied on any farm even outside of the present datasets;
- Finally, for each of the 11 types of events, a Boolean is provided, for the question "is there this type of event on this hour ?" (i.e. 1 means this type of event was reported for this hour; 0 means that this type of event was not reported for this hour). Note that in fact daily events are reported here at hourly scale.

Table 1
This table is linked to the dataset 1. For each cow, it indicates whether the dairy cow received a non-steroidian anti-inflammatory drug (Ketofen® 10%, 3 mg/kg; CEVA Santé Animale, Libourne, France) (NSAID), or a physiological serum (0.9% NaCl, 3 mL/100 kg, BIOLUZ, St Jean de Luz, France) (CONTROL). Cow 6664 is present in the dataset 1, but it did not receive lipopolysaccharide (LPS) as it was lame at the time of the LPS challenge, which is then noted as 'NONE' in the table.

Cow id	Treatment
6601	CONTROL
6610	NSAID[a]
6612	NSAID[a]
6613	NSAID[a]
6621	NSAID[a]
6629	NSAID[a]
6633	CONTROL
6634	NSAID[a]
6637	CONTROL
6638	CONTROL
6643	CONTROL
6646	NSAID[a]
6656	CONTROL
6664	NONE
6674	CONTROL
6675	CONTROL
6683	CONTROL
6686	NSAID[a]
6689	NSAID[a]
6690	CONTROL
6693	NSAID[a]
6695	NSAID[a]
6699	CONTROL
6701	NSAID[a]
6714	CONTROL
6721	CONTROL
6750	CONTROL
7600	NSAID[a]

[a] Non-steroidian anti-inflammatory drug.

There are 11 types of events:

- oestrus [ATOL_0005321];
- calving [ATOL_0000877];
- lameness [AHOL_0003029] includes all types of lameness and issues on claw or leg;
- mastitis [AHOL_0003088] includes all types of mastitis;
- Event LPS is specific to experimentation as it is for administered lipopolysaccharide (LPS) in the mammary gland on one day to induce inflammation [AHOL_0003064]. Table 1 provides the additional information on whether the cow received a non-steroidian anti-inflammatory drug or a physiological serum;
- Event acidosis [AHOL_0003154] stands for subacute ruminal acidosis. When the measure was not available, the dataset contains 'NA';
- Event labelled 'other_disease', which contains all other diseases such as colic, diarrhoea, ketosis, milk fever or other infectious diseases;
- Event accidents contain all types of accidents such as retained placenta or vaginal laceration;
- Event disturbance is mild intervention on animal (e.g. late feeding, alarm test, animal tied for injection, claw trimming, drying of the cow) and other issues on the day but that did not concern management changes;
- Event mixing is for when cows were mixed or moved to another park;
- Event labelled 'management_changes' contains marginal management such as ration changes or bed filling. This event is reported in the dataset, but is not considered to influence the animal behaviour;

Table 2 gives a summary of the number of events per type and per dataset.

- A final Boolean sums up the information on whether this hour is considered as normal (i.e. if all the Booleans (without considering the management changes one) are equal to 0, then this hour can be considered as normal, otherwise (at least one event) then the Boolean is set to 1).

Dataset 1 - This dataset contains data for 28 cows monitored for 6 months (5 124 cow × day, i.e. the number of times where data are present for a specific cow on a specific day). Due to some missing data, the dataset contains only 107 665 cow × hour observations (i.e. the number of times where data are present for a specific cow on a specific hour, 12.4% of missing data).

Dataset 2- This dataset contains data for 28 cows monitored during 2 months (60 days) (1 680 cow × day). Due to some missing data, the dataset contains only 40 246 cow * hour observations (0.2% of missing data).

Table 2
Number of events per type and per dataset of hourly dairy cow activities.

Type of Event	dataset 1	dataset 2	dataset 3	dataset 4
Oestrus	41	7	26	257
Calving	8	0	0	171
Lameness	4	16	0	114
Mastitis	9	3	0	32
Lipopolysaccharide (LPS)	27	0	0	0
Acidosis	0	271	0	0
other_disease	10	8	0	66
Accidents	0	0	0	15
Disturbance	173	671	0	12 223
Mixing	72	0	0	0
Management changes	0	168	0	2 581

Dataset 3 - This dataset contains data for 30 cows monitored for 40 or 41 days, resulting in 1 220 cow × day. Due to some missing data, the dataset contains only 26 224 cow * hour observations (10.4% of missing data).

Dataset 4 - This dataset contains data for 109 800 cow × day with 300 cows for year. Due to some missing data, the dataset contains only 2 177 207 cow × hour observations (17.3% of missing data).

Table 1 is linked to dataset 1. For each cow, it indicates whether the cow received a non-steroidian anti-inflammatory drug (Ketofen® 10%, 3 mg/kg; CEVA Santé Animale, Libourne, France) (**NSAID**), or a physiological serum (0.9% NaCl, 3 mL/100 kg, BIOLUZ, St Jean de Luz, France) (CONTROL). Cow 6664 is present in dataset 1, but it did not receive lipopolysaccharide (**LPS**) because it was lame at the time of the LPS challenge, it is then noted as 'NONE' in the column 'Treatment' of the table.

Experimental design, material and methods

All the data were obtained on dairy cows. Raw data from sensors were processed by the CowView system (GEA Farm Technology, Bönen, Germany): position changes were kept only if the position change was higher than 15 cm or if the cow kept this position for more than 60 s). Then using the building map, we extracted raw information on cow positions (i.e. in alleys, in cubicles or in feeding table) at hourly scale. Incomplete hours were not kept.

Event data were collected from logbooks or from the sanitary information system (SICPA sanitaire, https://doi.org/10.15454/A1UV8Q). The caretakers logged any event as soon as it was observed (oestrus, calving, lameness, clinical mastitis, clinical signs of other diseases, accident-related health problems, disturbances such as handling for vaccination, change of pen, mixing of animals) in a logbook (or the information system), together with the treatment applied to the animal.

Dataset 1 comes from INRAE Herbipôle experimental farm. The cows were milked at fixed times twice a day. The food was delivered in the morning then pushed back close to the feeding gates three times in the afternoon. The cows were administered 25 µg ultra-pure LPS from Escherichia Coli O111 (tlrl-3pelps, InVivogen, United States) in the mammary gland on one day to induce inflammation. The acute inflammation lasted 2 days. In addition, the challenged cows received an intramuscular injection of either saline solution (0.9% NaCl, 3 mL/100 kg, BIOLUZ, St Jean de Luz, France) (LPS group) or Ketoprofen (Ketofen® 10%, 3 mg/kg; CEVA Santé Animale, Libourne, France) (LPS + NSAID group) on average 30 min (minimum–maximum: 26–31 min) after been challenged. Volumes of saline solution injected in LPS group were equivalent to the volumes of Ketoprofen injected. Cow body temperature was monitored to check that they reacted to LPS. This dataset contains events of oestrus, calving, lameness, mastitis, LPS, other diseases, disturbance and mixing, but no occurrences of accidents or marginal management changes. Acidosis was not measured.

Dataset 2 comes from INRAE Herbipôle experimental farm. The cows were milked at fixed times twice a day, and fed twice a day. Half of the cows received a high-starch diet for 1 month to induce subacute ruminal acidosis. Ruminal pH was monitored using a sensor (eCow bolus, Exeter, UK). According to the method proposed by Villot et al. (2018), we normalised the ruminal pH values of each cow to take into account inter-individual variability, sensor drift and sensor noise. Then, we considered that a cow was under subacute ruminal acidosis (SARA) when the normalised ruminal pH (NpH) decreased by at least 0.3 for more than 50 min/d and the daily standard deviation in NpH was above 0.2 or the daily NpH range was above 0.8. This dataset contains events of oestrus, lameness, mastitis, acidosis, other diseases, disturbance and marginal management changes, but no occurrences of calving, accidents or mixing. LPS was never administered on these cows.

Dataset 3 comes from three commercial farms. On two farms, the cows were milked at fixed times twice or three times a day, and food was delivered twice a day or only once in the morning then pushed back after each milking. The third farm was equipped with an automatic milking system, so the cows had no fixed milking times. Food was delivered in the morning and regularly pushed back by a robot. Contrary to datasets 1, 2 and 4 where oestrus was detected by caretaker observation, in dataset 3, progesterone was assayed in the milk daily, and oestrus was detected when progesterone concentration dropped dramatically for at least three consecutive days (e.g. from 20 down to 5 ng/mL; Ovucheck® Milk test, Biovet®, Saint-Hyacinthe QC, Canada). This dataset contains only events of oestrus and no other types of events (LPS was not administered and acidosis was not measured).

Dataset 4 comes from a commercial farm with 300 cows monitored for 12 months. The farm was equipped with an automatic milking system. The food was delivered in the morning and regularly pushed back by a robot. This dataset contains events of oestrus, calving, lameness, mastitis, other disease, accidents, disturbance and marginal management changes, but no occurrences of or mixing. LPS was not administered, and acidosis was not measured.

Ethics approval

Datasets 1 and 2 were obtained in experimental conditions. The conditions for using the animals aligned with the framework of the EU Directive 2010/63 for the protection of animals used for scientific purposes. The INRAE 'Herbipôle' experimental facility (https://doi.org/10.15454/1.5572318050509348E12, UE 1414, Marcenat, France) received approval from the French Ministry of Agriculture to carry out experiments on live animals (EEA accreditation #C15-114-01). All scientists and technicians involved in the experiments received initial training for experiments on live animals and are regularly retrained to maintain and refresh their capacities, in line with French regulations governing experiments on animals. The protocol used in dataset 1 was submitted to and approved by the regional ethics committee (approval: APAFIS2015043014541577). The protocol used in dataset 2 did not require such an approval.

Datasets 3 and 4 were obtained with no additional interventions on animals because measurements, diet, housing, handling of the animals or any other environment or management factors were part of the on-farm routine.

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Isabelle Veissier: Conceptualization, Methodology, Validation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Supervision

Declaration of interest

Karen Helle Sloth was employed by GEA Farm Technology that commercialises the CowView system that was used to detect the position of cows. All the authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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