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Effects of Power Cuts on Dairy Cattle Behaviour

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Potential stress reactions of dairy cows caused by an energy-related failure of automatic milking systems (AMS) are presented in this study. It was carried out on four commercial dairy farms in Germany, 2014. All farms were using 1 Lely AMS for about 60 dairy cows. 12 adult Fleckvieh were randomly selected per farm. The cows under observation were given 6 days to get used to a daily routine. From the 7th to the 9th day a video baseline of the behaviour was taken. On days 10 to 13 a power cut was simulated and the behaviour video-taped again. A list with 19 behaviour parameters was created and statistically analysed. Locomotion, rumination and elimination behaviour tended to occur more often in the experiment. Differences were observed in the determined duration: a longer duration was measured in four parameters, a shorter duration in two compared to the basal measurement. In conclusion, the individual animal behaviour of a cow during the simulation of power blackouts is altered. However, a significant difference was only measured in two out of 19 parameters. Based on a new statistical hypothesis test for high-dimensional paired samples it could be investigated that the probability for the event that with a probability of higher than 0.54 behavioral changes of the milk cows occur, equals only 0.05. Parameters such as cortisol content, heart rate variability and paces may be included into this evaluation to record and emphasise individual animal reaction regarding health and stress. The results of this research project and all other test results will be part of the sub-project animal-machine interaction within the concept approach "Integrated dairy farming - stable 4.0".

1. Introduction

In the future, highly mechanised and automated dairy stables will increasingly require energy in form of electricity and heat. To achieve a high proportion of self-produced electricity and to keep the load on the public electricity network as low as possible, the project "Integrated Dairy Farming - Stable 4.0" was created (Höld et al., 2016).

The concept "Integrated Dairy Farming - Stable 4.0" describes the idea of a comprehensive sustainable stable energy management (Höld et al., 2015). It contains automatic production technology as well as regenerative energy resources and intelligent power grid connectivity.

Even nowadays, farms run by own family staff are trying to reduce physical work by greater flexibility through the acquisition of a milking implement which allows an animal individual milking. The result is a progressive increase in mechanisation and automation, especially in Bavarian dairy farms. In 2016, 1,751 Bavarian farms were already using AMS (Rieder, 2017). Applying automatic milking systems not only leads to organisational adjustments (Munksgaard et al., 2011) but also requires adapting energy supplies and the energy required must be available for 24 hrs/day.

The objective of the project "animal/machine interaction" within the concept "Integrated Dairy Farming - Stable 4.0" is to quantify potential stress reactions of dairy cows to energy-related failures of milking robots. In this study twelve focus cows out of a herd of four arbitrarily chosen farms were analysed before and after a simulated power cut. To simulate this power cut, the focus cows were not admitted to the milking robot for two hours on a whole day. Stress reactions can be detected via various hormones, by different physiological and/or behavioural parameters and therefore give information on animal welfare. Under identical conditions,

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every individual reacts differently to a stressor (Keeling and Jensen, 2009). Sambraus (1978) evaluates the activity changes, by which animals do not show their daily rhythm any more, typical for kind of preliminary stages of behavioural disorder and reactions to stressors. Also the change of frequency of specific behaviour patterns can be due to stress. Besides, animals should look longer and more often for a situation to be able to explain a certain behaviour, e.g., standing longer in a cubicle before lying down. Also incomplete movements or uncompleted activities can be clues to possible stress reactions. Normally the movement activity of cows in loose-houses is rather low; nevertheless, it increases while the cows are in heat. Local changes mostly appear only if dairy cattle visit different functional areas, e.g. for feeding. The stable system, technology used and farm management have a major impact on cattle's behaviour (Scheibe, 1987). But stress reactions also depend on the animal itself: Cows with a pronounced temperament deal better with stressful situations than fearful ones and stress leads to possibly suffering from a temporary decrease in productivity. In addition, older cows react less anxiously than younger cows (Phillips, 2002). The exploratory behaviour primarily serves to inform the cow about objects and to convey sounds from its environment. Older animals e.g. already know many objects and sounds from their environment. Lowering the head and stretching the mouth forward is a typical posture when a cow approaches an unknown object (Winckler, 2009). A cow's locomotion is based on push factors like food, water, housing or space conditions, but it is also influenced by social factors such as ranking and number of animals in a herd. Therefore, social interactions are increasing as a result of higher stocking densities (Phillips, 2002). Narrow and tight space conditions lead to the fact that animals with a lower rank limit their locomotion more, in order to maintain the distance to higher ranked cows and to avoid conflicts (Winckler, 2009). The aim of body care behaviour is to improve physical well-being (Sambraus, 1978) but it also has an impact on all nutritional, communicative and physiological functions of the cow (Winckler, 2009). Rumination e.g. is only shown by healthy cows who do not feel stressed (Phillips, 2002). The elimination behaviour provides information about the state of excitement of the cow. Increased excitement or fear in cows can lead to increased excrements Sambraus (1978). According to Fraser (1978) agonistic behaviour describes all forms of conflicting situations for animals. In addition, the behaviour depicts how animals attack, flee, threaten or avoid contact (Süss and Andreae, 1984). All behavioural co-ordinates apart from fights belong to the expression behaviour of the social behaviour. Aggressive expression can be divided into demonstrating, imposing and threatening (Sambraus, 1978). For evaluation of this study behaviour parameters were divided into categories. The information and data determined in the experiment give results about how cows cope with different milking times.

2. Material and methods

2.1 Farms and animals

This study was carried out on four commercial Bavarian dairy farms using a Lely Astronaut milking system from March to April 2014. The number of milking cows varied between 52 - 71 animals. Note that the farm management of the cattle was not abnormal. For technical reasons, on each farm 12 lactating Fleckvieh cows were selected randomly for the experiment by taking each forth cow from the increasingly order list of ear numbers to test their heart activity. At each farm, both lactating as well as pregnant animals were observed. The number of lactation periods was in the range of one to seven lactations, on average 2.4 lactations. The age of the cows was between two and eight years. The average age was 3.9 years and the average milk yield 26.9 l/day. The cows were kept in a loose housing system with a slatted floor and a lying area containing cubicles with a mattress system.

2.2 Experimental design

The total duration of the experiment was 13 days on each farm see figure 1. For six days (day 1 to 6) before data recording the animals had to wear a chest strap for measuring their heart activity so that they could get used to it and to the whole experimental procedures (habituation). The period of data collection (figure 1) on each farm was seven days (day 7 to 13), split into three days of basal measurement (day 7 to 9) and four days of test measurement (day 10 to 13), whereby for the statistical evaluation (Wörz et al., 2017) only three days were used.

Test days

1	2	3	4	5	6	7	8	9	10	11	12	13
Habituation						Basal measurement			Power cut simulation			

Figure 1: Experimental design

The basal measurement detected the condition of the animals without the influence of an energy-related failure of the milking robot. For the actual test measurement, the usual milking behaviour of the focus cow was taken into consideration to inhibit the milking permission of the respective focus cow once within 24 hours for two hours (block time), followed by the tapering, where the focus cow accustomed to normal behaviour.

2.3 Applied technology and data analysis

To record the behaviour of the focus cows Mobotix MX-D14Di-Sec D22N22 (Langmeil, Germany) cameras were been installed in the stables. For the night scene an infrared light (IR spotlight) was used. Video material was recorded on four Lacie 2big image servers. Thus there was a continuous recording of the behaviour over the whole 13 days. The video material was saved with the software "MxControlCenter". First, 6 blocks of 4 hours each, were computerised. Then the collected video footage was analysed with the evaluation software Interact 9 - Lab Suite Version 2011, Program Version 9.7.5.0, Light Version, Mangold International, Arnstorf, Germany. For evaluation behaviour parameters were divided into seven categories: locomotion behaviour, rumination, elimination behaviour, exploratory behaviour, body care behaviour, agonistic behaviour and expression behaviour. Frequencies and duration of the defined parameters have been determined and statistically analysed. Parameters of frequency: entry in milking robot, rumination, olfactory perception, defecate, urinate, scraping, grooming with tongue, focus cow does social licking, focus cow maintains social licking, aggressive focus cow, other cow aggressive against focus cow, displacement of focus cow, focus cow displaces, leg lifting, pattering back and forth, lowered head, rapid head movements, acoustic signalling, tongue rolling.

3. Statistical analysis, results and discussion

The behaviour was observed solely in the area around the milking robot see figures 2 and 3. A list with 19 behaviour parameters (different categories such as social, agonistic, aggressive, expressional, exploration or grooming behaviour) was created in the evaluation process. The observed incidences were evaluated with a new statistical hypothesis test for high-dimensional paired samples (Wörz et al., 2017). As a result, not all expected parameters occurred.

Figure 2: Automated milking system

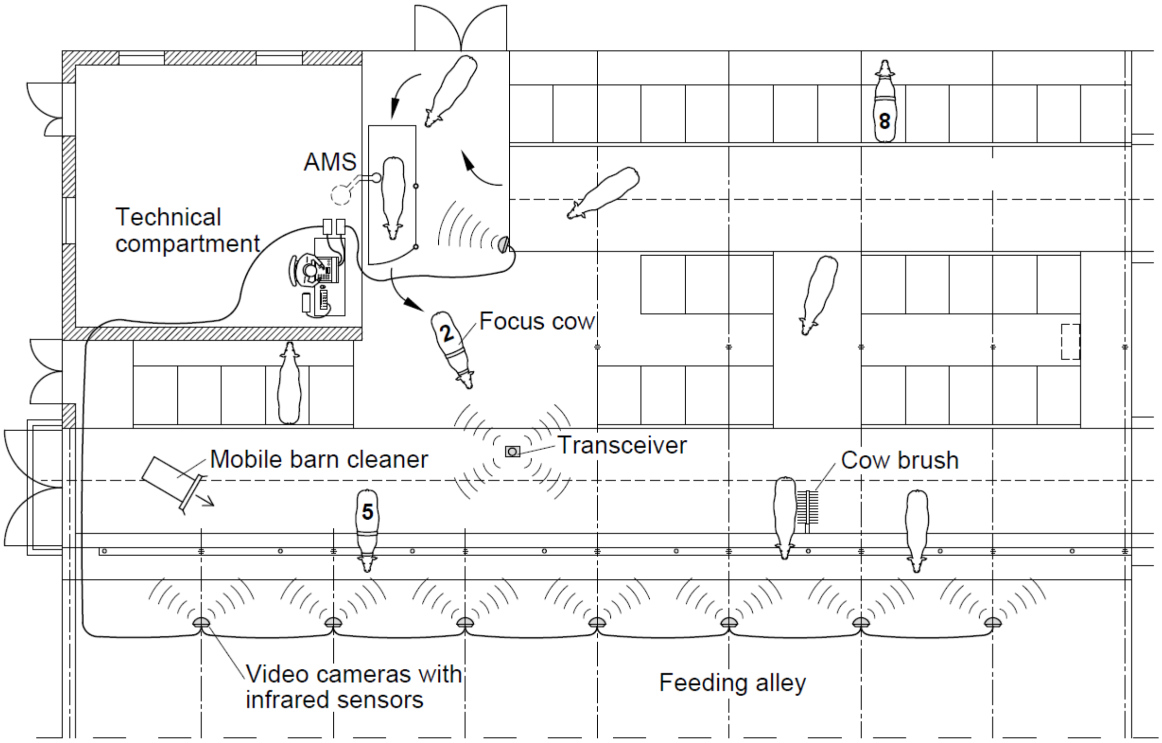

Figure 3: Layout of the stable

Locomotion, rumination and elimination behaviour tended to occur more often in the experiment. Most of the observations could be made in the field of expressional behaviour as well as agonistic behaviour and locomotion. The parameters lowered head posture and tongue rolling appeared significantly higher in the test measurement than in the basal measurement. Differences could also be deduced in the determined duration: a longer duration was measured in four parameters, a shorter duration in two compared to the basal measurement. But in summary, the statistical evaluation with ordinary statistical software packages as R could not measure significant differences between the vectorised basal and test measurements, the reason why the new statistical hypothesis test for high-dimensional data (Wörz et al., 2017) was used. Thereby, firstly the distance vector between the vectors of behavioural characteristics before the AMS and after the AMS visit with respect to the l1 vector norm ||x||1 = sum(|x|) or Manhattan norm respectively was calculated

```
 8   9   3  15  30  14  10   4   2  15   7  12   7  14   9  11  10  25  14  13   0  33   4  10  33  22   2
 0   1   2  12  21  12   8   1   0  15  10  11  19  11  36  28   1  14   9   2  12  18  85  44  12   0  16
 6  22   8   5   0   5  12   1   5   1  33  27   1   1   4  21 123  16  21  23   7  15 102   0   9   4  36
 0   0   0  14  65  52   2  19  23   5  19   0  60   0  16   3  16  70   2 102  27   0  50  13  12  13   4
21  32   4   7   0   2   0   0   0  33  67   7   6  10  83  61  21   8   0   0   0   8  19  13   6   3  41
16  12   6  26  49   2.
```

Secondly, the minima and maxima of the vectors of behavioural characteristics before the AMS visit resulting in value range intervals were identified,

```
Min: 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4  Max: 3  2  1  1  4  9  1  1  9 10  5  3  4 11 10  9  2  0.
```

Thirdly, for the vectors of behavioural characteristics before the AMS visit and for each behavioural characteristic the α-percent deviation (0 ≤ α ≤ 100) with respect to the length of the value range intervals was calculated resulting for α = 5 percent in

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0.20 0.15 0.10 0.05 0.05 0.20 0.45 0.05 0.05 0.45 0.50 0.25 0.15 0.20 0.55 0.50 0.45 0.10 0.00.
```

Fourthly, using the l_1 vector norm or Manhattan norm respectively, to each vector of behavioural characteristics before an AMS visit, the α- percent deviation environment was defined. For α = 5 percent, the α- percent deviation environment radius 4.45 was obtained. Our objective in the sequel was to verify, whether the corresponding vectors of behavioural characteristics after an AMS visit will statistically lie inside these environments or not. Thereto, a probability measure space i.e. a probability space Ω (set of all vectors of behavioural characteristics), a smallest σ-algebra Ã which yields the well-definedness of the random variables which map successively the considered vectors of behavioural characteristics before and after the AMS visit to all its components defining in combination with l_1 vector norm or Manhattan norm respectively the α- percent deviation environments and a probability measure P (binomial measure) were introduced. After defining random events involving the terms of (α = 5 %) deviations in form of open (α = 5 %) deviation l1-environments, the indicator functions of the corresponding random events are summed resulting in a random variable again, which defines the binomial measure and binomial distribution respectively. Based on our mathematical framework, the null hypothesis, which comprises the test condition that a vector of behavioural characteristics after an AMS visit lies outside the α percent deviation environment with a probability 0.5 + Δp or smaller, - 0.5 ≤ Δp ≤ 0.5, whereby Δp represents a relevant probability difference, and the alternative hypothesis, which comprises the test condition that a vector of behavioural characteristics after an AMS visit lies outside the α = 5 percent deviation environment with a probability greater than 0.5 + Δp at a significance level of 0.05 were considered. Herein, Δp is a relevant difference probability. After calculating the rejection regions by a backward calculation of max $P|H_0$ (rejection region := {c, …, n}) i.e. c = n, n – 1, …, 1 using the bisection algorithm, c = 87 and Δp = 0.04 are obtained. Thus, the rejection region is given by {87, 88, …, 141}. Now it was verified, whether the number of vectors of behavioural characteristics lying outside the (α = 5 %)-deviation environments, which equals the value 98 and is calculated from the underlying data does lie in the reject region, what is obviously true. Then, it was terminated and concluded that the power cuts statistically influence the behaviour of the milk cows of the four test farms per the behavioural changes of the underlying data with the marginal relevant probability difference of 0.04474369 with respect to the l_1 vector norm or Manhattan-norm respectively and a (α = 5 %)-deviation radius of 4.45 at a significance level of 0.05. The probability that with a probability of higher than 0.5 behavioural changes of the milk cows occur, equals only 0.05. For power and asymptotic power properties see Wörz et al., 2017.

Even though the statistical methodology was of high quality and has a very low rate of error, when considering good practice and interpretation of data, one must be aware that this study was carried out on conventional commercial farms and not under laboratory conditions. Therefore the power cut was simulated for only twelve cows for a short time. Not much data needed to be considered because only 48 animals in total were directly affected. The consequence of a real power cut would be a lot worse, as this would affect all animals of a herd and not only the focus cows. Parameters such as cortisol content, heart rate variability, milk yield and paces should be included into the statistical analysis by significant additional work in order to record individual animal reaction regarding health and stress.

4. Conclusions

The individual animal behaviour of a cow during the simulation of power blackouts is altered. However, a significant difference was only measured in two out of 19 parameters. In this study no strong statistical differences however still marginal direct and explicit stress responses caused by the simulation of the blackouts could be determined in the behaviour of the cows. Nevertheless, new questions which can be elaborated in additional studies were raised. Another study could aim to make more detailed statements about the influence of different milking times in the milking robots on the cow´s behaviour. Elaborating this is important for further development of new energy concepts in dairy milk stables. These concepts should guarantee energy distribution of the power in the dairy farms but should also ensure the well-being of the cows.

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