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Sound analysis in dairy cattle vocalisation as a potential welfare monitor

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ABSTRACT

In modern farming there is a growing demand for innovative tools gathering and analysing information concerning the herd, as well as individual animals. In Precision Livestock Farming (PLF), technology continuously measures various variables as activity, food intake or oestrus activity, thereby supporting farmers in monitoring his livestock. Sound analysis has shown to be useful as an early warning tool in pigs and it is unknown whether sound analysis can also be applied in cattle. Goal of this research was to determine whether a correlation can be found between cattle vocalisation and cattle behaviour.

The vocalisations and behaviour of Holstein Friesian cattle were observed using audio and video recordings. Four cameras and four microphones were installed at a high production dairy farm in Herwijnen, the Netherlands. Three sets (a set consisting of both a camera and a microphone) recorded dairy cattle between two and fourteen years of age, one set recorded heifers between four and ten months of age. Recordings were made for fifteen days in three consecutive weeks, ten hours per day.

Calls of cattle were traced to an individual cow and, if possible, linked with simultaneously expressed behaviour. The used ethogram consisted of six behavioural groups: lying & ruminating, feeding related behaviour, social interaction, sexual related behaviour, stress related behaviour and remaining behaviour. Lying & ruminating was a separate class since this behaviour expresses the needs of a cow. The maximum frequency in Hertz (Hz) of each call was determined. Statistical analysis showed a significant difference between the mean maximum frequency (Hz) of calls during lying & ruminating and calls recorded during other behaviours (83 ± 4.3 Hz versus 298 ± 8.0 Hz; $p < 0.05$). Calls by adult dairy cattle had a significantly lower maximum frequency (Hz) than calls by heifers. (332.6 ± 0.2 Hz versus 218.5 Hz ± 0.3 Hz; $p < 0.05$).

This study may provide a foothold towards the use of sound analysis as a tool for dairy cattle management. If calls by cattle can be used to monitor welfare, dairy farmers can be alerted when cattle welfare is decreasing.

1. Introduction

The growing world population results in an increasing demand for meat and other livestock products (Delgado, 2003; Pingali, 2007). To meet this demand, livestock farming is scaling up in European and BRIC countries (Brazil, Russia, India and China (Helfand and Levine, 2004; Henderson, 2011)). The ambition of modern livestock farming is to breed and maintain a productive and healthy livestock. In the past, livestock management was based on the experience of the farmer and individual animal observations by the farmer. Due to the growing number of animals per farm the farmer–cattle interaction is decreasing. Automatic animal monitoring can support the farmer in achieving and maintaining farm sustainability (Lokhorst et al., 2010; Banhazi et al., 2012).

Precision Livestock Farming (PLF) provides a tool to support the farmer in managing livestock when farmer-cattle interactions are decreased. PLF can combine continuously measured information with automated software tools, which can be used to control, monitor and model the health and behaviour of animals and their biological responses such as milk yield (Tullo et al., 2013). Automated software tools are able to detect behavioural changes early, which may lead to early intervention, possibly reducing veterinary costs in case of disease (Banhazi and Black, 2009).

Monitoring by PLF can be based upon variables such as weight, activity or vocalisation. The analysis of vocalisations is a promising tool for the interpretation of behaviour, health state and well-being of animals (Manteuffel et al., 2004). Further development of vocal analysis may provide a low cost tool for livestock management.

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Vocal analysis is well studied in pigs. It has been shown that the stress call from pigs is a rather sustained cry with high frequency bands. The relation of vocalisation to stress has been verified in various experiments where the general situations, aversive behaviour, stress hormones and brain activity were recorded parallel to the acoustic utterance (Kanitz et al., 1999; Otten et al., 2001; Tuchscherer et al., 2002). The association of distinct vocalisations with specific behaviour can give the possibility to recognize the state of individual animals or the whole herd by using sound analysis. Vandermeulen and co-workers found a 80% correlation between video and sound analysis recorded in a piggery (Vandermeulen et al., 2013a). This finding in pigs raises the question whether call recognition may also be applied in cattle, and hence, dairy farms. Therefore, the aim of this study was to determine whether a correlation can be found between cattle vocalisation and cattle behaviour.

2. Materials and methods

2.1. Animals and housing

The experiment was conducted between the 24th of February and the 28th of March 2014 on a dairy farm located in Herwijnen, the Netherlands. In this study, two groups of Holstein Friesian cattle were used. One group consisted of dairy cattle ($N = 95$) between two and fourteen years old. The other group contained heifers ($N = 46$) between four and ten months of age. Both groups were housed in the same building. Dairy cattle were housed on one side of the barn in a loose housing system (37.2×28.97 m) with slatted floors and 121 cubicles. The cubicles were 2.50 m long, with a compost bedding of 0.20 m thick. Dairy cattle were milked at 7:00 and 19:00 each day using a herringbone parlour, were fed *ad libitum* roughage and individual quantities of concentrates. Heifers were housed on the other side of the barn, in a loose housing system (9.5×31.2 m) with slatted floors and 51 cubicles. The cubicles were 2.20 m long; no bedding material was provided. *Ad libitum* roughage was provided twice a day, supplemented with concentrates.

2.2. Experiment and data collecting

The study consisted of a five day pilot study and fifteen days of audio and video recordings in three consecutive weeks, ten hours per day (07:00–17:00 h). Recordings were made using four side view cameras (M10, Axis Communications AB, Lund, Sweden). Cameras were installed between 2.50 and 3.00 m above ground level. Videos were recorded in .AVI 1.0 megapixel with 30 frames per second, a frame width of 1920 pixels and a frame height of 1080 pixels. Light was provided by daylight. Light intensity of 1.5 lux was sufficient for colour recordings which is easily reached by daylight.

Sound was recorded by four omnidirectional microphones (MKE 2, Sennheiser, Wedemark, Germany). Microphones were able to detect sound between 20 and 20.000 Hz and were positioned near the cameras at least 2.50 m above ground. Three sets of cameras and microphones recorded dairy cattle, one set recorded heifers (Fig. 2.1). Recordings were processed and synchronized with Media Recorder 2.5 (Noldus Information Technology) on a desktop computer (Intel Xeon Processor E5-1620, Quad core, 3.60 GHz Turbo. 8GB DDR3. 1TB HDD).

2.3. Video and sound analysis

The recorded video material was separated into video (.AVI) and sound (.WAV, Mono) recordings using PAZERA audio extractor. Sound recordings had to be amplified due to limited volume. Volume of recordings was amplified with 300% using PAZERA audio

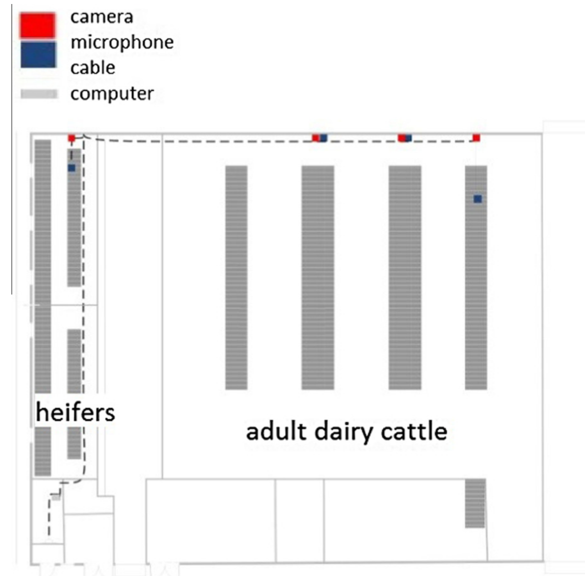

Fig. 2.1. Wiring diagram of the experimental setting.

extractor. Recordings of four different cameras and microphones were analysed simultaneously using the observer XT 11.5 (Noldus Information Technology). During the pilot week, manual detection was practiced under the supervision of cattle behaviour experts. After this, manual detection was performed by the researches themselves. Calls were manually detected using a start–stop behavioural coding scheme. Calls which were audible but not visibly attributable to a certain individual on video were not analysed. Calls which were visibly attributable to an individual were labelled in time. The simultaneously performed behaviour was described using an ethogram consisting the six behavioural groups: 'lying & ruminating', 'feeding related', 'social interaction', 'sexual behaviour', 'stress related behaviour' and 'remaining behaviour' (Table 2.1). Studies by Metz (1985) and Munksgaard et al. (2005) indicate that both the behaviours lying and ruminating are essential needs in the daily rhythm of a dairy cow. Therefore, the combination of lying and ruminating was used as a distinct behavioural group.

Maximum frequency (Hz) of each call was determined using UltraVox 3.0 (Noldus Information Technology). Each call was analysed using the .WAV file. Using the Call Labelling function of UltraVox 3.0, the maximum frequency (Hz) of each individual call was analysed in a spectrogram, logarithmically amplified to 30 dB or 45 dB depending on the volume of the call. Selected time was set on 15.0 s with the maximum density set at its highest possible SFT (Short-time Fourier Transform) window length (2048). The pitch reduction was set at 1.0 and the maximum frequency was set at 5000 Hz. UltraVox 3.0 also had the possibility to determine the average amplitude of each call. In general, the average amplitude was influenced by distance between the cow and the microphone. The average amplitude of calls was also found to be directly disturbed by sounds of other activities in the farm, as the trespassing of a tractor. Mean maximum frequency was not affected by these other sounds and therefore only maximum frequency was not taken into account during analysis. Finally the correlation between the maximum frequency (Hz) of calls and the behavioural groups was statistically tested.

2.4. Statistical calculation

Analysis was performed using SPSS Statistics 21.0 for Windows. Because multiple measurements were conducted per camera in