More than a fencing system? Testing the validity of virtual fencing collars for animal monitoring on pasture

Hamidi, D.[1], Komainda, M.[1], Grinnell, N.[1], Riesch, F. [1,2], Horn, J.[1], Hamidi, M. [3], Traulsen, I.[4], Isselstein, J.[1,2]

[1]University of Goettingen, Department of Crop Sciences, Grassland Science, Göttingen, Germany [2]Centre for Biodiversity and Sustainable Land Use, University of Goettingen, Göttingen, Germany, [3]Heisterholz-Mühle 1, 30916 Isernhagen, Germany, [4]University of Goettingen, Department of Animal Sciences, Göttingen, Germany

Key words: Precision livestock farming; Animal monitoring; Animal welfare; Pasture management

Abstract
High labour requirements for fencing and animal monitoring appear to be general obstacles for the wider use of pastureland for grazing livestock. Virtual fencing (VF) enables a less laborious pasture management. Fence lines can be easily drawn and moved using GPS data. The advantages of VF for reducing the labour inherent to controlled grazing management are obvious. Potential additional animal monitoring opportunities arising from such a VF system that uses real-time GPS data have not yet been studied. Lying is seen as an indicator for assessing comfort or restlessness of cattle. Therefore, we focus on lying behavior in this evaluation. Based on data from conventional GPS collars, lying and standing often cannot be distinguished. The VF collars (® Nofence, AS, Batnfjordsøra Norway) used in this study detect low movement via an integrated accelerometer and then send the same GPS position during this time of low movement, in order to save battery life. We tested whether this battery life save function could be suitable for the detection of lying behavior. To address this question in a two-step-approach, we first compared observational data with IceTag pedometer (IceRobotics Ltd. Edinburgh, Scotland) data. In the second step, the pedometer data were compared to VF collar data via a confusion matrix. With 93% precision, 89% accuracy and 83% recall in this second step, the use of the VF collars can be recommended for a valid measure of lying behavior monitoring on pasture, which would be an added benefit to VF technology.

Introduction
The ability to perform natural behaviors is one of the three overarching dimensions of animal welfare (Fraser et al. 1997), which are also included in the World Animal Health Organisation's definition of animal welfare. On pasture, cattle are able to pursue their natural behaviors e.g. grazing, lying and social interaction. Barriers to the implementation of grazing management include the high labour and time costs of ground-based-fencing and monitoring animals on pasture. The use of virtual fencing (VF) collars has the potential to provide a significant simplification of fencing, especially in the area of more complex grazing systems, such as rotational grazing, which is particularly time-consuming and promises optimal utilization of the available grassland. Fence lines can be easily drawn and moved with the help of GPS data. The collared animals recognize the positions of the fence via an acoustic signal (Campbell et al., 2017), which precedes a possible electric pulse that is applied if the animal does not stop or turn back at the VF line (conditional learning). Conventional GPS collars are commonly used to monitor walking distances and the distribution of animals on pasture (e.g. Ganskopp et al. 2001; Hamidi et al. 2021). To our knowledge, there is, so far, no robust data on how and whether the real-time GPS data collected by the VF collars can be used to improve animal monitoring on pasture. In order to clarify this question, a rotational grazing trial in summer 2021 was used to analyse lying behaviour detection with the Nofence© VF technology. We expected that the VF collars would overestimate lying time compared to IceTag pedometers due to confusion of lying and standing.

Methods
The trial was conducted on the experimental farm of the University of Göttingen in Relliehausen, Solling Uplands, Lower Saxony, Germany (51°46'48''N 9°42'15''E). 32 Fleckvieh heifers, equally divided in four groups, were equipped with VF collars (® Nofence, AS, Batnfjordsøra Norway) (Figure 1) and IceTag

pedometers (IceRobotics Ltd. Edinburgh, Scotland). Each group was assigned to one 2-ha pasture divided into four rotational grazing paddocks (0.5 ha each).

Validation step one: On the 25th, 26th, 27th, 30th and 31st of August and the 1st of September approximately two hours of continuous animal observation (seven focus animals) per day was performed using the application ‘Observasjonslogger’ by Morten Sickel. Lying time observed and pedometer-measured lying time were compared in a total number of 4,649 data points (each point refers to one minute). A confusion matrix was used to validate measured lying time from the pedometers against the manually recorded lying time during observation. Data were categorized beforehand into two classes of lying (yes/no) on a minute basis. Data recorded by pedometers that were shorter than one minute were excluded, as these were likely caused by hind leg movements of standing animals (Ungar et al. 2018). Adjacent cells to the minimum of 60 second bouts were added to the > 60 second lying events and categorized as yes. The pedometer data was classified as prediction and the observed data was classified as reference (truth). Then we used a confusion matrix, which is a special kind of a contingency table with two dimensions (reference and prediction), to determine the fit of the VF technology to observed data. As quality measures of the confusion matrix, we used (i) the accuracy, which indicates the percentage of correctly made predictions of a model, (ii) the precision, which indicates the ratio of correctly predicted true positives by the model and (iii) the recall, which is a metric that describes how well the model is able to identify positive outcomes.

Validation step two: 24-h-data of the VF collars and the pedometers between Aug. 27-Sept. 5, 2021, were used to compare VF collar-measured lying time with pedometer-measured lying time (in total 195,354 data points). The integrated accelerometer in the VF collars recorded data, which cannot be output at the moment due to the high energy costs. However, the accelerometer controls a battery save function by detecting low movements of the animals in a moving average of three minutes (the underlying algorithm of this battery save function is confidential, Nofence®). As a result, the same GPS position is transmitted when the animal is assumed to be lying down. Therefore, collar measured lying time is defined as at least two consecutive minutes of the same GPS position. Both data sets were again compared using a confusion matrix, with pedometer-measured lying time classified as reference and collar-measured lying time as prediction. Ruuska et al. (2018) suggested the use of a confusion matrix as a robust and stringent assessment of validity based on their study that compared three different validation methods for an automated system measuring cattle feeding behavior.

Results and Discussion

The validation of the pedometers against observational data in the present study yielded valid results (Table 1).Likewise, very good values for the agreement of the VF collars with the previously validated pedometers were obtained. The lying times of the animals are underestimated rather than overestimated by the VF collars compared to the lying times from the pedometers, which is visible due to the higher value for precision than for recall (Table 1). This was unexpected as other studies with conventional GPS collars have tended to overestimate lying times (due to the inability to separate standing from lying) (Ungar et al. 2011). Therefore, conventional GPS collars were not recommended for the detection of lying. The reason for this apparent contradiction could be the different ways of recording the movement and the absence of movement, respectively. The pedometer detects lying due to the hind leg movements in a very sensitive way (visible in excluded < 1-minute-lying-events). The VF collar detects lying via the moving average of less movement during the last three minutes. Based on these different ways to detect lying, it could be assumed that pedometer-detected lying is slightly overestimated and VF collar-detected lying is slightly underestimated. However, the results appear to be promising, so that the VF collars can be recommended for valid animal monitoring on pasture. A major advantage over the pedometer is the clear localization of the animals through the collar data. Location systems can give, among others, an indication of land/pasture/range use, behavioral patterns and social interaction of animals (Hofstra et al., 2022). Ungar et al. (2011) suggest to use GPS collar in conjunction with pedometers for best animal activity measurement.

Table 1: Results of the confusion matrices

	Precision	**Accuracy**	**Recall**
Step one (observation - pedometer)	98 %	97 %	92 %
Step two (pedometer -	93 %	89 %	83 %

virtual fencing collar)			

Consequently, the integrated accelerometer of the VF collar which controls the battery life save function has made the difference to conventionally used GPS collars for detecting lying. The full potential of the accelerometer for evaluating different behaviors cannot be achieved so far, due to high energy costs for data export as was also described by Riaboff et al. (2022). However, our approach to use the battery life save function (which sends the same GPS position during low movement) to detect lying behavior appears to be an additional aspect to the known features of GPS tracking such as detecting walking distances and animal location. Our convincing results indicate VF could be used as more than simply a fencing system.

Conclusions and Implications

The use of VF technology not only facilitates “fenceless” fencing, but also offers the possibility of continuous animal monitoring based on movement information obtained from real-time GPS data. Beyond just monitoring lying time, each individual animal can be precisely located, which opens up additional monitoring possibilities, e.g. detection of sick animals through behavioural deviations such as segregation from the group. Energy efficiency is expected to improve further so that the full potential of the integrated accelerometer can eventually be utilized in future.

Acknowledgements

We are grateful to Barbara Hohlmann, Laura Ahlers, Nele Busse and many others for supporting the field experimentation. Thanks to Knut Salzmann and Christina Behling for supervising the livestock management and for competent and patient handling of the animals. We thank Marten Steinke who provided the grazing livestock, the experimental area and provided resources for the general maintenance of the experiment. This study was supported by the Federal Ministry of Education and Research under grant number [031B0734A] as part of the project “GreenGrass”.

References

Campbell, D.L.M., Lea, J.M., Farrer, WJ, Haynes, S.J. and Lee, C. 2017. Tech-Savvy Beef Cattle? How Heifers Respond to Moving Virtual Fence Lines. *Animals*., 18:72.

Fraser, D., Weary, D. M., Pajor, E. A., and Milligan, B. N. 1997. A scientific conception of animal welfare that reflects ethical concerns. *Animal welfare.*, 6: 187-205.

Ganskopp D. 200. Manipulating cattle distribution with salt and water in large arid-land pastures: a GPS/GIS assessment. *Applied Animal Behaviour Science*., 73:251-62.

Hamidi, D., Komainda, M., Tonn, B., Harbers, J., Grinnell, N. and Isselstein, J. 2021: The Effect of Grazing Intensity and Sward Heterogeneity on the Movement Behavior of Suckler Cows on Semi-Natural Grassland. *Frontiers in Veterinary Science.* 8: 639096.

Hofstra, G., Roelofs, J. B., Rutter, S. M., Van Erp-van der Kooij, E. and de Vlieg, J. 2022. Mapping Welfare: Location Determining Techniques and their potential for managing cattle welfare-a review. *Dairy.*, 3: 776-788.

Riaboff, L., Shallo, L., Smeaton, A. F., Couvreur, S., Madouasse, A. and Keane, M. T. 2022. Predicting livestock behaviour using accelerometers: A systematic review of processing techniques for ruminant behaviour prediction from raw accelerometer data., *Computers and Electronics in Agriculture.* 192: 106610.

Ruuska, S., Hämäläinen, W., Kajava, S., Mughal, M., Matilainen, P. and Mononen, J. 2018. Evaluation of the confusion matrix method in the validation of an automated system for measuring feeding behaviour of cattle, *Behavioural Processes:* 148: 56-62,

Trenel, P., Jensen, M. B., Decker, E. L. and Skjoth, F. 2009. Technical note: quantifying and characterizing behavior in dairy calves using the IceTag automatic recording device. *Journal of Dairy Science.*, 92: 3397-3401.

Ungar, E. D., Schoenbaum, I., Henkin, Z., Dolev, A., Yehuda, Y. and Brosh, A. 2011. Inference of the Activity Timeline of Cattle Foraging on a Mediterranean Woodland Using GPS and Pedometry. *Sensors.*, 11: 362-383.

Ungar, E.D., Nevo, Y., Baram, H. and Arieli, A. 2018. Evaluation of the IceTag leg sensor and its derivative models to predict behaviour, using beef cattle on rangeland, *Journal of Neuroscience Methods.*, 300: 127-137.