Validation of Nedap Smarttag Leg and Neck to assess behavioural activity level in dairy cattle

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Abstract

The last decades, the number of dairy cows per farm has increased and the time spent on individual cows by the farmer has been reduced. To help the farmer detect changes in activity of cows associated with health issues, activity monitoring systems are being developed. The systems can help with daily farm management decisions, thus increasing farm profitability. Besides this economic benefit there is a social benefit: farmers highly value the herd being under continuous surveillance. Nedap Livestock Management (the Netherlands) introduced a leg activity meter and a neck activity collar: Smarttag Leg and Smarttag Neck. By registering activity of individual cows, the Smarttags help the farmer to detect oestrus and give alerts when activity deviates from normal patterns. The objective of this study was to validate results from the Smarttag Leg and Smarttag Neck, by comparing them with results from live observations and video recordings. Eight lactating dairy cows were observed for 22.5 hours each and video recordings were made of six dry dairy cows for 5.5 hours each. Lying, standing, walking, eating, standing up and ruminating were recorded. Data were compared with results from the Smarttag Leg and Smarttag Neck by calculating Cohen's Kappa, univariate linear regression analysis, Pearson's correlation and concordance correlation coefficient. Visual observations and video observations show correlation coefficients of >0.85 with the results of the Smarttags for all behaviours except walking. Correlations between visual and video observations and Smarttag results for walking were 0.45 and 0.50 respectively, possibly due to low incidence and difficulties in observing this behaviour. These results provide strong evidence that the Smarttag Leg and Smarttag Neck can reliably be used to monitor specific behaviours. With this system, the farmer can monitor behaviour and detect behavioural changes.

Keywords: dairy cows, pedometers, locomotion, lying behaviour, sensor technology

1. Introduction

In time the number of cows per dairy farm has increased and, as a consequence, the time spent on individual cows has been reduced. Driven by reducing workload and increasing efficiency and profitability, interest of farmers and industry for precision dairy farming has increased (Bikker, 2014). To support decision making and improve farm productivity and profitability, precision dairy farming technologies are developed (Asseldonk *et al.,* 1999). An example is the development of oestrus detection tools. Several studies (Hockey *et al.,* 2010; Müller *et al.,* 2003*;* Roelofs *et al.,* 2005) showed that pedometers and neck mounted collars can be used to predict the time of ovulation, showing better results than visual observation (Roelofs and Van Erp-Van der Kooij, 2015) and increasing pregnancy rates (Roelofs, 2013).

Changes in behavioural activity of farm animals are widely used as an indicator of welfare, health and comfort (Mattachini *et al.,* 2013; Müller *et al.,* 2003). To help the farmer detect changes in activity, activity monitoring systems are developed. The systems can help improve the daily farm management decisions and, thus, farm profitability. In addition to this, farmers highly value the knowledge that the herd is under continuous surveillance (Kamphuis, 2015).

Nedap Livestock Management (the Netherlands) introduced a leg activity meter and a neck activity collar: Nedap Smarttag Leg and Nedap Smarttag Neck. These systems measure activity of cows

continuously and help the farmer to detect oestrus and abnormalities in behaviour that may refer to health problems. Besides number of steps, the Nedap Smarttag Leg activity meters measure walking, standing, lying time and stand-ups. Activity recording based on accelerometers is commonly used and is easy to apply, detecting quantity and intensity of activities (Patterson *et al.,* 1993; Tyron, 1991). Apart from oestrus detection, they can be used for health indication. The (increased or decreased) duration and frequency of lying and standing time is directly related to clinical health, especially to identify lameness (Chapinal *et al.,* 2010; Garbarino *et al.,* 2004; Juarez *et al.,* 2003). Cow comfort can be indicated by lying behaviour (Haley *et al.,* 2000). Behaviours are interconnected: if standing and walking time decrease, for example by lameness, lying time will increase. The Smarttag Neck measures eating and resting, as well as rumination time. These behaviours can provide relevant information on food and water intake (Chapinal *et al.,* 2007) and are important in understanding the nutrition, production, social welfare, and overall health of dairy cattle (Krawczell, 2012). On average, a dairy cow ruminates about 35-40% of the day, mostly when lying down but sometimes also when standing, walking or during other activities (Bar *et al.,* 2010; Beauchemin, 1991). Time spent ruminating is an important health indicator, with stress, anxiety or disease decreasing rumination time (Beauchemin, 1991; Bristow *et al.,* 2007; Büchel *et al.,* 2014; Hansen *et al.,* 2003; Herskin *et al.,* 2004; Schirmann *et al.,* 2009; Welch, 1982). Digestibility, forage quality, NDF intake and dietary composition also influence rumination (Beauchemin, 1991; Welch *et al.,* 1970).
The overall objective of this study was to validate the measures generated by the Nedap Smarttag Leg and Nedap Smarttag Neck systems, by comparing these results with measures from live observations and time-lapse video recording.

2. Material and methods

2.1 Animals, feed and housing

To validate results of the Nedap Smarttag Leg and Nedap Smarttag Neck systems, cows were observed visually and using video recordings at a dairy farm in the Netherlands. Visual data were collected from eight lactating Holstein Friesian cows, and video data from six dry Holstein-Friesian cows. Cows were housed in a free stall with slatted floor and cubicles, with *ad libitum* access to roughage and water.

2.2 Measurement of activity

The cows were equipped with activity meters on the front leg and on the neck (Smarttag Leg and Smarttag Neck, Nedap Livestock Management, Groenlo, The Netherlands). Leg meters measured number of steps, walking, lying, standing time and number of stand-ups. Neck collars measured eating, resting and ruminating time. Smarttags have a G-sensor which measures accelerated movements in a particular direction, based on a three-dimensional accelerometer. The tags distinguish in motions for- and backwards, left and right and up and down.

2.3 Observation of behaviour

Five trained observers independently recorded behaviour of eight cows by direct visual observation for a period of three days, eight hours/day. All behaviours measured by the activity meters were recorded. Also the behaviour of six cows was recorded with a webcam (Logitech Webcame Software Inc.), resolution 1290×702 and 15 frames/second, for 12 hours/cow. Camera images were imported to a computer and observed and analysed by two trained observers with ObserverXT12 software (Noldus 2015). All behaviours measured by the activity meters were recorded. Smarttag data were recorded in 15-minute periods.

2.4 Statistics

Results from video and behavioural observations were converted to behaviours per quarter, corresponding to the data from the Smarttags. This was done by finding the main behaviour per minute, and converting this to behaviours per quarter. Data were analysed using SPSS (SPSS21.0.0.0, IBM Company Inc., USA). To evaluate the correspondence between individual observers and between visual or video observations and activity monitor sensors recordings, measures of interrater agreement (Cohen's Kappa statistic), univariate linear regression analysis and Pearson's correlation with concordance correlation analysis (CCC) were used. Kappa is expressed as a number between zero and one, and validated according to Landis and Koch (1977): poor (<0.00), slight (0.00-0.20), fair (0.21-0.40), moderate (0.41-0.60), substantial (0.61-0.80), and almost perfect (0.81-1.00). Pearson's correlation and CCC were determined to the criteria of Hinkle *et al.* (2003): negligible (0.00-0.30), low (0.30-0.50), moderate (0.50-0.70), high (0.70-0.90), and very high (0.90-1.00).

3. Results

Visual observations of eight cows for 180 hours were available, and a total of 720×15 minutes of data (appr. 90 quarters/cow) for both sensors. Video data of six cows for 63 hours were available, 252 quarters of data for the Smarttag Leg and 108 quarters for the Smarttag Neck.

Table 1 shows the results of the correlation analyses: the Kappa value, the univariate linear regression analysis and the concordance correlation coefficients, per Smarttag.

The kappa values for resting, eating and ruminating (Smarttag Neck) were fair to moderate. For the Smarttag Neck, the kappa values for walking were fair, for standing moderate, for lying and stand-ups substantial to almost perfect. Kappa for the agreement of observers showed an almost perfect agreement. In the linear regression analysis, no effect of observers was found. For the visual and video observations, R^2 of resting, eating and ruminating (Smarttag Neck) showed high correlations, and high correlations for lying and standing, a low to moderate correlation for stand-

Table 1. Statistical results of Kappa, univariate linear regression analyse and concordance correlation coefficient for visual (Exp 1.) and video (Exp. 2) observations.[1]

Tag	Behaviour		K	R	C	RC	C_b	CCC
Smarttag Neck	Eating	Exp. 1	0.403	0.801	0.585	0.930	0.998	0.892
		Exp. 2	0.562	0.940	0.315	0.982	0.999	0.969
	Ruminating	Exp. 1	0.470	0.884	0.867	0.920	0.997	0.937
		Exp. 2	0.543	0.807	0.807	0.871	0.996	0.895
	Resting	Exp. 1	0.331	0.803	0.037	0.881	0.994	0.890
		Exp. 2	0.489	0.820	0.537	0.906	1.000	0.905
Smarttag Leg	Lying	Exp. 1	0.838	0.986	0.059	0.992	1.000	0.993
		Exp. 2	0.748	0.940	-0.004	0.962	0.999	0.969
	Standing	Exp. 1	0.560	0.981	0.063	0.960	0.999	0.989
		Exp. 2	0.526	0.930	0.611	0.950	0.999	0.963
	Walking	Exp. 1	0.258	0.256	0.321	0.624	0.901	0.445
		Exp. 2	0.372	0.265	0.179	0.430	0.977	0.503
	Stand-Up	Exp. 1	0.851	0.726	0.015	0.870	1.000	0.851
		Exp. 2	0.817	0.413	0.044	0.866	0.612	0.953

[1] K=Kappa; R^2=Pearson's correlation; C=Constante; RC=Regression coefficient; C_b=Correlation Bias; CCC=Concordance correlation coefficient.

ups and very low correlations for walking (Smarttag Leg) were found. Gradients are mostly ~1 (very high agreement). The concordance correlation coefficient (CCC) was high or very high for all behaviours except walking.

4. Discussion and conclusions

Data of cow behaviour is commonly recorded on video for subsequent analysis, or collected directly by a human observer (O'Driscoll, 2008), which is time consuming, labour intensive, and one may influence behaviour while observing (Krawczell, 2012; Müller, 2003). Only one cow can be observed simultaneously when observing visually (Schirmann, 2009). In this study, one cow was observed at the time. Inter-observer differences can be a disadvantage when more than one observer is used (Martin and Bateson, 1993). In this study, observers studied different cows and no effect of observer was found. Videos were analysed by two researcher. To check for reliability, both researchers analysed two identical videos of two cows, one hour per cow. This showed an almost perfect agreement.
Müller *et al.* (2003) and Munksgaard *et al.* (2006) reported in their study high levels of correspondence between video recording and automatic devices when considering the total duration of behavioural activities. The advantages of video recording as a control to validation studies are that video can be stopped, rewinded and showed slowly so behaviours could be observed easier and reassessed. The camera was placed above the cows, this was an excellent position for all behaviours except ruminating. Most cows ruminate while lying down (Beauchemin, 1991), which was difficult to see. Bikker *et al.* (2014) and Beauchemin *et al.* (1989) found a lower correlation between visual and sensor observation for eating than for ruminating, similar to our findings. However, this is not found in the CCC. Eating shows a higher correlating than ruminating in the video analysis. It was easier to see a cow eating on video than with live observations. Ruminating was always difficult to observe. A side-effect is the tuning of the Smarttag Neck: short periods of resting during ruminating are measured as ruminating, while observers record this as resting. Bikker *et al.* (2014) present in their study the evaluation of a resting sensor with a high correlation (R^1=0.98). We did not find such high correlations. Resting while lying was difficult to spot. Another explanation for the lower result is that we recorded head movements (head bumping, grooming, scratching) as resting, while the Smarttag Neck records it as remaining behaviour.
Observed lying behaviour corresponds almost perfectly with the Smarttag Leg results. Cows lie 12-14 hours/day (Fregonesi *et al.,* 2007; Van't Hoff, 2010). Those lying bouts are easy to observe. Mattachini *et al.* (2013) and O'Driscoll (2008) showed in their study similar results. Standing measured by the Smarttag Leg shows also good results. Walking is a difficult behaviour to measure and the results affirm this. A standing cow may make sporadic movements such as short stops or sudden direction changes, without having ended the sequence of body movements (Trénel *et al.,* 2009), for example to change the eating place. This behaviour was not classified by the observers, while it seems that the Smarttag Leg does record this. Kajava *et al.* (2014) also concluded that lying and standing behaviour have a high agreement (R^2=0.99) and walking a lower agreement (R^2=0.69). When short movements of the leg were added to the walking observations, agreement was higher (R^2=0,89). Another explanation for the difference in standing and walking time is lameness. When the leg equipped with the Smarttag Leg is painful, the cow will stand less on this leg, even lifting it up or putting it in a different direction. Smarttag Leg sensors record this differently than the observers. Furthermore, lameness can influence walking behaviour, putting more pressure on the non-lame leg or switching her legs more quickly (Hassal *et al.*, 1993).
Results for stand-ups were corrected, because of a time lag in the Smarttag results. The agreement is almost perfect, but the gradient is 0.73. This shows that the number of stand-ups measured with the Smarttag Leg was correct, but the timing was incorrect.
We conclude that the Nedap Smarttag Leg and Nedap Smarttag Neck are useful systems to help the farmer monitor behaviour and detect behavioural changes in cattle.

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