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Validation of an automated system for monitoring water intake and drinking behaviour in dairy calves

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Abstract

The provision of palatable drinking water *ad libitum* for cattle is often neglected on farm and is considered difficult and impractical to monitor, particularly on an individual animal basis. The objective of this study was to validate an automated system for monitoring individual water intake and drinking behaviour of dairy calves. Nineteen dairy calves were observed over five days for eight hours/day. Calves were individually identified as they visited a water trough within a narrow chute where the number and duration of visits were recorded using an overhead photoelectric sensor, and water intake was recorded using a flow meter. Data from the automated system were compared to behavioural observations from video recordings across the same time period. The automated system was highly correlated with behavioural observations for both the number of visits (R^2=0.96, P<0.001) and visit durations (R^2=0.94, P<0.001), but showed no correlation for water intake (R^2=0.01, P>0.1). This system could be used as a reliable automated method for recording drinking behaviour in terms of the number and duration of visits. However, alternative systems for measuring water intake need to be investigated and incorporated into the automated system. This information could be used to investigate a number of questions regarding water use and quality, and their effects on calf health and welfare and could be integrated into other automated systems used on farm for daily animal monitoring.

Keywords: water intake; drinking behaviour; dairy calves; automated monitoring

Introduction

Although water is acknowledged as an essential requirement for animals (Drackley 2008), compared to other essential nutrients (carbohydrates, fats, proteins, minerals and vitamins), its provision and quality are often neglected on farm (Beede 2005). Previous studies have shown that for adult dairy cattle, partial water deprivation results in reduced feed intake and milk production (Little et al. 1978; Little et al. 1980), behavioural problems such as increased aggression (Little et al. 1980), physiological changes (Hogan et al. 2007), and altered urine and faeces concentrations (Hogan et al. 2007). Compared to adult cattle, few studies have been undertaken to investigate water intake in calves.

Traditionally, as with feeding behaviour, it is common for drinking behaviour to be monitored manually from live observations or video recordings (Huzzey et al. 2005; Mitlohner et al. 2001), and intake to be monitored by measuring residuals (Morris et al. 2010). However, these methods are often labour intensive, difficult and impractical to conduct, particularly in order to monitor individual animals. Previous research using these manual methods has often been carried out using animals housed in individual pens, tie stalls or trained to access purpose-built feeding bins, and may not be representative of animals that are group housed (Chapinal et al. 2007; Chizzotti et al. 2015). The development of an automated water system that can reliably monitor water intake and drinking behaviour would provide an alternative to the labour-intensive methods which are currently used, and could also enable monitoring of animals group-housed or managed on pasture. There has been an increasing reliance on automated systems on farm in response to the increasing need to reduce labour costs, increasing herd sizes, and fewer experienced stockpeople in the industry. An automated system that could provide information regarding water intake, integrated with other automated data collected on farm could allow for daily monitoring of animal health and welfare.

Research is required to investigate the drinking behaviour of calves (e.g., at what age they begin to consume water, number of visits to the trough, and water intake) to determine water requirements and the effects of water intake on calf health, welfare and productivity. The aim of this study was to validate the use of an automated system capable of monitoring individual water intake and drinking behaviour of dairy calves. The study was part of a larger project investigating automated methods for early disease detection.

Materials and methods

All animal procedures were approved by the University of Waikato Animal Ethics Committee under the New Zealand Animal Welfare Act 1999 (Protocol #985).

Animals & experimental design

The study was undertaken at the Tokanui research farm, AgResearch Ltd, Te Awamutu, New Zealand, between July and October 2016. Data from 19 (managed in a group of 35 calves) mix-breed heifer calves (average 20 days old), were obtained over five days for eight hours/day (00:00-04:00h and 20:00-24:00h). Calves were housed in a barn in a pen (7.5x14.0 m) constructed on a dirt floor with walls on all four sides. Within the pen, an area (100 m^2) of woodchip (25 cm deep) was provided as bedding material. Calves were fed using two automated calf feeders (RFID Calf Feeder, A&D Reid, Temuka, New Zealand) and provided access *ad libitum* to meal (Superior, OSP Stockfeeds, Auckland, New Zealand), water and straw.

Automated water system

The automated system consisted of a water trough (10 L) that was positioned inside a narrow chute (0.4x1.2 m), designed to allow one animal at a time to enter. As individuals entered the chute they were identified using radio frequency identification (RFID) ear tags and an RFID reader (G03121, Gallagher, Hamilton, New Zealand) attached to the side of the chute. The automated system determined the number and duration of visits to the trough based on the beam from an overhead photoelectric sensor (WTB27-3S1511, SICK, Germany) being broken and then reconnected as the calf entered and backed out of the chute. A flow meter (SPX-075, Seametrics, USA) was connected to the trough which recorded water intake during each visit.

Behavioural observations

Behaviour at the water trough was recorded continuously in real time (30 frames per second) using security cameras (DS-2CD2332-1, Hikvision, China) secured to the ceiling of the calf barn at a height of 2 m above the ground. Infrared lights built in to the cameras allowed behavioural observations to be carried out at night without affecting the calves' behaviour. Video footage was analysed continuously for each animal to investigate water intake and drinking behaviour including visit frequency and duration. The start of a visit to the water trough was defined as being when the poll of the calf's head moved in front of the overhead sensor. The end of a visit to the water trough was defined as being when the calf moved backward such that its entire body was situated behind the overhead sensor. A drinking event was defined as being when the calf's head was situated over the water trough and the water was seen to move. This could not provide information regarding the volume of water the calf had consumed during a given visit; but it was used as an indicator for when it would be expected that a change in water volume may be detected by the flow meter. This was compared to a non-drinking event, defined as being either when the calf did not place its head over the trough or if the calf's head was placed over the trough, but the water was not seen to move. These non-drinking events were used as indicators for when it would not be expected for the flow meter to detect any change in water volume.

Video footage was analysed using Adobe Premiere Pro CC (Version 10.4 Good Buddy). Each calf had a numbered ear tag, was fitted with a coloured collar (Calf neck bands, Shoof International Ltd., Cambridge, New Zealand) and also had photographs of its coat pattern taken to allow for individual identification during video analysis.

Statistical analysis

Using Microsoft Excel 2016 (Microsoft Corporation, Washington, USA), data recorded from the automated system were regressed against data gathered from behavioural observations from the video recordings in order to assess the level of agreement between the two methods for recording water intake, number of visits and visit duration.

Results

Based on the 51 visits observed during the observation period, the recordings from the automated system were highly correlated with behavioural observations for the number of visits (R^2=0.96, $P<0.001$, Fig. 1). For the number of visits there is marginal evidence that the sensor detected slightly more visits than recorded via behavioural observations. For five of the animals the automated system detected one more visit than the behavioural observations; the exact binomial test had a P value of 0.063. There is not significant evidence that the bias changes across the range of values. Lin's concordance value is 0.968. Recordings from the automated system were also highly correlated with behavioural observations for visit durations (R^2=0.94, $P<0.001$, Fig. 2). A Bland Altman graph of differences plotted against the means showed no evidence of any change in bias across the range of values and the average bias was not significant (0.13±0.072 (mean difference ± SEM)). Lin's concordance value is 0.966. Of the 51 visits observed, nine visits were recorded as being non-drinking events based on behavioural observations and correctly were not detected by the flow meter. However, in contrast the remaining 42 visits were all recorded as drinking events but only two of these drinking events were detected by the flow meter. Overall, there was no correlation between water intake measured from the automated system vs. behavioural observations (R^2=0.01, $P>0.1$).

Discussion

The results show that this automated system can reliably record drinking behaviour in terms of the number and duration of visits. However, the poor correlation between the two methods when measuring water intake suggests that the flow meter used in this study was not sensitive enough to accurately and reliably measure the small volumes of water that were being consumed by the calves during each visit. In a previous study, Chapinal et al. (2007) validated the use of the Insentec monitoring system (Insentec, Marknesse, Netherlands) as an automated method of measuring both feed and water intake of adult cattle. Chapinal et al. (2007) found that durations of feeding and drinking visits and feed and water intake per visit recorded by the Insentec system were highly correlated with direct observations ($R^2 \geq 0.99$). This is similar to the present findings for the duration of drinking visits, however, the Insentec system used by Chapinal et al. (2007) showed a much stronger correlation with water intake recorded per visit. Compared to the flow meter used in the current

Figure 1 Correlation between the number of visits by calves to the water trough obtained through behavioural observations from video recordings compared to the number of visits as recorded by the automated system for a total of 51 visits.

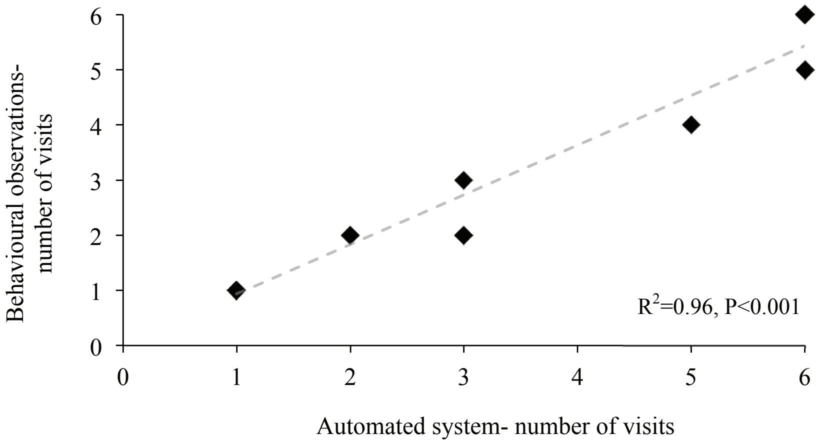
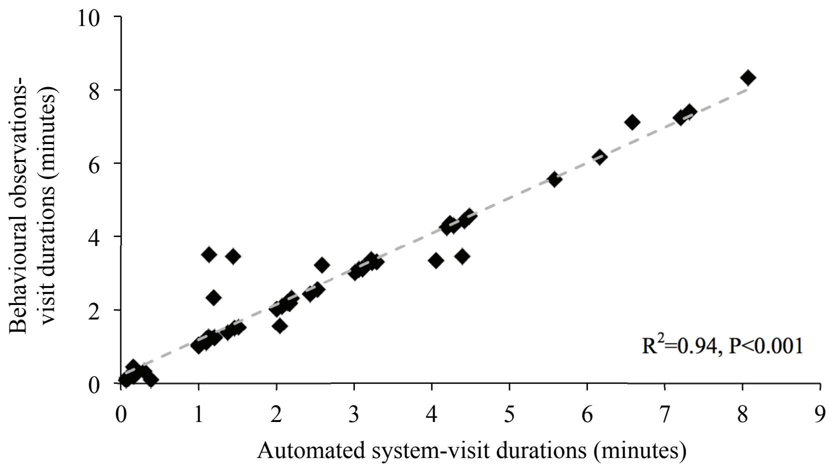


Figure 2 Correlation between visit durations (minutes) by calves to the water trough obtained through behavioural observations from video recordings compared to visit durations as recorded by the automated system for a total of 51 visits.



study, the Insentec system instead used a weigh scale to measure water intake, which was likely to have been more sensitive and reliable than the flow meter and could explain the inconsistency between these two studies. Another explanation for the inconsistency is that Chapinal, et al. (2007) investigated the water intake of adult cattle, which are likely to have consumed larger volumes of water per visit in comparison to the low consumption of calves in this study and would have been easier for the system to detect.

In conclusion, the system was able to reliably, automatically record drinking behaviour in terms of the number and duration of visits. However, an alternative system to measuring actual water intake that is sensitive and accurate enough to measure small volumes of water intake needs to be investigated and incorporated. This system could be used to investigate a number of questions regarding water use and consequent effects on animal health, welfare and productivity. Additionally, the development of an automated water system, integrated into other automated data collection on farm, could enable continuous animal health and welfare monitoring.

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