Transitioning from conventional to automatic milking: Effects on the human-animal relationship

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ABSTRACT

There are several differences in how an automatic milking system (AMS; milking equipment not requiring human intervention for the milk harvesting process) and a conventional milking system (CMS) are managed, where the effect of milking system type on the human-animal relationship has remained unexplored. A survey and observations from 5 Australian dairy farms transitioning from CMS to AMS were taken twice, 1 yr apart, before and after transition to an AMS. The farmers completed a survey and had all farmer-cow interactions documented for 3 d. In addition, a random selection of lactating cows had their avoidance distance (the distance at which they move away from an approaching person) recorded and were involved in a handling test during both visits. The survey findings indicated that basic management practices remained mostly unchanged, whereas records of farmer-cow interactions showed 4 out of 5 farms had less interaction time after AMS transition. This was caused by a reduction in milk harvesting tasks, where a small portion of this time was re-invested into time that farmers spent around the cows without directly interacting with them and into tasks involving close cow contact. Overall, an approximate 27% decline was observed in avoidance distances of cows from an AMS compared with the CMS. A handling test was performed on 4 of the 5 farms before and after AMS transition, where the farmers were asked to move a selection of cows through a gate one at a time. In the AMS more vocal effort was required to move the cows, and the cows responded with a reduced occurrence of running past the farmer and reduced occurrence of slipping in an attempt to avoid the farmers compared with the CMS. Overall, results show that farmers spent less time interacting with cows in the AMS, and that cows were less fearful

around people as seen by reduced avoidance distances and reduced stress responses to close handling.

Key words: behavior, dairy cattle, handling

INTRODUCTION

Since the early 1990s, automatic milking systems (AMS; milking equipment not requiring human intervention for the milk harvesting process) and other automated technologies have been leading the way in advancements of dairy farming. The practical and social benefits of such technology include providing dairy farmers with additional time and increased work flexibility (de Koning, 2010). As farmers commonly have little time flexibility and often have difficulties obtaining reliable labor in certain regions (Rossing and Hogewerf, 1997), it is not surprising that researchers have reported the adoption of AMS to be positive (Mathijs, 2004; Tse et al., 2017) with improved labor efficiency, more flexibility, reduced working hours, and lower physical workloads (Molfinio et al., 2012). The benefits and appeal of AMS to farmer lifestyle are clearly apparent (with no evidence of negative effects); however, to ensure commercial viability and potential long-term sustainability, investigation of the ability of cows to adapt and perform in such a system is vital. As there are differences in the way cows are managed between the 2 milking system types, researchers have been following the progression of AMS, and in so doing, have reported on the health and performance of the cows in these systems. The main research conducted comparing AMS and conventional milking systems (CMS) can be broadly categorized into behavior and health of lactating cows (Jacobs and Siegford, 2012).

The stress response of cattle in different environments has been widely studied in an effort to understand changes to their emotional state. Milking in an AMS compared with a CMS has been shown to reduce cow stress levels as measured by lower cortisol levels by Lexer et al. (2009), lower cortisol levels and no difference in heart rate variability by Jurkovich et al. (2017), and a reduced heart rate, adrenaline concentra-

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tion, and stepping during milking despite a higher (but still acceptable) cortisol level by Hopster et al. (2002). Measures of stress response have also been reported not to differ between the 2 types of milking systems, where cortisol levels (Gygax et al., 2006), heart rate, and heart rate variability (Hagen et al., 2005) have remained unchanged. Abeni et al. (2005) found AMS cows had slightly higher cortisol level to CMS cows but reported that concentrations were still within an acceptable range. Similarly, Hagen et al. (2004) reported that the 2 milking systems were comparable as AMS cows stepped less during milking but had a higher cortisol level and similar heart rate to CMS cows. In addition, higher stress levels have also been reported in an AMS by Gygax et al. (2008) who reported AMS cows as having an increase in stepping during milking, increased heart rate, and reduced heart rate variability. This finding was similar to results of Wenzel et al. (2003) who also reported AMS cows as stepping more frequently during milking, having a higher heart rate, and having a higher cortisol level. The overarching finding of these studies is that the stress response of cows in either system is comparable and is more likely to be linked to individual farm management than milking system type.

To examine potential longer-term effects of milking system type, exploration into cow health and physiology has been undertaken. Improvements or no significant changes to cow health have been recorded in an AMS when farms are well managed (Dearing et al., 2004; Svennersten-Sjaunja and Pettersson, 2008), particularly when cows remain managed on pasture (Ketelaar-de Lauwere et al., 1999). However, 1 study had identified a potential for an increasing occurrence of lameness in an AMS after 12 mo due to a higher uptake of full-time housing in European countries (Hillerton et al., 2004). Measures of udder health such as SCC have been reported to increase immediately after robot installation (Kruip et al., 2002; de Koning et al., 2003; Poelarends et al., 2004), whereas other studies report declines or no change in SCC (Berglund et al., 2002; Helgren and Reinemann, 2003). With overall health and behavior of cows showing minor and inconsistent differences between system types, it is likely that the welfare of cows in both system types is similar and dependent on good management. Management is highly dependent on humans, suggesting that the human factor of a milking system is likely to have the greatest effect on cow performance and welfare (Coleman and Hemsworth, 2014). As an AMS changes the way in which cows are managed and interact with humans, particularly with the inclusion of voluntary cow traffic, it is important to understand how this change affects the human-animal relationship.

To identify how farmers and cows transition collectively into an AMS, additional research into the farmer-cow relationship and how it may change after AMS adoption (from CMS) needs to be conducted. The objective of this investigation was to identify if changes exist in the farmer-cow relationship after AMS transition and if this can be linked to changes in farm routine and the avoidance response of cows to an unknown person. As it is often stated anecdotally that cows are quieter in an AMS (Holloway et al., 2014; Butler and Holloway, 2016), it was hypothesized that after AMS transition, the farmer-cow relationship would be improved as indicated by reduced avoidance distances and fear responses of cows during handling.

MATERIALS AND METHODS

Farms

Five farms that were transitioning from CMS to AMS located in New South Wales, Victoria, and Tasmania (Australia) participated in the study during 2015 and 2016. Dairy farmers that were known by the FutureDairy (Camden, Australia) research group to be transitioning from a CMS to an AMS during this time were notified of this study and invited to participate voluntarily. Four of the farms were pasture based and 1 farm was an indoor system. The farms milked from 280 to 540 lactating cows in either a herringbone or rotary milking parlor before transition. The farms were a mix of seasonal, split, and year-round calving and produced on average 14 to 31 kg of milk/cow per day. The pasture-based CMS farms grazed their cows on 1 to 3 pasture allocations per day across 77 to 300 ha, and 3 of the 4 pasture-based farms provided additional feed on a feed pad. All farms were fetching and milking their cows twice daily.

After AMS installation, the farms were milking in 3 or 4 single-stall AMS (1 farm using Lely, Maasland, the Netherlands, and 3 using DeLaval, Tumba, Sweden) with 1 farm milking in an automatic milking rotary (AMR, DeLaval). The farms continued as 4 on pasture and 1 indoors. Three farms reduced milking herd size and 2 maintained the same cow numbers compared with the previous CMS. The number of pasture allocations per day increased on 3 of the farms, although general feeding supplementation strategies (such as concentrates and mixed rations) remained the same. Three of the pasture-based farms reduced the total amount of grazing land available to the cows. In addition, 2 farms maintained the use of their CMS infrastructure for milking fresh or treated cows. One farm maintained a separate milking herd in their CMS, using their AMS to boost cow numbers and production, but only cows

that transitioned to the AMS were monitored after the AMS transition occurred for this study.

Design

Each farm was visited twice, once in 2015 while milking conventionally, and again 12 mo later after they had transitioned to automatic milking. The visits were timed 12 mo apart (± 9 d) so that the climate conditions, as well as average DIM of the cows (for split and seasonal calving herds) would be relatively similar at both visits. The first visit to each farm was timed to be within 2 mo of the farmers predicted start-up time for their AMS; however, unexpected delays meant that this time varied, thus actual start-up of the AMS took place from 11 d to 6 mo after the first farm visit.

Each farm visit was carried out over 6 d, during which the farm owner or manager (depending on who spent more time with the cows) was asked to complete a questionnaire survey on some aspects of the farm layout and management, as well as their attitudes to certain farm tasks. Human ethics approval was granted through The University of Sydney Human Ethics Committee (protocol number: 2014/1006). On the first day of each farm visit, a copy of the list of all cows currently in the milking herd was obtained, with information on each cow's age, DIM, and average milk yield (MY) where available. From this list, approximately 70 cows from each herd were selected as focal cows based upon sample size figures reported by Hoffman et al. (2012). The focal cows were selected to ensure that a mix of different cow ages, DIM, and MY were obtained. Cows in the milking herd were ordered from highest to lowest DIM, split into 3 even groups, then each of those groups was ordered highest to lowest age and split into another 3 even groups, and the same process was followed for MY. This produced 27 groups of cows where within each group the cows were assigned a random number (using random number generation in Excel, Microsoft Corp., Redmond, WA), and depending upon the number of focal cows required, cows were selected from each group based upon those that had the highest random number. This process was repeated for the second farm visit so that another random selection of cows was used of a similar average age, DIM, and MY as the first visit; however, some of the same cows were used at both farm visits ($n = 4$). After the focal cows were selected, they were marked with tail paint across their hips for ease of identification in subsequent observations. Marking was undertaken during milking in the conventional systems, and in the AMS cows were drafted into nearby stock-handling yards or were marked in the shed of the indoor system. Animal ethics approval was granted

through The University of Sydney Animal Ethics Committee (protocol number: 2014/676).

During d 2 to 4 of all farm visits, the daily farm routine was recorded by the lead author to observe the interactions between the cows and the farmers. The frequency and duration of the interactions between farm staff and the cows, as well as the types of interactions (i.e., the types of tasks conducted by the farmers) were recorded. During the observation time, the observer avoided any physical or visual (where possible) contact with lactating cows to prevent the cows from becoming acclimated to their presence. Following this, on d 5, avoidance distances of the focal cows marked on d 1 were taken by a single observer quietly walking (at a consistent pace) toward the shoulder of each marked cow in the paddock (or shed of the indoor system). The distance at which the cow moved away from the observer was recorded by a handheld laser distance measurer (Laser Distance Measurer 30 m, Ryobi, Doncaster, Australia). Validation of the laser's accuracy was compared by simultaneous testing with the traditional method of measuring the approximate distance 65 individual cows moved away from an observer with a tape measure. This comparison test indicated an agreement of ± 0.65 m for the 2 measuring methods. Because the use of the laser removes the human error associated with measuring the distance to an animal, accuracy was predicted to be greater than the traditional measuring method.

On d 6, 4 of the 5 farms participated in a handling test, where the focal cows were drafted into a holding yard, and the farmers were asked to encourage the cows through a gate into another holding yard, one at a time. The cows were drafted after milking in the conventional systems, and in the AMS, 2 farms drafted the focal cows into a paddock overnight, and a random selection of cows were brought into a holding yard on the other 2 farms where drafting facilities could not accommodate a large number of specific cows. During the handling test, the amount of effort used by the farmers (physical and vocal) to move each cow through the gate, and the response of each cow (walking, running, slipping, or a combination of these) were recorded. One pasture-based farm did not participate in this test due to time and space limitations.

Data Collection and Statistics

Survey. At both visits to each farm the survey was completed by the same farm staff member, as was the handling test. Questions about general farm layout and management were included in the survey to identify any differences that may have occurred after the farms transitioned into AMS. The remaining questions in the

survey were designed to gain an understanding of the farmer's perceptions of cows and dairy farming, before and after their farm transitioned to automatic milking. The answers to these questions were labeled from 1 to 5, or 1 to 7 based on a Likert scale of strongly disagree to strongly agree or from low to high. These questions were separated into 4 categories: negative attitudes, positive attitudes, caring for cows, and handling of cows. Questions on the 5-point scale were divided into and positive and negative attitudes. Negative attitudes included statements such as "cows are easily frightened" and "little experience is required to work with cows," positive attitude included statements such as "cows handle change well" and "cows are fast learners." Questions on the 7-point scale were then divided into questions related to caring for cows and handling of cows. Caring for cows included questions on how much time they spent talking to, or caring for cows, and questions about handling included the amount of vocal or physical effort required to fetch their cows. Three different questions from the second survey were not answered by 2 different farmers, so random numbered answers were generated using R version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria) so as not to discard the entire questionnaire record of the farmer and to have a complete data set for subsequent analyses.

Four principal component analyses (PCA) were performed in Genstat 16th edition (VSN International, Hemel Hempstead, UK), one for each of the 4 categories of questions. A minimum eigenvalue of 1 was used to determine the number of principal components extracted, with individual component loadings of at least 0.5 in absolute value used to show factors of a high loading, similar to the method described by Fraser and Bugnyar (2010). Any questions that did not load highly on any of the components were removed (1 at a time) and the PCA was run again. From this method of data refinement, 2 questions from negative attitudes, 4 from positive attitudes, 1 from caring for cows, and 1 from handling of cows were removed. After the PCA was completed, a Spearman's rank correlation r_s was performed to identify any correlations between the component scores and the count of vocal and physical effort used by the farmers during the handling test. These correlations were identified as either strongly correlated ($|r_s| \geq 0.7$), moderately correlated ($0.5 \leq |r_s| < 0.7$), or not correlated ($|r_s| < 0.5$).

Routine. The approximate 3-d routine of each farm (both visits) was organized into separate tasks, and categorized as activities that took place either near lactating cows (near) or with the lactating cows (milk, fetch, feed, and contact). The tasks were as follows: milk—

milk harvesting and associated tasks; fetch—actively encouraging cow movement on foot, with a vehicle, or with the aid of a dog; feed—distributing feed in the presence of cows; near—tasks in close visual proximity to the cows without interacting with them [e.g., hosing yards, building works, observing cows or moving fences (excluding milking, fetching, and feeding)]; and contact—physical contact with cows in a confined area [e.g., vaccinations, hoof trimming, and AI (excluding milking, fetching, and feeding)].

The approximate amount of time (min) that the farmers were observed performing each of these tasks over the 3 d was added to obtain an approximate daily average. This was further analyzed by separate linear mixed models (fitted using a REML procedure) in Genstat 16th edition to identify any effect of milking system on time spent (duration) on each task. Before analysis, duration was transformed [$\log_e(\text{duration} + 1)$] to improve data normality and constant variance. The 5 models looked at the duration in minutes spent per day on each task (milk, fetch, feed, near, and contact), with dairy type (CMS or AMS) as the explanatory variable and farm as the random term (farm A, B, C, D, and E) for each model. Predicted means were back-transformed for presentation of the results.

Avoidance Distances. The identification numbers of the cows that had their avoidance distance measured (in meters) were recorded along with the cow's approximate age in days and DIM obtained from farm records. Two-sample *t*-tests were used to identify if a difference was present in the avoidance distance of cows on each farm before and after AMS installation. The avoidance distance of the cows was transformed [$\log_e(\text{distance} + 1)$] to improve normality before analysis. Means were back-transformed for presentation of the results.

Second, a linear mixed model (fitted using a REML procedure) was applied to identify if any associations were present between avoidance distance [$\log_e(\text{distance} + 1)$ transformed] of the cows and cow age and DIM, as well as farm type (AMS or CMS). The full model included distance (avoidance distance, m) as the response variable, age (in months, approximate), DIM, and dairy type (AMS or CMS) as the explanatory variables, and farm as the random term. Model-based means were back-transformed.

Handling Test. The human and cow responses during each handling test were counted to determine if there was a difference in the probability of occurrence of the behaviors before and after AMS installation. Separate logistic regression models were fitted to the data to estimate the probability of a particular behavior (human: physical or vocal; cow: walk, run, or slip) being expressed, with dairy type (CMS or AMS) as the

fixed effect, farm as the random effect, and the number of cows in each test as the binomial total.

RESULTS

Survey

The survey provided basic descriptive information on the management of the farms both before and after transition to AMS. The amount of grazing land utilized decreased on 3 of the 4 pasture-based farms; however, all farms maintained a similar feeding strategy with regard to supplements and use of mixed rations. One farm changed their calving strategy and 3 farms milked fewer cows in the AMS compared with their previous systems. The bulk milk cell counts increased on 2 farms and decreased on 2 farms after transition, with the final farm remaining relatively unchanged. Two farms also achieved higher average MY, where the other 3 had slightly lower yields. Last, 3 of the farmers believed that they spent less time per day interacting with their cows after the transition to AMS. After checking recorded

farmer routines, this belief was found to be true on all 4 pasture-based farms, but not on the indoor farm.

The full PCA results of the survey are presented in Table 1. The PCA based on questions related to negative attitudes (**PCAneg**) resulted in 4 components with eigenvalues of 3.3, 2.7, 1.6, and 1.2, respectively. The 4 components explained 32.9, 26.7, 15.6, and 12.2%, respectively, of the total variation of negative attitudes of the farmers, totaling 87.4% of the variation. Questions pertaining to attitudes toward cows loaded heavily on the first component (**PC1**), questions on fear responses loaded to the second component (**PC2**), questions on working with cows to the third component (**PC3**), and questions on cow traits to the fourth component (**PC4**). One question, “cows are aggressive to their own kind,” loaded relatively heavily on PC1 (0.50) and PC2 (0.48), suggesting that it is a complex variable and is partly explained by both components. The PCA of questions related to positive attitudes (**PCapos**) had the first 3 components extracted with eigenvalues of 2.0, 1.5, and 1.1, respectively. These 3 components explained 39.8, 31.0, and 22.0% of the variation, respectively, ex-

Table 1. Principal component analysis loadings, where high loadings are identified in bold¹

Question	Component			
	1	2	3	4
Negative attitude				
Cows are ugly	0.62	−0.01	−0.03	0.11
Cows don't feel pain like humans	0.54	−0.21	0.06	0.05
Cows are aggressive to their own kind	0.50	0.48	0.04	−0.29
Cows are easily frightened	−0.02	0.59	−0.12	0.03
Cows are frightened of people	−0.19	0.55	0.12	0.15
Cows are lazy	−0.09	0.14	0.65	−0.11
Little experience is required to work with cows	0.01	0.00	0.53	0.10
Little time is required to manage cows	0.09	−0.18	0.50	0.00
Cows are greedy	−0.03	−0.02	0.06	0.70
Cows are smelly	0.16	0.14	−0.04	0.60
Positive attitude				
Cows are entertaining	0.68	0.11	−0.31	
Cows are friendly toward people	0.66	−0.13	0.33	
Cows require respect	−0.23	−0.73	−0.03	
Cows are intelligent	0.24	−0.66	−0.01	
Cows are easy to work with	−0.01	0.06	0.89	
Caring for cows				
How often do you watch your cows?	0.74	0.12	0.00	−0.04
Importance of husbandry in determining the productivity of your cows	−0.11	0.68	0.12	0.15
How often do you talk to your cows?	0.28	0.65	−0.12	−0.15
How important is routine for your heifers?	−0.30	0.12	−0.72	0.03
How important is routine for your cows?	0.29	−0.15	−0.67	−0.01
How much time is required to care for your heifers?	−0.13	0.13	−0.05	0.83
How much time is required to care for your cows?	0.42	−0.23	0.05	0.51
Handling cows				
How do your cows react when you walk among them?	−0.67	0.13		
How do your cows react to being handled in a confined space?	−0.63	−0.16		
How difficult are your heifers to break into milking?	0.30	−0.75		
How much physical effort is required to fetch your cows?	0.26	0.61		

¹Loadings for up to the first 4 principal components are shown for each of the 4 categories of questions: negative attitudes, positive attitudes, caring for cows, and handling cows.

plaining 92.8% of the total variation. Questions related to positive cow behavior loaded heavily on PC1, questions related to positive attitudes toward cows loaded on PC2, and a questions related to cows being “easy to work with” loaded on PC3. The third PCA looked at questions related to “caring for cows” (**PCAcare**) and identified 4 components with eigenvalues >1 (2.2, 2.0, 1.4, and 1.0, respectively). The first 4 components explained 31.3, 28.5, 20.7, and 15.0%, respectively, of the variation, totaling 95.4%. Questions related to observing cows loaded heavily on PC1, questions related to the importance of management and interaction with cows loaded on PC2, the importance of routine loaded on PC3, and the time required to care for cows loaded on PC4. The question “how much time is required to care for your cows” also loaded relatively heavily on components 1 (0.42) and 4 (0.51), indicating that it is also a complex variable. The final PCA on questions about the handling of cows had the first 2 components extracted with eigenvalues of 2.0 and 1.4, explaining a variation of 50.7 and 35.1%, respectively (85.8% total variation explained). Questions associated with the reaction of cows to people loaded heavily on PC1, and questions related to the effort required to work with cows loaded on PC2.

Variation in the response of individual farms both before and after transition to AMS for each of the PCA was seen, showing that the perceptions and attitudes of farmers are likely to be considerably variable between farms. No clear positive or negative patterns were observed in scores of farmer attitudes before or after transition to AMS across all farms; however, some individual farm effects were observed. Notable farm-specific results were evident for farm B, which had a positive score for most components in PCAneg, negative scores on all components within PCApos, and positive scores on all components in PCAcare. Farm C

was found to have negative scores on most components within PCAneg.

The amount of physical effort used by the farmers during the handling test was strongly and positively correlated with PC3 of PCApos ($r_s = 0.80$), moderately and positively correlated with PC1 of PCApos ($r_s = 0.53$), and moderately and negatively correlated with PC3 of PCAneg ($r_s = -0.61$). The amount of vocal effort used by the farmers to encourage the cows to move in the handling test was strongly negatively correlated with PC4 of PCAneg ($r_s = -0.90$) and moderately negatively correlated with PC4 of PCAcare ($r_s = -0.54$).

Routine

From the 3 d of observation of time spent on regular farm tasks, linear mixed model analysis revealed that 4 of 5 farms had less total farmer-cow interaction time after AMS installation. The predominant cause of the reduction in interaction time on the 4 farms was the absence of twice daily milking. An increase in close contact and in conducting tasks near the cows was recorded in the AMS; however, this time did not compensate for the loss in milking time. No significant differences were observed in the tasks feed and fetch, but significance was identified in milk, near, and contact (Table 2).

Avoidance Distances

The *t*-tests revealed that 4 of the 5 farms had significantly reduced avoidance distances recorded after transition to AMS (Table 3). Further linear mixed model analysis identified significant associations between cow age ($P = 0.001$) and milking system type ($P < 0.001$) with avoidance distance across all farms, with cow DIM not showing a significant association ($P = 0.470$). Predicted mean avoidance distances were created for various cow ages (which assumes a linear trend), revealing a negative trend of avoidance distance with age, where older cows had a shorter distance at which they would move away from a human. In support of the separate *t*-tests conducted for each farm, the REML analysis found that AMS (mean $\pm$ SD; 2.39 m $\pm$ 0.02) was associated with a lower avoidance distance than CMS (mean 3.28 m $\pm$ 0.02).

Handling Test

Results from the logistic regression of the handling test on 4 farms found no differences in the amount of physical effort used by the farmers to encourage the cows through the gate. Table 4 shows that the use of

Table 2. Predicted mean time (min/d) spent interacting with lactating cows in the conventional milking system (CMS) and in the automatic milking system (AMS) for each task (feed, fetch, milk, near, and contact)¹

Task	Milking system		<i>P</i> -value	SED ²
	CMS	AMS		
Feed	6.3	3.4	0.48	0.65
Fetch	82.5	73.8	0.60	0.19
Milk	245.7	1.2	<0.01	0.80
Near	0.0	59.8	<0.01	0.44
Contact	3.3	17.6	0.03	0.44

¹Results based on separate linear mixed model analysis for each trait, with back-transformed model-based means.

²SED = standard error of difference of means.

Table 3. Individual farm (A–E) *t*-test results of mean avoidance distance (m) of cows when managed in the conventional milking system (CMS) and approximately 1 yr later in the automatic milking system (AMS) with 95% CI for difference in the means

Farm	Milking system		<i>P</i> -value	95% CI	SED ²
	CMS ¹	AMS ¹			
A	2.82	2.22	<0.001	0.08, 0.30	0.05
B (indoor)	2.68	1.94	<0.001	0.16, 0.35	0.04
C	3.51	3.48	0.904	NS	0.05
D	3.68	2.67	<0.001	0.16, 0.40	0.05
E	3.64	1.81	<0.001	0.43, 0.91	0.07

¹Avoidance distances presented in meters.²SED = standard error of difference of means.

vocal effort by the farmers and the response of the cows (walk, run, and slip) to being asked to move through the gate were significantly different between milking systems.

DISCUSSION

The objective of this study was to identify whether changes exist in the farmer-cow relationship after transitioning from conventional to automatic milking, and if this can be linked to changes in farm routine and the avoidance response of cows to an unknown person. The findings of this study suggest that the farmer-cow relationship did change after transition to AMS as seen by the reduced fear responses expressed by cows when approached and handled. The near elimination of milk-harvesting-related tasks, and the increase in time spent near the cows and in close contact with the cows in the AMS could have contributed to this change in the farmer-cow relationship.

Survey

From the surveys that the farmers were asked to complete, basic changes in farm management were identified. The amount of land used for grazing declined on 3 of the pasture-based farms and the maximum num-

ber of cows milked on the farm was also reduced on 3 farms. It is unknown whether the reductions in farming scale were deliberate decisions by the farmers as no consistent changes to stocking densities were seen, and this information was outside of the scope for this study. Feeding strategies remained relatively unchanged, similar to findings of Tse et al. (2017) on indoor systems, where the only difference seen was the utilization of 3-way grazing (or 4-way grazing on 1 farm) on the pasture systems to achieve acceptable levels of voluntary cow traffic. Changes in MY and bulk milk cell counts varied between farms, showing increases, decreases, and relatively stable levels. This is not dissimilar to previously reported findings of Hillerton et al. (2004), where consistency in findings have been difficult to determine; however, an increase in SCC and decrease in MY would not be uncommon during the transition period (Poelarends et al., 2004).

Subsequent questions in the survey were aimed at understanding how farmers perceive their cows, and the emphasis they put on cow management, which was analyzed by the PCA. This information of farmer attitude can then be further used to indicate the way in which they handle their cows (Hemsworth et al., 2000). Hemsworth et al. (2000) identified that a positive attitude was negatively correlated with the number of negative interactions of farmers with cows. Further-

Table 4. Separate logistic regression models showing the predicted proportion ($\pm$ SE) of cows handled where vocal or physical effort was used by the farmers, the proportion of cows responding by walking, running, or slipping during the handling test, and the odds ratio (with 95% CI) of each behavior being performed on farms with a conventional milking system (CMS) or an automatic milking system (AMS)

Item	Milking system		<i>P</i> -value	Odds ratio
	CMS	AMS		
Vocal	0.06 $\pm$ 0.03	0.13 $\pm$ 0.05	0.002	2.23 (1.34, 3.71)
Physical	0.06 $\pm$ 0.04	0.04 $\pm$ 0.03	0.26	0.71 (0.39, 1.29)
Walk	0.46 $\pm$ 0.07	0.73 $\pm$ 0.06	<0.001	3.23 (2.30, 4.54)
Run	0.51 $\pm$ 0.07	0.28 $\pm$ 0.06	<0.001	0.38 (0.27, 0.53)
Slip	0.09 $\pm$ 0.03	0.01 $\pm$ 0.01	<0.001	0.12 (0.04, 0.35)

more, positive stockperson attitude toward patience with cows, contact with cows, and being comfortable around cows, as well as negative attitudes toward punishing cows were identified as the best attitudes for predicting the behavior of stockpeople (Waiblinger et al., 2002). Therefore, positive loadings on the PCA for positive attitudes and negative loadings on the PCA for negative attitudes may indicate that the interactions of the farmers with their cows were more positive in the present study. Although the categorization of the components is somewhat subjective, the component scores relating to each farm for negative attitudes and positive attitudes did not appear to identify any patterns among CMS or AMS to indicate any consistent attitude changes. Greater variation in results appears between farms than between farm system types. This variation may suggest that the transition from CMS to AMS does not change the positive or negative nature of farmer attitude toward their cows; however, a larger sample size would be needed to confirm this. A similar trend was also seen in farmer attitude toward “caring for cows” and “handling of cows.”

The component scores derived from the PCA of negative and positive attitudes, caring for cows and handling cows were tested for correlations with human behavior during the handling test. The amount of physical effort used by the farmers to encourage the cows to move during the handling test was positively correlated with a positive attitude toward cows being easy to work with. When cows are fearful of humans, they often have a larger flight distance than cows which have been well handled (Waiblinger et al., 2003). This increased flight distance is likely to reduce the amount of physical effort required to move an individual animal as they are more likely to move away from an approaching human before physical contact can be made, although it can make a cow more difficult to handle (Rushen et al., 1999). Therefore, a quiet cow may be considered easier to handle; however, as they are less fearful of humans, the amount of effort required to move them would be greater as suggested from this correlation. This same behavior may also explain our finding that the amount of physical effort used by the farmers was positively correlated with positive attitudes toward cow behaviors and negatively correlated with negative attitudes toward working with cows.

The amount of vocal effort used during the handling test was strongly negatively correlated with negative attitudes toward cow traits. This is dissimilar to the findings of Hemsworth et al. (2000) who reported that attitudes toward general characteristics of cows had a poor correlation with farmer behavior. The amount of vocal effort used in the present study to move cows was also moderately reduced for farmers who indicated

more time was required to care for their cows. This indicates that farmers who are quieter during handling are more inclined to take greater care of their cows, similar to reports by Hemsworth et al. (2000) who suggested that positive attitudes toward handling cows (indicating greater care) were associated with fewer negative behaviors expressed by the farmers. Although some correlations were found between principal component scores and farmer behavior during the handling test in the present study, the number of handling tests conducted ($n = 8$) was small and may have affected the findings.

Routine

On a CMS farm, the main interactions that lactating cows have with humans occur when they are being fetched for milking, during milking and occasional herd health practices. In the current study, these farmer-cow interactive tasks occupied on average 5.6 h/d when the farms were still operating with a CMS (excluding office hours and other tasks). However, on an AMS, the daily tasks are often more variable and with working hours being more flexible (Molfino et al., 2012), regular tasks can take place at different times and for different durations. In the current study, 4 of the farmers reduced the amount of time spent near or interacting with their lactating cows after installation of the AMS to an average of 2.6 h/d (excluding office hours and other tasks). This was due to milk-harvesting-related tasks being mostly eliminated in the AMS and not all additional time being absorbed by other cow interactive tasks. Similar changes to farm routine have also been reported by Molfino et al. (2012), who suggested that AMS farmers spent less total time at the dairy each day, thus positively affecting quality of life, reducing physical work, and increasing time available for alternative management tasks. In the current study, farmers appeared to allocate some of their additional time in the AMS toward tasks conducted near the cows (e.g., hosing yards or moving fences) and in close contact with the cows (e.g., hoof care, herd health, or collar fitting). These times are indicative only as sample size was relatively small and daily routine often varied day to day, particularly after AMS installation. In addition, some farms were still going through the transition and adaption process. On farms where changes to management and infrastructure (outside of the milking units) were still taking place, more farmer-cow interactions than normal (in that system) were noted. This included construction on laneways, fencing, gates, and some cow training.

Changes to time spent distributing feed (with cows present) and fetching cows varied among farms but

were not significantly different overall. Many of the farmers often spent large portions of the day near the AMS (or in the paddocks) performing tasks such as feeding calves, moving machinery, or conducting other maintenance activities. Therefore, it is possible that cows saw humans relatively frequently around the farm; however, recording of all farm routine and farmer-cow interactions was difficult to achieve particularly in the AMS. Furthermore, as cows voluntarily traffic around the farm in an AMS, it is possible that an individual cow can go for several days without directly interacting with the farmer, or they may interact with a farmer multiple times a day. As such, results may not represent the amount of time during a day in which every cow interacted with the farm staff but will provide information on the nature of most farmer-cow interactions. The only farm that recorded more interaction time with the cows after the shift to the AMS was the indoor system, which changed from spending approximately 5.7 h/d interacting with cows in the CMS, to 6.8 h in the AMS. On this farm, staff spent much more time fetching and interacting with cows due to a desire to achieve greater levels of milk production. Also fetching in an indoor AMS requires the individual cows that have not volunteered for milking to be identified from the remainder of the cows in the herd, which may affect total time spent fetching. In contrast, in a pasture AMS the cows to be fetched are all those that have not returned from a particular paddock; therefore, the fetching task is simpler. The indoor farm also had the shortest length of time between AMS start-up and the collection of data for this investigation; therefore, the increased interaction may also be due to factors such as training or system learning.

Avoidance Distances

With AMS farmers spending less total time interacting with their cows, and the nature of these interactions somewhat changing, it was unknown what effects this may have on the way the cows react around humans. Mattiello et al. (2009) suggested that smaller farms with a high level of close farmer-cow interaction and low amounts of mechanization were more likely to have a more positive farmer-cow bond. This suggests that transitioning to AMS where mechanization level is greater and farmer-cow interactions are reduced, the quality of the farmer-cow bond would decline. As avoidance distance of cows to an unfamiliar person provides a good reflection of the human-animal relationship (Waiblinger et al., 2003), it was used in the current study to make comparisons of changes to the human-animal relationship before and after transition on each

farm. Results from the *t*-test analysis identified that 4 farms had significantly shorter avoidance distances after transitioning to AMS. The reduced avoidance distances in the current study is misaligned from the previous finding of Mattiello et al. (2009), suggesting that the change in the nature of the farmer-cow interactions in the present study was of a greater influence on the human-animal relationship than the frequency or duration of interactions. The reduced avoidance distance in the current study also differs from the findings of Jurkovich et al. (2017) who did not find any differences in the avoidance distance of cows just before and 2 mo after the change to AMS in an indoor situation. In that study, only a small sample of cows (19 cows out of the initial group of 27) from a single CMS farm that transitioned to an AMS were observed. Observing cows within the first 2 mo of transition may not have allowed enough time for the cows to completely adapt to the AMS, suggesting that future research should observe cow avoidance distance at multiple time points post-AMS transition. In addition, the sampling method (analyzing the average of 2 approach distances per cow per milking system) may have limited the ability of the researchers to detect variation. Farm C (Table 3) was the only farm that appeared to have no differences in mean avoidance distance, suggesting the nature of handling techniques and the farmer-cow bond were unchanged. This farm had the median avoidance distance of all the farms in the CMS, but the greatest avoidance distance in the AMS. It is unknown why this farm had no change; however, it may be linked to ongoing construction on this farm (for the AMS), interrupting cow flow into the milking facility, or the occasional use of a dog when fetching cows because other farms did not use a dog.

Further mixed model analysis confirmed an overall trend for reduced avoidance distances after the farms had transitioned to AMS. The near elimination of milk harvesting tasks and increase in tasks involving near and contact is thought to play a role in this change due to the link between positive handling and avoidance distance (Waiblinger et al., 2003). Regardless of milking system type, the heart rate of cows has been shown to increase during milking (Gygax et al., 2008), and when considered with the step kick behavior of cows during milking, suggests that the milking process contains some level of discomfort (Hagen et al., 2004). Furthermore, Hemsworth et al. (2000) reported that negative interactions between farmers and cows were moderately negatively correlated with the percentage of cows approaching within 1 m of the farmer. With the removal of human association with the milking process, cows may be less likely to associate humans with

stressful and uncomfortable situations, altering the human-animal relationship as shown by the reduced fear responses of cows in the current study.

Cow age was also seen to have associations with avoidance distances where predicted means (which assume data linearity with age) indicated a negative trend of avoidance distances with age. This is different from the results of Waiblinger et al. (2003) who observed the avoidance distances of younger versus older cows on multiple farms, ultimately concluding that there were no differences in avoidance distance between cows of different age groups. Because of this, further research is suggested to look at the interaction of avoidance distances of cows in different age groups with milking system type as they transition to an AMS.

Handling Test

The handling test used in this study was designed to record the reactions of the cows when in a confined and abnormal situation, and the effort used by the farmers to achieve the desired result. Overnight drafting into a paddock was used on 2 AMS farms to enable the focal cows to be separated from the main herd. This process was not considered likely to affect cow behavior because cows are regularly drafted to different sections of the property for pasture rotation as part of normal farm routine. After transition to AMS, the farmers used more vocal effort to encourage cows to move through the gate. It is thought that this increase is a result of the cows being less fearful of humans entering their flight zone due to positive handling (Hemsworth, 2003), thereby requiring additional effort to encourage the cows to proceed through the gate. This response was also found in the PCA of "handling of cows," where a positive loading on the amount of effort required to fetch cows was associated with negative loadings on the reaction of cows to human presence. Further evidence to support the reduction in fear response of cows to the handling test is from the reduction in the proportion of cows running, slipping, or both. When a human enters too far into the flight zone of a cow, the cow will often respond by running away (Grandin, 1980). Cows that are quieter, however, will often be less agitated (Grandin, 1997), suggesting that the AMS cows were quieter as seen by the reduction in running and slipping in the current study. Farm B was the only farm that had recorded a greater proportion of cows running during the handling test after transition. Unlike all other handling tests performed, the test for farm B (indoor system) after transition had to be performed in an area where the cows rarely go, because once the cows entered the AMS herd they were unlikely to leave that section of the housing until dry off. In this situation, cows ap-

peared to be running due to the excitement of exploring a new area rather than stress as they continued running, jumping, and flicking their tails after they had gone past the farmer.

Some changes in farm routine were not accounted for in the interpretation of data in this study including changes to feeding regimens, husbandry, land size, stocking densities, and time to transition after the first farm visit, which does constitute some limitations to the study. Previous social research studies of dairy farm attitudinal segmentation in the Australian dairy industry would suggest that management style and approach to farming is consistent within a particular type of farmer/segment (Waters et al., 2009). As our focus was on animal-human interactions, it is therefore unlikely that the above limitations would be substantial; however, a greater sample size is recommended for further studies to reduce the effect of uncontrollable factors including changes to farm structure and unpredicted delays in AMS start-up.

Records of cow parity were not readily available at all farms, and due to the close relationship between parity and age, age was used as the best available proxy measure for the selection of focal cows. Monoparous cows were not specifically accounted for as the selection was random and included cows milking for the first time in both systems (therefore balanced across both visits). It is recommended that future similar studies consider both age and parity to ensure that the proportion of monoparous and primiparous animals is consistent during pre- and post-AMS visits. In addition to the selection of focal cows, 3 cows on 1 farm and 1 cow on another were selected both before and after transition. This represents a potential limitation to the study, but given the low number of animals and the time elapsed between both measurements, it was considered to have minimal effect on study conclusions. In addition, previous research has compared the 2 different brands (Lely and DeLaval) of milking equipment and found that one brand was associated with more restless behavior than the other (Gygax et al., 2008), which represents another limitation of the present study.

CONCLUSIONS

The main objective of the current study was to identify and quantify changes in farmer routine that may cause changes in the farmer-cow relationship and the avoidance response of cows to humans. Results of this study showed that farmers overall spent less time interacting with cows in the AMS due to the near elimination of milk-harvesting-related tasks. The general reduction in avoidance distance and cow stress response during the handling test indicates that the cows had

become quieter in the AMS. Results from this study indicate that the farmer-cow relationship had improved after AMS transition and that this may be related to changes in farmer routine.

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