Automated recording of waiting time in front of AMS and the effect of dominance in dairy cows on waiting time

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Abstract

Social dominance in cattle is important when resources are scarce and competitive situations occur such as in a queue in front of an automated milking system (AMS). We aimed to 1) create and validate an algorithm to automatically register waiting time in front of an AMS (WT_AMS) for individual cows and 2) study the effect of dominance on observed WT_AMS. Our research took place on a commercial dairy farm in the Netherlands housing 110 Holstein Friesian dairy cows and operating a two stand GEA MIone AMS. Cows were fitted with a NEDAP SmartTag Neck that included cow location. Fifteen one-hour-long observation periods took place during which three researchers noted the time an animal came into a preselected open waiting area in front of the AMS and the time of either leaving the waiting area or entering the AMS. During the time an animal was in the waiting area dominance behavior performed or received by the focal animal was registered. An algorithm was developed to determine the WT_AMS based on location data. WT_AMS for observations and algorithm were strongly correlated (Spearman's rank-order correlation: r=0.828; p=0.000; n=112). A weak negative correlation was found between dominance and waiting time in front of the AMS (r=-0.248; p=0.01; n=66). In conclusion, the algorithm can be used to automatically assess WT_AMS accurately, and dominance behavior was found to have a small effect on waiting time in front of the AMS. More research is needed to determine the effect, for instance, of disease on individual WT_AMS.

Keywords: dairy cow, behavior, dominance, waiting time, location system

Introduction

Cows associate with each other in a non-random way, which results in unevenly distributed social interactions (Sueur et al., 2011). Cows form preferential relations with some individuals while avoiding others (Gygax et al., 2010; Boyland et al., 2016). This social behavior may be used as a welfare indicator in cattle, where affiliative behavior is suggested to be a positive welfare marker (Boissy et al., 2007; Rault, 2012), and changes in behaviors could be used as a predictor for disease (Weary et al., 2009; Proudfoot et al., 2012; Sepúlveda-Varas et al., 2016; Weigele et al., 2018). Social relations can be inferred by comparing locations of group members in relation to each other (Chopra et al., 2020; Ren et al., 2021). The location of a cow in a functional area is closely related to the activity of the animal e.g feeding, lying, and drinking (basic needs) and thus, location can be used to infer its behavioral budget (Porto et al., 2014; Chapa et al., 2021). Advances in the development of sensors and data science which can be used to automate the collection and processing of social interaction data have the potential to revolutionize our understanding of animal social networks (Gygax et al., 2010; Krause et al., 2013; Croft et al., 2016). Multiple technologies are now available for automated monitoring of the location of individual animals, e.g Global Positioning Systems (GPS), Ultra Wide Band (UWB), and Bluetooth (Hofstra et al., 2022). Location monitoring in dairy cows is currently only used to locate an individual within the herd as an aid for the farmer. Location data is usually not stored and used in any other capacity. However, the location, posture, and movement of the cow are key elements in recognizing the animal and its behavior. Social behavior in cattle such as dominance behavior is important when resources are scarce and competitive situations occur for instance in a queue in front of an automated milking system (AMS). According to Ketelaar et al. (1996) dominant animals tend to enter the AMS more often without waiting or spend less time waiting. Whereas, cows with low dominance tend to wait longer before entering the AMS and seem to adapt their visits to the AMS to avoid dominant animals (Ketelaar-De Lauwere et al., 1996). Deviations in waiting time in front of the AMS might therefore indicate changes in behavior, which could be an indicator of changes in welfare. The aim of our research was 1) to create and validate an algorithm to automatically register the waiting time in front of an AMS (WT_AMS) for individual cows based on cow location data and 2) to study the effect of dominance on observed WT_AMS.

Materials and methods

Research location

Our research took place on a commercial dairy farm in the Netherlands housing 110 Holstein Friesian dairy cows in a freestall barn with concrete slatted floors and 121 deep-litter cubicles. All cows were milked with a two-stand GEA MIone AMS. The parity ranged from 1 to 8. The farm used the free-traffic system, in which all the cows had access to all areas in which they resided (e.g., cubicles, feeding fence, drinkers, AMS, and the grooming brush) at all times.

Cow location data

All cows were fitted with a NEDAP SmartTag Neck that included location registering their location every 5 seconds. Location data was stored locally before being uploaded to a PostgreSQL cloud database.

Behavioral observations

Fifteen one-hour-long observation periods took place between December 2021 and February 2022. Observations started either at 11:00 or at 15:00. An open waiting area (OWA) in front of the AMS of 13.2 x 5.0 meters was defined based on previous pilot observations of the queue in front of the AMS. During the observation periods, three researchers noted the time of animals coming into the OWA and the time of entering the AMS (Figure 1). Animals leaving the OWA without entering the AMS were scored as 'Abandoned'. Each researcher observed two cows simultaneously. When one of the cows either went inside the AMS or 'abandoned' the OWA the observer would select a new cow as it moved into the OWA whilst communicating the cow number with the other researchers. When more than six animals were present in the OWA they could not all be observed. Five minutes prior to the end of an observation period, the observers stopped observing new cows. However, the cows that were already being observed were observed till they either 'abandoned' the OWA or entered the AMS. During the time an animal was in the OWA all occurrences of dominance behavior performed or received by the focal animal were registered using an ethogram (Table 1). The observed waiting time in the OWA before entering the AMS (WT_AMS_Obs) was time entering AMS minus time entering OWA.

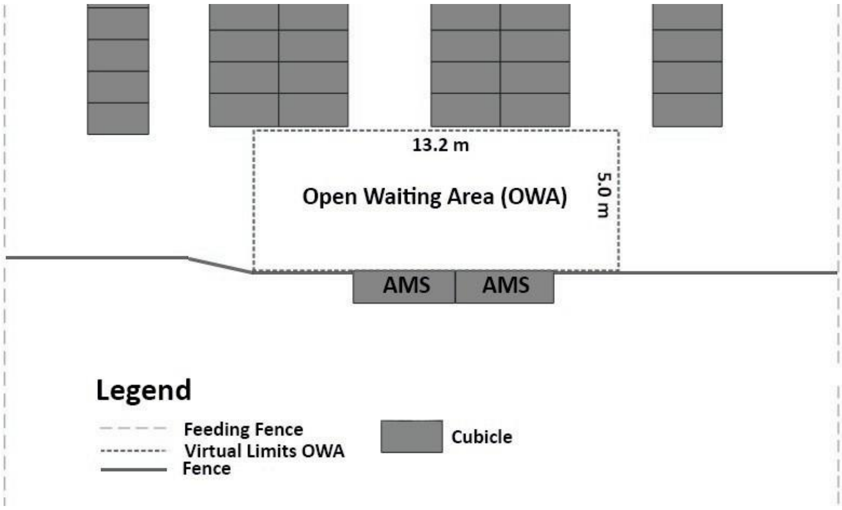

Figure 1: Map of the free stall with AMS and predefined open waiting area.

Table 1: Ethogram of dominance behavior.

Dominance	Behavior	Description
Dominant	Forceful displacement	Pushing, bumping, or rubbing with the head/body against another cow causing the receiving cow to move away (for at least half an animal's length or at least one step to the side of an animal's width).
	Headbutt	The cow bumps another cow with the head/horn base against the head/horn base.
	Being avoided	Another cow voluntary leaves its place in the queue when the focal cow comes within one meter of it. This happens without physical interaction with the other cow. This behavior was noted when the focal cow took this spot within 10 seconds.
Subordinate	Receiving forceful displacement	Being pushed, bumped, or rubbed with the head/body of another cow causing the focal cow to move away (for at least half an animal's length or at least one step to the side of an animal's width).
	Receiving headbutt	Another cow bumps the focal cow with the head/horn base against the head/horn base.
	Avoiding	The cow voluntary leaves its place in the queue after another cow comes within one meter of it. This happens without physical interaction with the other cow. This behavior was noted when the other cow took this spot within 10 seconds.

Inter-rater agreement

A Fleiss' kappa was run to determine if there was agreement between the behavioral observations of the three observers using a fifteen minutes video clip in which three animals were scored by all observers.

Algorithm

A python script was developed to determine the waiting time in the OWA before entering the AMS. The input data was the collected location data in the PostgreSQL cloud database which is structured as Timestamp; Cow_id; X-coordinate; Y-coordinate. The python script searches the location data for a set timeframe and triggers once a cow has two consecutive data points within an area marked as the AMS. It then checks the data points of this individual going back in time, checking whether these data points are in the OWA until a data point is found outside the OWA. The timestamp of the last data point in the OWA before a data point outside the OWA is found is considered the moment of entering the OWA. The timestamp of the first data point in the AMS is considered the moment of leaving the OWA. The delta of the timestamps of the data points for entering and leaving the OWA was considered to be the waiting time in the OWA before entering the AMS (WT_AMS_Alg). The output data is structured as Cow_id, Start-waiting; End-waiting; Waiting-time.

Validation algorithm

WT_AMS_Obs and WT_AMS_Alg were matched based on cow number and the time of entering the AMS. Repeated visits by the same cow to the AMS during the observation periods were classified as independent data. A Spearman's rank-order correlation was performed to test the correlation between WT_AMS_Obs and WT_AMS_Alg.

Data analysis dominance behavior vs WT_AMS

For each animal a dominance ratio was determined by dividing the number of dominant behaviors by the total number of dominance behaviors ergo dominant + subordinate behaviors. Repeated visits by the same cow to the AMS during the observation periods were classified as independent data. A Spearman's rank-order correlation was performed to test the correlation between WT_AMS_Obs and dominance ratio.

Results and discussion

Fleiss' kappa showed that there was good agreement between the researchers, $\kappa=0.729$ (95% CI, 0.544 to 0.914), $p < 0.000$. A total 235 times cows were observed entering the OWA (104 individuals) of which 120 times animals subsequently entered the AMS (71 individuals). The algorithm yielded 112 matching results. WT_AMS_obs and WT_AMS_alg were strongly correlated (Spearman's rank-order correlation: $r=0.828$; $p=0.000$) (Figure 2). The median waiting time in front of the AMS was 10 minutes (sd 11.2). The eight instances where WT_AMS_Obs could not be matched with WT_AMS_alg were due to the animals having no or just one data point in the AMS. These were animals that were rejected by the AMS immediately after they entered the AMS. Also, several cases could be identified where WT_AMS_Alg was significantly shorter than WT_AMS_Obs. Nine cases could be identified where the location-data points were positioned just outside the waiting area for one or more instances during the observed waiting time, thus, prompting the script to register a later moment for entering the waiting area than the observers. This could have been due to the observers not always being able to see the boundaries of the OWA correctly in crowded situations in front of the AMS or due to some minor inaccuracy of the cow location-determining system. This issue could be tackled by enlarging the waiting area slightly into the central walkway where most of the nine cases were located (Figure 1). Without these nine cases the correlation between WT_AMS_Obs and WT_AMS_Alg was slightly stronger (Spearman's rank-order correlation: $r=0.900$; $p=0.000$) (Figure 3).

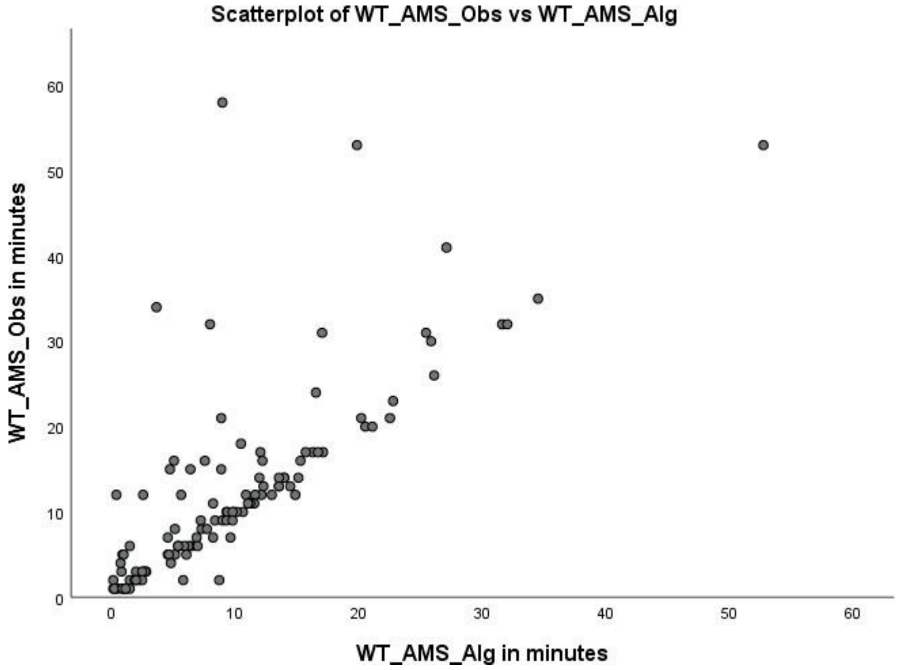

Figure 2: Scatterplot of observed (WT_AMS_Obs) and algorithm-based (WT_AMS_Alg) waiting time in front of the AMS.

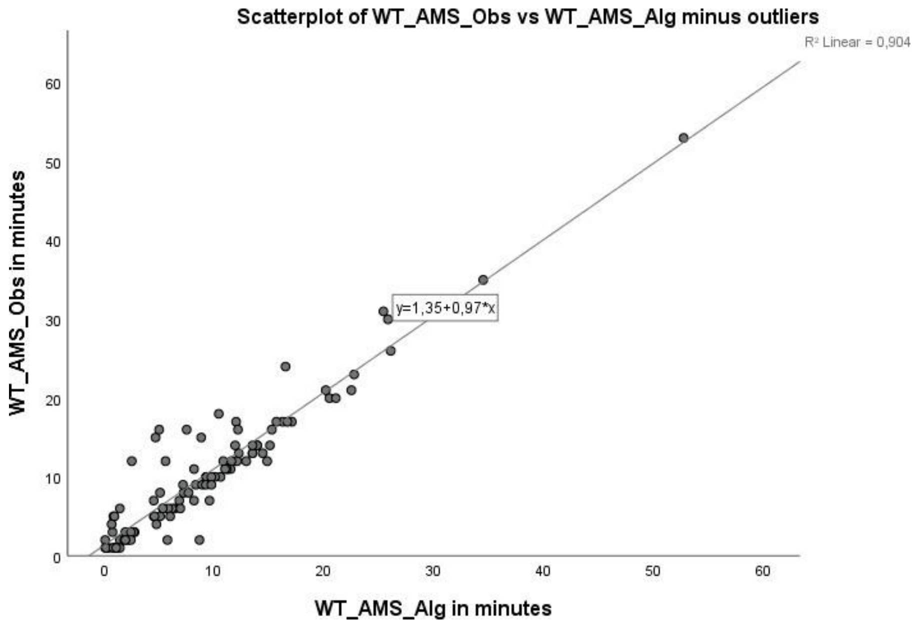

Figure 3: Scatterplot with trendline of observed (WT_AMS_Obs) and algorithm-based (WT_AMS_Alg) waiting time in front of the AMS minus nine explainable outliers.

For 109 of the 112 matched instances, where cows entered the AMS, dominance behavior was recorded (66 individuals). Repeated visits by the same cow to the AMS during the observation periods was considered to be independent data since group composition of animals waiting in the OWA and thus the dominance ratio of the focal cow in regard to her conspecifics could change with every visit. A weak negative correlation was found between dominance ratio and WT_AMS_Obs (Spearman's rank-order correlation: r=-0.248; p=0.01). However, correlation between dominance ratio and WT_AMS_Alg was not significant (r=-0.182, p=0.059). Although we found but a weak effect of dominance ratio on WT_AMS the negative correlation is in line with previous research on dominant cows having priority over other cows for resources (Friend and Polan, 1974; Galindo and Broom, 2000).

For the future, we would recommend considering the number of animals present in the waiting area during WT_AMS when investigating the correlation between WT_AMS and dominance ratio. A short WT_AMS in a crowded situation might be a better predictor of dominance than a short WT_AMS with hardly any animals present in the waiting area.

The future goal for our research is to monitor waiting time over a prolonged period and determine if deviations in waiting time in front of the AMS have any value in predicting disease. Furthermore, empirical observation showed that mainly subordinate animals abandoned the OWA after waiting more than 15 minutes. This could be a promising avenue for further research regarding subordinate animals. Getting a clearer picture of which animals in the herd are the more subordinate animals might also provide the farmer with better insight into which animals are possibly more at risk for disease since these social factors contribute to disease risk (Galindo and Broom, 2000; Proudfoot and Habing, 2015).

Conclusions

We have successfully developed and validated an algorithm that can monitor waiting time in front of the AMS for individual cows using location data. Dominance behavior was found to have a weak effect on waiting time in front of the AMS. More research is needed to determine the effect of, for instance, disease on individual waiting time in front of the AMS and the effect of dominance on waiting time in front of the AMS.

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