



Sveriges lantbruksuniversitet  
Swedish University of Agricultural Sciences

Department of Animal Nutrition and  
Management

# Cow traffic in an automatic milking rotary system – With or without parallel guiding of cows for milking

*Kotrafik i ett automatiskt mjölkningskarusellsystem – Med eller  
utan parallell guidning av kor till mjölkning*

Lisa Pettersson

**Degree project • 30 credits**

Agricultural Science Programme - Animal Science

Management, Ruminants

Uppsala 2019



# Cow traffic in an automatic milking rotary system – With or without parallel guiding of cows for milking

*Kotrafik i ett automatiskt mjölkningssystem – Med eller utan parallell guidning av kor till mjölkning*

Lisa Pettersson

**Supervisor:** Jan Olofsson, Swedish University of Agricultural Sciences, Department of Animal Nutrition and Management

**Examiner:** Rolf Spörndly, Swedish University of Agricultural Sciences, Department of Animal Nutrition and Management

**Credits:** 30 credits  
**Level:** Second cycle, A2E  
**Course title:** Degree Project in Animal Science - E30  
**Course code:** EX0551  
**Programme/education:** Agricultural Science Programme - Animal Science  
**Course coordinating department:** Department of Animal Nutrition and Management

**Place of publication:** Uppsala  
**Year of publication:** 2019  
**Online publication:** <https://stud.epsilon.slu.se>

**Keywords:** cow traffic, parallel guiding, automatic milking rotary, cow behaviour

**Swedish University of Agricultural Sciences**  
Faculty of Veterinary Medicine and Animal Science  
Department of Animal Nutrition and Management  
Management, Ruminants



## Abstract

Automatic milking systems and automatic milking rotary systems (AMR) where the cows are gathered and held in a waiting area prior to milking are dependent on cows to enter the milking unit voluntarily. A low rate of cows that voluntarily enter the milking unit affects both the economy, working safety and cow health negatively. Both the flow of animals as well as the interactions in this enclosed area can be affected by various designs of the waiting area. The present study examined dairy cow behaviour, milking time and labour in an AMR with two different waiting area designs: with parallel guiding or no parallel guiding. The parallel guiding consisted of two railings placed in front of the entrance to the AMR. These railings separated the cows, creating what could be seen as three corridors in front of the AMR. A control treatment without parallel guiding and a treatment with parallel guiding was applied for two weeks each. Two groups, *G1* and *G2*, of approximately 60 lactating cows each of Swedish Red and Swedish Holstein breeds were included in the study. The *G1* group consisted of mainly primiparous cows and *G2* of mainly multiparous cows. For analysis of the behaviours, 20 focal animals were marked in each group. The staff gathered the cows in one of the two waiting area designs prior to milking but were not permitted to interact with the cows for 40 minutes after that. During these 40 minutes, the cow behaviour was studied. An ethogram was used. For example, it was noted if a cow pushed another cow. Both the performing and the receiving animal was noted. When 40 minutes had passed, the staff were allowed to fetch cows that had not entered the AMR. The period from the staff's first interaction to the last cow entering the milking unit was also studied, each time staff interacted with a cow was noted as well as the total time for staff interaction. Data was collected during 6 milking occasions per group on the second week of each treatment. This was performed twice for each treatment, resulting in a total of 48 milking occasions studied, 24 during each treatment. The results showed a lower frequency of behaviours when parallel guiding was practised ( $p=0.04$ ), as well as lower total staff interaction time ( $p=0.04$ ) and staff interactions ( $p=0.0002$ ). The majority of behaviours were performed by the lightest (40%) or heaviest animals (37%), and multiparous cows (58%). The number of performed, as well as received behaviours, seemed to be increasing with days in milk. The animal receiving a behaviour was in most cases primiparous cows (63%). The majority of the staff interactions were also performed on first parity cows (57%) and the heaviest cows (50%). The number of received staff interactions seemed to be increasing with days in milk. No difference was found between treatments in total time for milking, total walking and waiting time before milking or time spent in waiting area. Neither was a difference found regarding the time spent in waiting area as a group retrieved from the video recordings. However, the parallel guiding did overall not result in longer time intervals when compared to no parallel guiding. The milk yield during the periods when parallel guiding was practised was found to be higher compared to when no parallel guiding was practised ( $p<.0001$ ). The parallel guiding was not found to have any negative effects on either working time, animal behaviour or milk yield. Further studies are needed to investigate the effects of the parallel guiding in more depth.



# Innehållsförteckning

<b>Abbreviations</b>	<b>1</b>
<b>1 Background</b>	<b>2</b>
<b>2 Literature review</b>	<b>3</b>
2.1 <i>Waiting area</i>	3
2.2 <i>Behaviour and social dominance</i>	4
2.3 <i>Labour</i>	5
2.4 <i>Milking and waiting time</i>	7
2.5 <i>Factors affecting milk yield</i>	9
<b>3 Aim and hypotheses</b>	<b>10</b>
<b>4 Material and methods</b>	<b>11</b>
4.1 <i>Animals, Management, and Housing</i>	11
4.2 <i>Study design</i>	12
4.2.1 <i>Milking routines</i>	14
4.3 <i>Data collection</i>	14
4.3.1 <i>Behaviour registrations</i>	14
4.3.2 <i>Staff interactions</i>	15
4.4 <i>Statistical analysis</i>	16
4.4.1 <i>Behaviour</i>	16
4.4.2 <i>Staff interaction</i>	17
4.4.3 <i>Time intervals</i>	17
4.4.4 <i>Order of entrance</i>	17
4.4.5 <i>Milk yield</i>	17
<b>5 Results</b>	<b>18</b>
5.1 <i>Behavioural analysis</i>	18
5.2 <i>Analysis of staff interaction</i>	20
5.3 <i>Time interval analysis</i>	22
5.4 <i>Order of entrance</i>	23
5.5 <i>Milk yield</i>	23
<b>6 Discussion</b>	<b>24</b>
6.1 <i>Behaviour</i>	24
6.2 <i>Staff interaction</i>	25
6.3 <i>Time intervals</i>	26
6.4 <i>Milk yield</i>	27
6.5 <i>Study limitations and further studies</i>	27
<b>7 Conclusion</b>	<b>29</b>
<b>Acknowledgements</b>	<b>30</b>
<b>References</b>	<b>31</b>

## Abbreviations

AMS	Automatic milking system
AMR	Automatic milking rotary
WA	Waiting area
WP	With parallel guiding
NP	No parallel guiding
G1	Group 1
G2	Group 2
FA	Forward area
BA	Backward area
IPC	Interactions per cow
DIM	Days in milk



# 1 Background

The dairy industry has developed considerably during the last decades. A combined effect of significant advances in genetics, nutrition, farm management and milking machines has led to the dairy industry we know today (Jacobs & Siegford, 2012a). The first automatic milking system (AMS) were installed in the Netherlands in 1992 (Svennersten-Sjaunja & Pettersson, 2008) and by the year of 2016 about 90 000 (28%) of all dairy cows, in Sweden were housed in an AMS (LRF Mjök, 2017; Jordbruksverket, 2019). One of the most recent AMS systems is the automatic milking rotary (AMR<sup>TM</sup>, DeLaval International AB, Tumba, Sweden). This system, which was launched in 2010, has 24 milking places and 5 robotic arms. An AMR of this size has a maximum capacity of approximately 90 cows per hour and is designed to operate larger groups of animals, between 300 to 800 cows (Jacobs & Siegford, 2012a).

The efficiency of an AMS depends on cows to voluntarily enter the milking unit as an individual, apart from its herd and without assistance from staff (Jacobs *et al.*, 2012). If the cow does not enter the AMS voluntarily, fetching will be required, resulting in economic losses (Drach *et al.*, 2017). In an AMS or AMR system, the cows may be gathered in a confined area prior to milking, here called waiting area (WA). In such a batch milking system, it is essential that cows are moving voluntary from the waiting area into the parlour. A low animal flow resulting in long waiting time in the WA is not only bad for the economy, it is also likely a stressful environment for the cow (Dijkstra *et al.*, 2012). The flow of animals entering the AMR, as well as the interactions between them, can be affected by various designs of the entrance area of the milking parlour (Wierenga, 1990; Dahlgren, 2013)

It is important to find solutions, making the voluntary movement of cows in the barn more efficient and thereby improving the situation for both the farmer and the animals. In this study, the chosen area for investigations regarding the movement of cows are the WA in an AMR, but the results may be applied in any situation where a queuing situation may arise. Investigations regarding the design of the waiting area and the behaviour of the cows in confined situations are therefore of importance. One way of improving the way cows are entering the parlour, or any other situation where the cows are queuing is by using a parallel guiding of animals in front of the rotary. Parallel guiding is the use of railings to separate the cows. Because of this, the present study examines dairy cow behaviour, milking time and labour in an AMR with two different waiting area designs: with parallel guiding (WP) or no parallel guiding (NP).

## 2 Literature review

### 2.1 Waiting area

The productivity of an automatic milking system depends on the productivity of the milking equipment and the intensity of the cow traffic (Mangalis *et al.*, 2015). The ideal would be that each cow would occupy the milking place in due time, not reducing or stopping the rotation speed (Mangalis *et al.*, 2015). A well-planned WA is the key to a fast and efficient entrance into the parlour (Albright *et al.*, 1992). The WA is an area in front of the milking unit where the cows usually are gathered and held prior to milking. The characteristics of the WA differs between systems. It can be a closed WA where the only way out is through the milking unit (Hermans *et al.*, 2003), or an open WA where the cows have the opportunity to return to the resting area (Melin *et al.*, 2006). Some systems do not even have a WA, the selection is then performed in the milking unit (Stefanowska *et al.*, 1999a) or in a selection gate located in front of the milking unit (Stefanowska *et al.*, 1999b). Advantages with a closed WA are that it ensures that all cows go through the milking unit (Uetake *et al.*, 1997) and that it encourages the flow of queuing cows through the milking system (Jacobs *et al.*, 2012).

The waiting area should be dimensioned according to the throughput of the milking system (Albright & Arave, 1997). The International Commission of Agricultural and Biosystems Engineering recommend 1.4-2.0 m<sup>2</sup> per cow (Flaba *et al.*, 2014). Consequently, it is the size of the milking herd, which is dependent on milking time and size of the milking parlour, that decides the total size of the waiting area (Fernández *et al.*, 2009). Mangalis *et al.* (2015) concluded that cow crowding in the WA has an impact on the intensity of cow traffic. For instance, if the crowding was 1.1-1.2 m<sup>2</sup> per cow in a WA with mechanic drivers, the traffic intensity was higher compared to a crowding of 1.5-1.7 m<sup>2</sup> (Mangalis *et al.*, 2015). Generally, higher stocking densities have been found to potentially reduce the welfare due to an increased frequency of agonistic interactions because of competition over resources (Metz & Mekking, 1984; Fregonesi & Leaver, 2002). Kondo *et al.* (1989) found that the number of agonistic encounters decreased if space allowance increased.

In order to ensure a high and continuous cow traffic entering the rotary platform and to make the staff labour easier, mechanical drivers (crowding gate) can be used (Mangalis *et al.*, 2014). These mechanical drivers crowd the cows in the WA by reducing available space (Albright *et al.*, 1992), ensuring a continuous movement into the milking unit (Mangalis *et al.*, 2015). The mechanical drivers keep the stocking density stable, even though cows are leaving the WA. Mangalis *et al.* (2015) state that excess cow crowding has been found to promote the occurrence of stressful situations when cows are entering a rotary type milking equipment. For example, a situation where two cows are trying to enter the milking equipment at the same time (Mangalis *et al.*, 2015).

A master thesis by Andersson (2014) examined the behaviour and throughput of dairy cows when entering and exiting two types of parallel rotaries. The two types of rotaries had either a one-cow entry lane or a 1.5-cow entry lane. In the one-cow entry lane, the cows had to walk one after the other to the rotary. The 1.5-cow entry lane was wider, resulting in cows being able

to pass each other before entering the platform. She found no difference in behaviour of the cows between the two rotaries, except for more pushing being performed in 1.5 cow entry lane.

The master theses by Dalemar (2017) and Dahlgren (2013) studied differently shaped waiting areas at the same location as the present study. Dalemar (2017) compared single alley and open waiting area. Dahlgren (2013) compared a large waiting area, a reduced waiting area and a single alley. The results of the two different master theses were contradictory, Dahlgren (2013) concluded that the use of the single alley design decreased the frequency of aggressive interactions as well as time spent herding cows. Dalemar (2017) did on the other hand conclude that aggressive interactions were more frequent in the single alley design compared to the open waiting area.

## 2.2 Behaviour and social dominance

The complex of relationships found in groups of animals, which is the result of the phenomenon that one animals' behaviour within a pair can be inhibited by the other, is called social order, rank order, dominance, or hierarchy (Beilharz & Zeeb, 1982). When establishing these relationships, many factors are involved. Once formed, they are usually stable for a long time (Beilharz & Zeeb, 1982; Wierenga, 1990). Regarding these influencing factors, the literature is inconsistent. Philips and Rind (2002) used the term dominance value. This value was attributed to a cow, based on at least one aggressive interaction with at least ten other cows and can be seen as a measure of social dominance. In the study, dominance value was positively correlated with parity number as well as body weight. O'Connell *et al.* (1989) found that age was related to social rank. But in a study by Ketelaar-de Lauwere *et al.* (1996), social rank and age or parity number showed no correlation, but social rank and days in milk were positively correlated. The lack of correlation between social rank and age or parity number could be explained by the fact that all cows in the study were in their first to third lactation (Ketelaar-de Lauwere *et al.*, 1996). Due to the fact that it has been observed that dominance values differ over the years for cows (Wierenga, 1990), it is difficult to state if dominance values are affected by age or parity number. Several authors have found no correlations between dominance value and milk yield (Collis, 1976; Ketelaar-de Lauwere *et al.*, 1996; Phillips & Rind, 2002). Cows in late gestation tend to avoid agonistic interactions. Hence, stage of gestations might be a factor that influences the dominance status of a cow (Beilharz & Zeeb, 1982). Body weight is another factor, found by several authors to correlate to social rank (Wagnon *et al.*, 1966; Dickson *et al.*, 1967a; Bouissou, 1972). Bouissou (1972) studied the influence of body weight and horns on social rank during the establishment of social hierarchy in heifers. It was concluded that horns were the major affecting factor, although both factors were of importance.

Beilharz and Zeeb (1982) highlight the importance of separating social dominance and aggression. Dominance is present whenever the behaviour of one animal is inhibited in the presence of another animal. Aggression does on the other hand involve motivation and behaviours that result in repelling other animals. It can be described as an interaction where a butt or push is performed against another cow (DeVries & von Keyserlingk, 2006). Aggression might be involved when dominance relationships are established, but a high ranked cow is not

necessarily aggressive once stable relationships are formed (Beilharz & Zeeb, 1982). Although, it is shown that the subordinate animal showed fewer displacements than the dominant animal in 95% of all pairs (Wierenga, 1990). Moreover, Collis (1976) found that the animals dominance value and amount of initiated aggressive interactions were positively correlated. But there are situations where the subordinate animal can displace the dominant animal and this action is more common in situations of overcrowding (Wierenga, 1990).

Cows do often have to stand during long periods of time, waiting in the WA. The dominance value and arrangement of cow traffic affects this waiting time (Thune *et al.*, 2002). Due to this waiting, the WA is likely to be a stressful environment for the cows; they are restricted from performing many behaviours such as feeding, eating and lying down, and furthermore is the locomotion activity reduced (Dijkstra *et al.*, 2012). The cow's daily budget of behaviours is negatively affected by this waiting. It can result in behaviours being lost from their daily repertoire (Dijkstra *et al.*, 2012). The restriction in performing these lost behaviours may cause stress (Dijkstra *et al.*, 2012), which is shown to impair health, welfare and productivity. In a behavioural study by Dijkstra *et al.* (2012) it was found that the most prevalent activity in the WA was rumination. In average, 30-50% of the cows ruminated while waiting. The majority of rumination was seen in the WA with the smallest group size, shortest waiting time and the largest space per cow (Dijkstra *et al.*, 2012). The presence of rumination can be seen as an indicator of the absence of stress, since only healthy and unstressed animals ruminate normally (Dado & Allen, 1994; Lidfors, 1996). However, as the animals in the study were not individually identified, it couldn't be said if the cows started ruminating as time elapsed or if the ruminating cows were performing the behaviour throughout the waiting time and were among the cows remaining last in the WA (Dijkstra *et al.*, 2012). Other behaviours such as aggression, self-grooming, cows grooming another cow, mounting and vocalization seemed to be poorly expressed in the WA. These behaviours occurred below 2% among the cows. Dijkstra *et al.* (2012) concluded that the percentage of these behaviours decreased as the group size in the WA decreased. This could be the result of the social environment in the WA being less stressful for the remaining cows as other cows exit (Dijkstra *et al.*, 2012).

It is important that the cow has time to perform the behaviour of lying down. Rushen & de Passillé (1999) states that high producing dairy cows spend approximately 40% or 50% of their day laying down to ensure high production. When cows lay down, the blood flow to the udder doubles and the rumination lasts for longer periods. Hence, a decreased waiting time, resulting in more time lying down and ruminating, can improve productivity (Rushen & de Passillé, 1999) as well as health status (Galindo & Broom, 2000). It has also been shown that increased time spent standing (Galindo & Broom, 2000) and time away from the resting area (Cook & Nordlund, 2009) give increased risk as well as incidents of lameness. Lameness does not only cause pain, it can also negatively affect the cows' motivation to visit the milking unit since lameness limits their movements (Klaas *et al.*, 2003).

### 2.3 Labour

One of the largest costs in dairy production is the cost of labour (Gustafsson, 2009). In Sweden, labour has been found to constitute around 24% of the total cost per kg ECM (Hedlund, 2008).

The amount of labour needed is decreasing with increasing herd size (Hadley *et al.*, 2002; O'Donovan *et al.*, 2008; Gustafsson, 2009) and is dependent on work routines and automated tasks (O'Brien *et al.*, 2012). A study by O'Brien *et al.* (2007) indicated that larger farms tend to use more labour efficient technologies, such as better facilities and less intensive work routines compared to the more traditional labour-intensive methods. A study by O'Donovan *et al.* (2008) states that labour input per cow had decreased with a rate of approximately 1 h per year over 20 years when the results of the study were compared to data of O'Shea *et al.* (1988).

The AMS requires that cows voluntarily enter the robot or rotary without assistance from staff in order to be efficient (Jacobs *et al.*, 2012). If the cow does not voluntarily visit the AMS, the farmer has to manually fetch the cow. This does also apply to systems where the cows are gathered in a WA prior to milking. Fetching a small number of cows requires minimal effort and can in many barns be combined with other tasks such as cleaning (Rodenburg, 2017). Fetching a larger number of cows requires more labour and interferes with the voluntary traffic to the robot (Rodenburg, 2017) and results in economic losses (Drach *et al.*, 2017). The need to fetch cows could be one of the largest factors reducing the expected decrease in labour when converting to AMS (Bach *et al.*, 2007).

Investigations regarding the willingness of cows to voluntarily enter a milking parlour (non AMS), performed by Albright *et al.* (1992), showed that only 21.4% of the cows in the study voluntary or by vocal request by the farmer entered the parlour. More recently, in a Canadian survey of 43 herds in robotic systems, it was reported that  $14.6 \pm 10.3$  % of the cows needed fetching once or twice per day. In that study, the producers reported that the top three reasons for fetching were; "lazy cows" (57.6%), lame cows (19.0%) or due to cows that were new to the system (11.0%) (Rodenburg & House, 2007). In an even more recent study by King *et al.* (2016), data from 41 Canadian AMS herds showed a lower fetching rate, where  $8.1 \pm 6.7$  % of the cows were fetched at least once a day. It has also been observed that voluntary entering increased as weeks in lactation increased (Jacobs & Siegford, 2012b). After the first week of lactation, 60% of the cows entered milking voluntary. This increased to 75% after two weeks. One month after introduction to the AMS, 95% of the cows voluntarily entered the milking. Cows that were deemed unsuitable, based on teat and udder conformation, needed to be fetched more often (Jacobs & Siegford, 2012b).

Type of cow traffic has an impact on the fetching frequency. The number of fetched cows was considerably higher in free cow traffic compared to forced (Ketelaar-de Lauwere *et al.*, 1998; Rodenburg & House, 2007; Forsberg, 2008). In a study by Rodenburg and House (2007) farms with free cow traffic reported an average of 16.2% fetched cows, while farms with some kind of guided cow traffic fetched on average 8.52% of the cows once or twice daily. Rodenburg (2017) found similar results regarding free and guided cow traffic when excellent management was applied or when the number of cows was well below the capacity of the robot. When circumstances were less ideal and the guided traffic was combined with a waiting area it resulted in longer standing times and stress, especially for the low ranked cows. If the

management was poor when free cow traffic was conducted, more labour was needed for fetching.

### Working safety

According to 3§ in the Swedish work environment regulations on animal work state that the buildings where animals are kept should be dimensioned and maintained so that working with animals offers safety (AFS 2008:17). Further, 4§ states that if the animals are kept in loose housing systems, the staff must be able to quickly get away safely. According to 9§ regarding driving paths, trusses, gates and other aids shall offer the possibility of protection or escape routes for those who perform the work of moving animals (AFS 2008:17).

A survey among 110 dairy producers in Minnesota reports that the producers view was that cattle-related injuries predominantly were the handlers fault. Either because of lacking attention to the animal or due to poor cattle handling skills. The least important factor regarding the worker injuries was considered the facility design (Sorge *et al.*, 2014). A study on 12 dairy farmers with loose housing systems states that the producers considered the facilities to be of importance for the safety when handling cattle. Especially old facilities were considered to be a risk regarding the safety. Escape routes for the handler and gates with horizontal rails that are easy to climb were among other factors mentioned by the farmers to be of importance in making a facility safer (Lindahl *et al.*, 2012).

## 2.4 Milking and waiting time

Milking is the most time-consuming task on a dairy farm (O'Donovan *et al.*, 2008; Taylor *et al.*, 2009). For instance, it required up to 57% of farm labour when 20 farms in New Zealand using batch milking in grazing dairy systems were studied (Taylor *et al.*, 2009). A reduced need for labour regarding the daily milking routines and less heavy work are reasons for using an AMS (Stal *et al.*, 2003; Jacobs & Siegford, 2012a). A survey among 107 farmers that recently invested in an AMS in Belgium, Denmark, Germany and The Netherlands reported an average labour saving of 19.8% (Mathijs, 2004). When only farms that had kept their herd size more or less stable were considered, the average labour saving was increased to 21.3% (Mathijs, 2004). A study by Gustafsson (2009) comparing working time in various milking systems found that batch milking systems, such as tandem/herringbone/parallel/rotary, are the most time-consuming systems while AMS require the least time per cow. The rotary parlour required 2.15 minutes per milked cow, which is the lowest time for labour associated with milking of all batch milking systems (Gustafsson, 2009).

The waiting time, which is time spent in waiting area prior to milking, in the study by Dijkstra *et al.* (2012) varied from 1 minute to almost 2 hours. Dijkstra *et al.* (2012) examined three cowsheds. The first cowshed consisted of 519 dairy cows with a mean annual milk production of 6374 kg per cow. The cows were divided into four groups according to milk yield. The cows in cowshed 1 were milked in a 2 x 12 DeLaval tandem milking parlour twice a day. The mean initial space in the WA were 1.5 m<sup>2</sup> per cow. The second cowshed consisted of 561 dairy cows with a mean annual milk production of 7916 kg per cow. The cows were divided into two

groups according to milk yield and milked in a 2 x 20 Strankgo tandem milking parlour three times a day and had an mean initial space in the WA of 1.1 m<sup>2</sup> per cow. The third cowshed consisted of 693 dairy cows divided into five groups according to milk yield with a mean annual milk production of 7675 kg per cow. The cows were milked in a 2 x 12 DeLeval tandem milking parlour three times a day. The mean initial space in the WA were 1.9 m<sup>2</sup> per cow. All three cowsheds used automated crowd gates in the WA. The cows were gathered in the WA prior to milking. The mean waiting time in the three cowsheds was 44, 63 and 27 minutes respectively. Social rank and cow traffic arrangement have been found to affect the waiting time. Submissive and dominant cows had an average waiting time of 95 and 78 minutes respectively in a free cow traffic system, against 240 and 140 minutes respectively with guided cow traffic (Thune *et al.*, 2002). Halachmi (2009) investigated the effect of hierarchal order on cow queue length when cows voluntary visited an AMS. The mean waiting time in the queue to the AMS was 69 minutes for low ranked cows and only 3.5 minutes for the high ranked cows in an AMS. Melin *et al.* (2006) did also observe that low ranked cows spent longer time in the waiting area to an AMS. A study using a prototype of a robotic rotary reported a median waiting time before milking of 129 min, and just over 70% of the cows had entered the rotary after 4 h (Scott *et al.*, 2014). Scott *et al.* (2014) report that heifers exited the waiting area more rapidly compared to cows later in lactation and that older cows spend at least 1.4 times longer in the WA.

The degree of motivation to enter the milking unit is essential for effective cow traffic (Melin *et al.*, 2006). Prescott *et al.* (1998) found that the motivation to be milked is variable between cows, but overall, the motivation is weak. The conclusion was that the motivation to be milked is not enough to attract the cows to an AMS. Compared to being milked, feeding is significantly more rewarding and could be used to motivate cows to be milked (Prescott *et al.*, 1998). In contrast to this, concluded Melin *et al.* (2006) that both the motivation to milked and to be fed are significant motivations in attracting a cow to the milking unit in an automatic milking system. However, it was concluded that a high motivation to feed was given priority over the motivation to be milked. Kolbach *et al.* (2013) found that the proportions of bails that were occupied in a robotic rotary were significantly higher when the cows were fed in the bail. Since feeding contributed to voluntary entry to the milking unit, it was concluded that feeding could avoid delays in cow traffic (Kolbach *et al.*, 2013). In a study by Scott *et al.* (2014), the time spent waiting was nearly halved when the cows were offered feed in a prototype of a robotic rotary compared to no feed. Pirkelmann (1992) concluded that the cows could be motivated not only by supplying concentrate or roughage in the milking unit, but also by locating the milking unit between the lying area and the feeding area when forced cow traffic is conducted.

The entrance order into the milking unit has been found to be relatively constant by several authors (Rathore, 1982; Grasso *et al.*, 2007). Rathore (1982) found that high yielding cows voluntarily entered the milking unit earlier than low yielding cows. This is supported by several more recent studies, also concluding that high yielding cows enter the milking parlour first (Albright *et al.*, 1992; Phillips & Rind, 2002; Grasso *et al.*, 2007; Berry & McCarthy, 2012). Milking order in an AMS is also influenced by dominance. Low ranked cows spent longer time in the WA compared to high ranked cows (Ketelaar-de Lauwere *et al.*, 1996; Phillips & Rind, 2002; Melin *et al.*, 2006). Furthermore, health status does also affect the order of entrance.

Cows with health problems such as lameness (Main *et al.*, 2010) and udder diseases tend to enter the milking parlour towards the end of the milking (Dijkstra *et al.*, 2012) and cows entering early have been found to have lower somatic cell count (Rathore, 1982; Berry & McCarthy, 2012). Hence, high yielding healthy cows tend to enter the milking unit first, while lame and low yielding cows enter last.

## 2.5 Factors affecting milk yield

Mixing groups of cows do sometimes result in a reduction in milk yield, but there are great variations between studies. Jezierski and Podluzny (1984) report a mean decrease in milk yield of approximately 4% due to social tensions after a group change. Phillips and Rind (2001) investigated the effect of mixing primi- and multiparous cows during grazing on the milk production. The mixing of primi- and multiparous cows resulted in a reduction in milk yield, which probably was due to reduced grazing time and increased standing time. Collis *et al.* (1979) found no change in milk yield despite an increase in aggression due to minor regroupings.



### 3 Aim and hypotheses

The aim of this study was to compare cow traffic, social interactions, milking efficiency and working environment and time with or without a so-called parallel guiding of cows for milking in an AMR. The hypotheses were that the parallel guiding: 1) would give a better working environment because of a higher frequency of voluntary entrance to the AMR and consequently a reduced working time fetching cows, 2) would make the milking more efficient because of a higher animal flow through the AMR and that 3) aggressive behaviour would be less frequent when the WA had parallel guiding.

## 4 Material and methods

### 4.1 Animals, Management, and Housing

The study was performed at the Swedish Livestock Research Centre at Lövsta, Swedish University of Agricultural Sciences, Uppsala. Two groups of cows (G1 and G2) of both Swedish Red (SRB) and Swedish Holstein (SH) breed were used in the study, approximately 120 dairy cows in total. The reason for the group arrangement were the already established housing of cows in the barn, the two groups were housed in different pens. All cows were not present during the whole experiment due to regroupings, drying off or for health reasons. Group 1 consisted mainly of primiparous cows and G2 consisted of both primi- and multiparous cows. The characteristics of each group are described in table 1. No correlation between body weight and breed was seen, but a slightly positive correlation between body weight and the number of calvings was noted ( $r=0.30372$ ,  $p<.0001$ ).

Table 1. Description of the characteristics of the two groups, G1 and G2. Showing the share of breeds, Swedish Holstein (SH) and Swedish Red (SRB), mean body weight and mean milk yield.

	G1		G2	
Breed	48% SH	52% SRB	38% SH	62% SRB
Body weight (mean)	588 kg		634 kg	
Milk yield (mean per milking)	15 kg		16 kg	
Share of primiparous cows	Mainly primiparous cows		Both primi- and multiparous cows	

In each group, 20 focal animals were marked, by painting the number of the cow on the back of the animal, approximately every second day. These cows were selected, looking for normal distribution regarding days in lactation. As G2 consisted of both primi- and multiparous cows, 10 primiparous and 10 multiparous cows were marked. There was a positive correlation between body weight and the number of calvings regarding the focal animals ( $r=0.45285$ ,  $p<.0001$ ).

Each group was batch milked twice daily, G1 first and G2 secondly, at approximately 05:30 and 15:30, in the DeLaval Automatic Milking Rotary™ (AMR™). The AMR had a platform containing 24 milking places and 5 robotic arms. Two out of these five robotic arms prepared the udder by cleaning and pre-milking the teats. Two robotic arms attached the teat cups and one robotic arm sprayed the teats after milking. The milking was performed on quarter level. The working time for the robotic arms for cleaning and pre-milking was 35s. The arms that attached teat cups had a maximum working time of 50s and the arm applying teat spray operated during 30s. The AMR had a time-out set for 60s, meaning that the AMR would rotate one milking place if it had been inactive, i.e. no cow had entered the available milking place, for 60s.

The cows in the study were housed in a free-stall system, separated in two pens with a stocking density of  $\leq 1:1$  (cow:cubicle). Each group of animals had four concentrate feeders, where the cows were fed concentrates according to their calculated requirements in relation to their individual milk yield. The cows were fed silage *ad lib.* but the number of feeding places differed

between the groups, G1 had an cow:feeding place ratio of 3:1 whereas G2 had a ratio of 2:1. A rough overview of the barn is shown in figure 1.

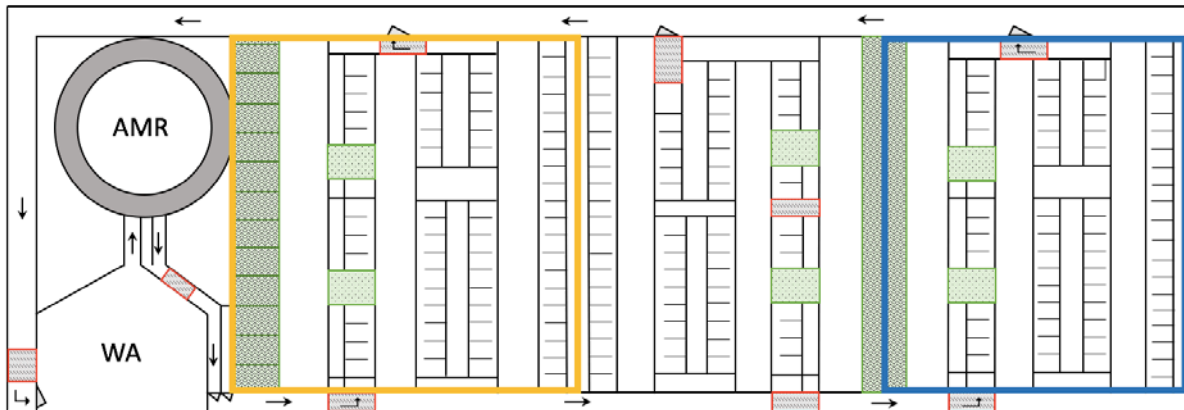


Figure 1. A rough overview of the whole cow barn. The yellow and blue outlines the pen where G1 resp. G2 were housed. The red boxes are selection gates, the green boxes are feeding places (waved) and concentrate feeders (dotted). The arrows indicate the way cows move to and from milking.

#### 4.2 Study design

In this study, two differently designed waiting areas were studied; an open waiting area with or without parallel guiding of cows for milking in an AMR. A crowd gate, automatically decreasing the available space in the waiting area was used in both treatments. The parallel guiding consisted of two railings (approximately 2m x 1.7m and 2.5m x 1.7m, respectively) in front of the entrance to the AMR (fig. 2), creating what could be seen as three corridors in front of the AMR. During the video analysis it was noted if the action was performed in the backward or forward area of the waiting area (fig. 3). This separation was only a theoretical separation, not a physical separation of the waiting area.

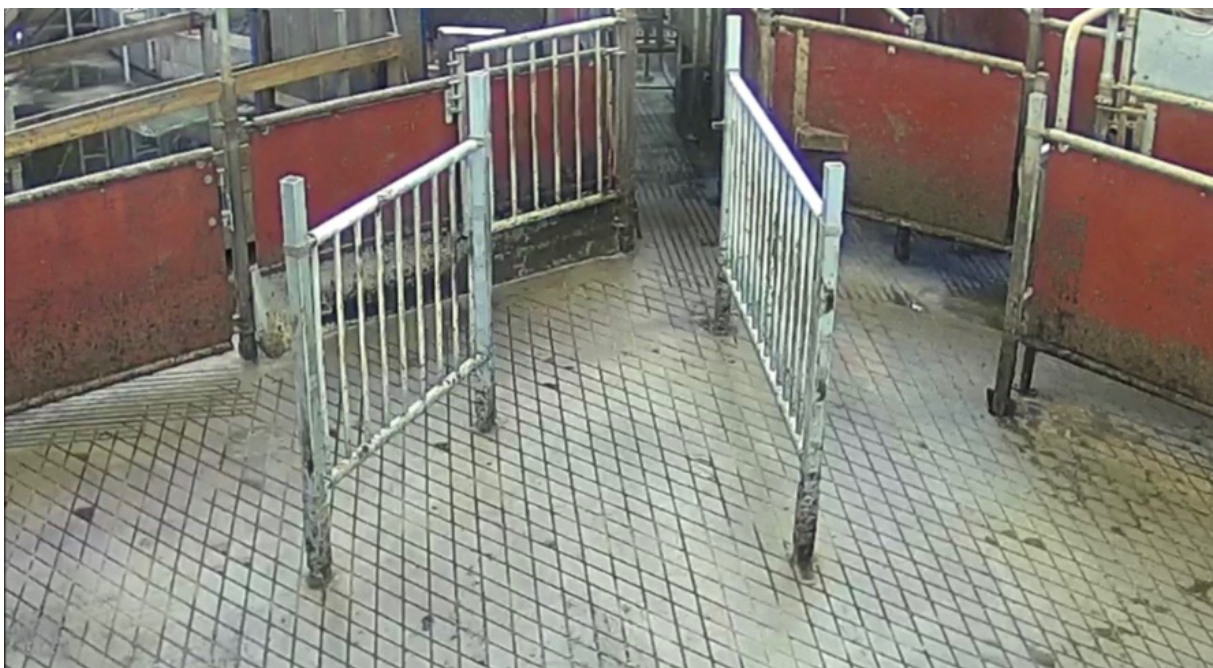


Figure 2. The picture shows the placement and design of the two railings used in the parallel guiding treatment.

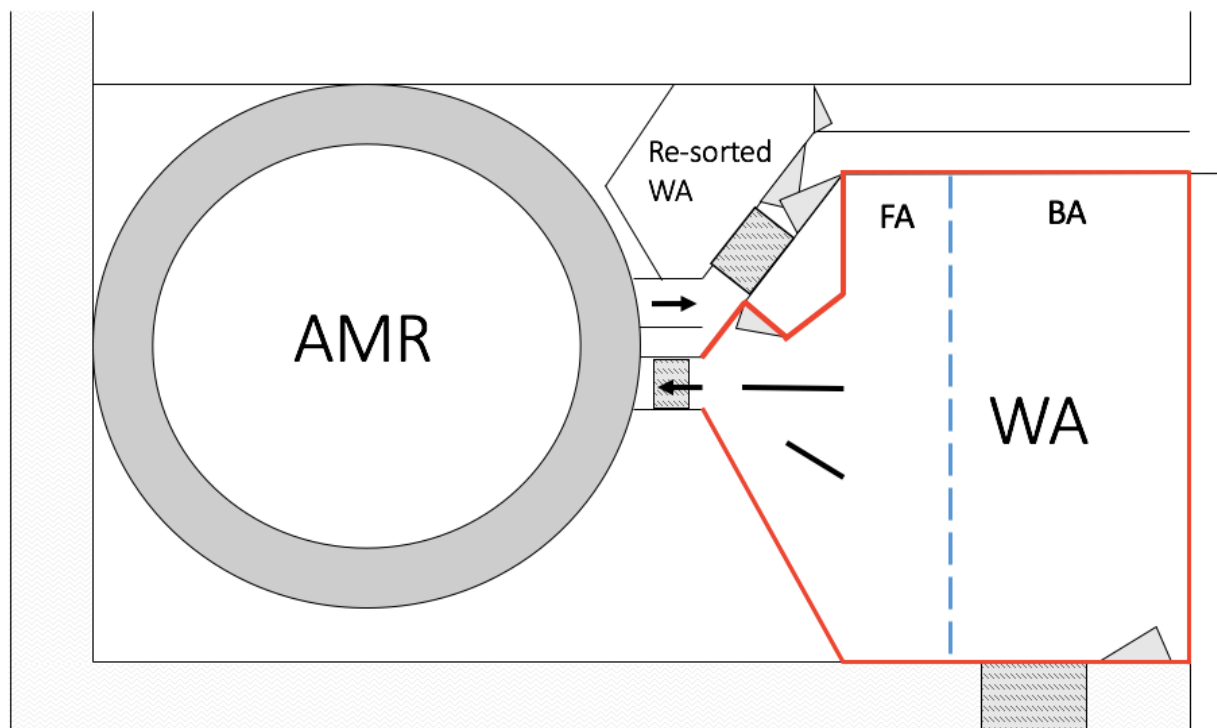


Figure 3. Indicates placement of the two railings and outlines the WA. The blue line shows the theoretical separation of the forward area (FA) and backward area (BA) and red lines mark the outline of the WA. The railings are indicated by the two black lines in the FA. Three cow identifying portals are plotted, marked by small black lines; one is located in the raceway to the WA, one at the entrance to the AMR, and one after milking where the cows are either redirected back to the AMR, back to the feeding area in respective pens or to the re-sorted WA to the left. Arrows show entrance and exit in the AMR.

Each treatment was repeated twice during two week periods in 8 consecutive weeks; data was collected the second week in each period. Hence, 14 milkings (morning and afternoon) was recorded each data collection week for each group. Out of these 14 milkings, the last 6 fully functioning milkings for each group were chosen to be studied, resulting in 48 group milkings being studied in total. This is visualised in table 2.

Table 2. Visualisation of the study layout for data collection during the two treatments, with parallel guiding (WP) and no parallel guiding (NP) for the two groups, *G1* and *G2*. The first week was habituation (H) and during the second week data from 6 milkings (m) per group were collected. This was performed twice for each treatment.

	NP		WP		NP		WP		Total
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	
<i>G1</i>	H	6 m	H	6 m	H	6 m	H	6 m	24
<i>G2</i>	H	6 m	H	6 m	H	6 m	H	6 m	24
									48

#### 4.2.1 Milking routines

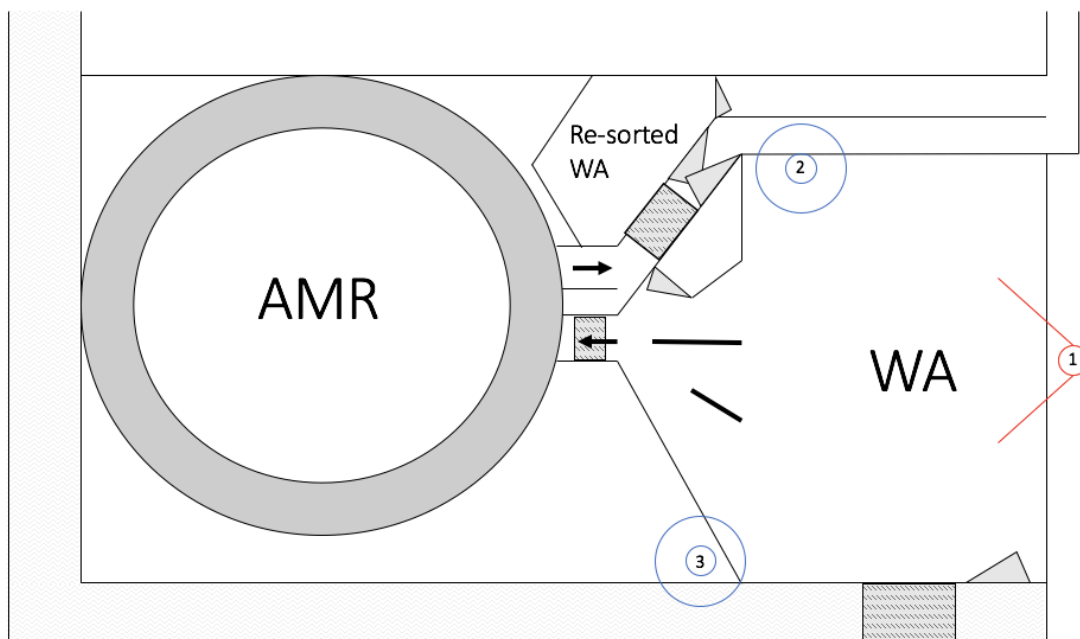
The staff gathered the 60 cows from one pen to the waiting area prior to milking. When the gate to the waiting area was closed behind the cows, the staff were not allowed to intervene with the cows for 40 minutes. If the AMR had been inactive for 10 minutes, an exception was made and the staff was allowed to look for the reason for inactivity. In that case, the staff was for instance allowed to herd the cow blocking the entrance to the AMR. When 40 minutes had passed, the staff could complete the milking according to normal milking routines. Cows that did not complete the milking was automatically re-sorted once back to the waiting area. If the cow were not completely milked despite the resorting, she was directed to a separate waiting area for re-sorted cows. These cows were brought back to the WA by the staff at the end of the milking. Cows that needed any special treatment or had an udder not appropriate for the AMR was set for manual milking and redirected to the waiting area for re-sorted cows.

Exceptions to the routines were made once a week when CMT (California Mastitis Test) and bacteria test were performed. Cows that were new to the system were excluded from the mentioned routines; during the first four consecutive milkings, a complete udder emptying was performed.

#### 4.3 Data collection

##### 4.3.1 Behaviour registrations

Behaviours were registered by three surveillance cameras. The three cameras were placed overlooking the WA (fig. 4). Two were placed on the sides of the WA (Fisheye view, SAMSUNG SNF-8010VMP) and the third was placed overlooking the WA and the entrance to the WA (regular view, SAMSUNG QNV-7010RP).



*Figure 4.* The numbers indicate where cameras were located. Number 1 was the regular surveillance camera and number 2 and 3 were the fisheye cameras. Note that the visual field is not marked on the drawing. All view fields were overlapping.

The behaviour registrations were recorded continuously through observations of recorded videos. The behavioural observation started when the first cow entered the WA and ended at staff's first interaction (approximately 40 minutes after closed gate). The ethogram used for behaviour observations is shown in table 3. The ethogram in table 3 is the same as in the master thesis by Dalemar (2017) with the addition of mounting, attempt to mount and licking. Both the animal performing the behaviour and the animal receiving the behaviour was noted. During each experimental treatment, six milkings were analysed for social behaviours. It was also noted if the behaviour was performed in the backward or forward area of the WA (fig. 3).

*Table 3.* Ethogram of behaviours and definition used for analysing. Including description of each behaviour and source of behaviour and the description. Partly modified from Dalemar (2017).

<b>Behaviour</b>	<b>Description</b>	<b>Author and study</b>
Butting	Punch with head on the body of another cow. Usually neck, shoulder or rump. Short time behaviour, less than 1s. If there are several actions during 3s it will be calculated as one interaction.	Dickson et al. (1967), Reinhardt et al. (1978), and Bouissou et al. (2001).
Pushing	Pressing body against on another cows' body and giving a push. Registered if it occurs for a longer time (2s or more).	Rousing and Wemelsfelder (2006).
Displacement	When a butt or push from a cow results in a withdrawn from the attacked animal. Registered when a cow flee from the actor cow, or trying to.	Huzzey et al. (2006), and DeVires et al. (2004).
Mounting	Raising the anterior part of the body onto the body of another cow.	Hurnik et al. (1995), Reinhardt et al. (1978) and Dahlgren (2013)
Attempt to mount	Attempt to mount that not succeeds, e.g. falls of or the receiving animals flees before succeeded mounting.	Hurnik et al. (1995) and Dahlgren (2013).
Licking	The tongue is slid over the surface of an object or animal.	Hurnik et al. (1995)

#### 4.3.2 Staff interactions

Staff interactions was analysed from continuous observations of recorded videos, starting from staff's first interaction to the last cow entering the AMR. The number of animals left at the time for the staffs first interaction and working time was noted. Staffs interactions were observed according to table 4.

*Table 4.* Definition of the observed interactions performed by staff.

<b>Type of interaction</b>	<b>Description</b>
Physical	Physically touching the cow. One interaction is >10 s. Hence, six interactions on the same cow can be observed during one minute.
Body language	When the staff by gestures or other non-physical actions affect the cow to move.

#### 4.3.3 Milking time registrations

The herd management software DelPro TM (DeLaval International AB, Tumba, Sweden) collected data regarding the gate passages automatically. This information resulted in individual time intervals for each cow and treatment. Three data sets for investigating *total walking and waiting time before milking*, *time in waiting area* and *total time for milking* were analysed.

*Total walking and waiting time before milking* corresponds to the time from when the cow left the pen until she entered the AMR. *Time in waiting area* corresponds to the time from when she entered the WA until she entered the AMR. The time from the cow left the pen until she entered the pen again after milking is referred to as *total time for milking*.

Two time intervals were retrieved from the videos. These were *the total time in the waiting area for the whole group* and *total time for labour*. *Total time in the waiting area for the whole milking* is the waiting time for the whole group and was calculated from the first animal entered the WA in the video recordings until the last animal entered the AMR. The time from staff's first interaction, after the 40 minutes with no interactions, to the last animal to enter the AMR is referred to as *time for labour*. It should be noted that this is the whole time interval between first interaction to last animal to enter the AMR, not only the time staff is actively there.

#### 4.4 Statistical analysis

Each cow was grouped according to body weight into three classes of similar size; weight class I <600 kg, weight class II <660 kg and weight class III >660 kg. For each cow, days in lactation (DIM) was calculated as the number of days from calving to the date when each milking was performed. The cows were divided into five DIM classes with a similar number of cows in each; DIM class I <100 days, DIM class II < 150 days, DIM class III < 190 days, DIM class IV <230 and DIM class V >230 days. Regarding the number of calves, the cows were grouped in two classes, either primiparous or multiparous cows.

##### 4.4.1 Behaviour

For analysis of behaviour data as described in table 3, the number of behaviours was registered in Microsoft Excel (2016). The frequency of each behaviour was summarized for each treatment day and group (*G1* and *G2*). The frequency of the behaviours was used to compare treatments and groups (*G1* and *G2*) with a Student's paired t-test in Excel. Differences between the two groups of cows and treatments are presented as MEAN ± STDEV.

The behaviour registrations in Microsoft Excel (2016) was merged with data of days in milk, number of calvings and body weight. A chi-square test within the FREQ procedure (SAS 9.4, SAS Inst. Inc., Cary, NC, USA) was used to see what characteristics the cow that performed or received a behaviour. The share of cows with a certain characteristic that is performing or receiving a behaviour are presented as percentages. Due to the characteristics of the groups, this was only analysed for *G2* where the focal animals were both primi- and multiparous cows.

#### 4.4.2 Staff interaction

Registrations of staff interaction were registered in Microsoft Excel (2016). The number of staff interactions was summarized for each treatment and group (*G1* and *G2*). Total staff interaction time was calculated using registered time from Microsoft Excel. The frequency of the interactions as well as the time intervals were used to compare treatments and groups (*G1* and *G2*) with a Student's paired t-test in Excel. Differences between the two groups of cows and treatments are presented as MEAN ± STDEV.

The staff interaction registrations in Microsoft Excel (2016) was merged with data of number of calvings, days in milk and body weight. The cows were divided into three body weight classes and five classes depending on days in milk with close to equal number of cows in each, as in the behaviour analysis. A chi-square test within the FREQ procedure (SAS 9.4, SAS Inst. Inc., Cary, NC, USA) was used to see what characteristics the cow that was left when staffs first interaction was performed and those who needed interactions. The share of cows with a certain characteristic are presented as percentages. Due to the characteristics of the groups, this was only analysed for *G2* where the focal animals were both primi- and multiparous cows.

#### 4.4.3 Time intervals

The data from the herd management software DelPro TM was through Microsoft Excel adjusted to fit SAS. The effect of treatment, number of calvings, days in milk and body weight on total walking and waiting time before milking, time in waiting area and total time for milking was tested with a linear mixed model (SAS 9.4, SAS Inst. Inc., Cary, NC, USA). The statistical model included the fixed effects of treatment, group, days in milk, number of calvings and body weight. Interaction effect of treatment × group was used. Solution was used in the model statement to see the effect of the significant results. Data on time intervals are retrieved from individual time intervals for each cow and is presented as LSMEAN ± SE.

#### 4.4.4 Order of entrance

Factors affecting milking order were investigated with proc MIXED and proc CORR in SAS. First, each cow was ranked according to the entrance time; the cow entering the AMR first received a 1 and the second received a 2 and so on. The statistical model included the fixed effects of the number of calvings, days in milk, body weight and milk yield. The same fixed effects were used to test any correlations.

#### 4.4.5 Milk yield

The effect of treatment, group and the interaction effect of treatment × group on milk yield was tested with proc MIXED in SAS. Cow was included as a repeated measure and compound symmetry was added to correct for the date.



## 5 Results

Not all gate passages were registered in DelPro™, which resulted in some time intervals could not be retrieved for each cow. The number of cows registered in each time interval is shown in table 5.

*Table 5.* Mean number of cows per group registered in each time interval during the studied milkings. In each group a maximum of approximately 60 cows could have been registered.

Time interval	Number of registered cows (mean ± STDEV)
Total walking and waiting time before milking	49 ± 9.7
Time in waiting area	49 ± 9.7
Total time for milking	54 ± 7.6

### 5.1 Behavioural analysis

When all behaviours were considered, more behaviours occurred in the no parallel guiding treatment (NP) compared to the treatment with the parallel guiding (WP) ( $p=0.04$ ; table 6). All of the specific behaviours (butting, pushing, displacement, mounting, and attempt to mount) occurred more often in NP. However, no significant difference between the treatments was found (table 6). A difference in the number of behaviours was found between treatments for G1 ( $p=0.03$ ; table 7) and for treatment NP between G1 and G2 ( $p=0.04$ ; table 7).

*Table 6.* Mean number of behaviours performed in the two treatments, with (WP) or without parallel guiding (NP). P-values (t-test) indicating differences between treatments for each behaviour, where \*= ( $p<0.05$ ), \*\* = ( $p<0.01$ ), NS = not significant.

Behaviour	NP (mean ± STDEV)	WP (mean ± STDEV)	P-values
All	34.8 ± 12.4	28.2 ± 8.4	*
Butting	20.6 ± 5.0	19.5 ± 6.1	NS
Pushing	8.8 ± 4.8	6.5 ± 3.1	NS
Displacement	2.0 ± 4.0	0.8 ± 1.2	NS
Mounting	1.5 ± 2.5	0.8 ± 1.6	NS
Attempt to mount	2.2 ± 3.3	0.8 ± 1.6	NS

*Table 7.* Mean number of behaviours performed by the two groups, G1 and G2, in the treatments and significance levels between different comparisons. Groups compare within and between the no parallel guiding treatment (NP) and with parallel guiding treatment (WP). P-values (t-test) indicating differences between treatments for each behaviour, where \*= (p<0.05), \*\* = (p<0.01), NS = not significant.

	Number of behaviours ( Mean $\pm$ STDEV)				Significance level			
	G1		G2		G1	G2	G1 vs. G2	
	NP	WP	NP	WP	NP vs. WP	NP	WP	
All	39.8 $\pm$ 10.3	30.8 $\pm$ 8.5	29.8 $\pm$ 12.6	25.6 $\pm$ 7.7	*	NS	*	NS
Butting	22.2 $\pm$ 4.5	20.8 $\pm$ 5.9	19.1 $\pm$ 5.3	18.1 $\pm$ 6.2	NS	NS	NS	NS
Pushing	10.7 $\pm$ 5.6	6.9 $\pm$ 3.1	7.2 $\pm$ 2.5	5.8 $\pm$ 3.5	NS	NS	NS	NS
Displacement	3.0 $\pm$ 5.0	0.5 $\pm$ 1.2	1.1 $\pm$ 2.6	0.9 $\pm$ 1.8	NS	NS	NS	NS
Mounting	2.1 $\pm$ 2.7	0.8 $\pm$ 1.4	0.8 $\pm$ 2.1	0.9 $\pm$ 1.8	NS	NS	NS	NS
Attempt to mount	2.5 $\pm$ 3	1.3 $\pm$ 2.1	1.8 $\pm$ 3.6	0.3 $\pm$ 0.7	NS	NS	NS	NS

Significant more behaviours were performed in the forward area (FA) compared to the backward area (BA) in both treatments (p<0.01; table 8). Fewer behaviours were performed in BA when WP was compared to NP (8.7  $\pm$  4.9 and 12.5  $\pm$  8.0 respectively, p=0.05; table 8). No difference in the total number of interactions in FA between the treatments. A significant difference between BA and FA was found in nearly all comparisons, the exception was for G2 in NP (p=NS; table 8).

*Table 8.* Mean number of behaviours performed in backward (BA) or forward (FA) area during the two treatments, with parallel guiding (WP) or no parallel guiding (NP). P-values (t-test) indicating differences between treatments for each group and treatment, where \*= (p<0.05), \*\* = (p<0.01), NS = not significant.

	Number of behaviours (Mean $\pm$ STDEV)				Significance level			
	NP		WP		BA	FA	BA vs. FA	
	BA	FA	BA	FA	NP vs. WP	NP	WP	
All	12.5 $\pm$ 8.0	22.6 $\pm$ 8.3	8.7 $\pm$ 4.9	19.5 $\pm$ 7.9	*	NS	**	**
G1	12.2 $\pm$ 7.0	27.6 $\pm$ 6.0	9.3 $\pm$ 5.5	21.4 $\pm$ 8.7	NS	NS	**	**
G2	12.8 $\pm$ 9.3	17.6 $\pm$ 7.3	8 $\pm$ 4.3	17.6 $\pm$ 6.7	NS	NS	NS	**

### 5.1.1 Focal animals

The animal performing a behaviour was in 40% of the cases in weight class I and 37% of the cases in weight class III. Most performed behaviours were by multiparous cows (58%). Regarding the animals performing a behaviour, the number of behaviours increased with increasing DIM class. The animals in DIM class V were in most cases the animal performing a behaviour (40%), DIM class IV performed 32% of the behaviours, DIM class III 19%, DIM class II 6% and DIM class I 3%.

The animal receiving a behaviour was in most cases primiparous cows (63%), the distribution among the weight classes of animals receiving a behaviour was fairly even; weight class I 30%, weight class II 29% and weight class III 41%. Regarding the animals receiving a behaviour, the

number of behaviours increased with increasing DIM class. The animals in DIM class V were in most cases the animal receiving a behaviour (55%), DIM class IV received 19% of the behaviours, DIM class III 10%, DIM class II 9% and DIM class I 7%.

## 5.2 Analysis of staff interaction

The total time for staff interactions was lower in WP compared to NP when both groups were considered ( $p=0.04$ ; table 9). No difference was found in G1 regarding total time for staff interaction. Less time was needed in WP compared to NP in G2 ( $p=0.01$ ; table 9). It was also found that the parallel guiding lowered the total number of interactions needed when both groups ( $p=0.0002$ ; table 10), as well as only G2 ( $p=0.008$ ; table 10), was considered.

*Table 9.* Mean number of minutes from staffs first interaction to last cow entering the milking unit in the two treatments, with parallel guiding (WP) or no parallel guiding (NP). P-values (t-test) indicating differences between treatments, where \* = ( $p<0.05$ ), \*\* = ( $p<0.01$ ), NS = not significant.

	NP (Mean $\pm$ STDEV)	WP (Mean $\pm$ STDEV)	P-value
All	24.5 $\pm$ 8.4	20.1 $\pm$ 6.4	*
G1	18.8 $\pm$ 3.9	18.7 $\pm$ 6.7	NS
G2	26.5 $\pm$ 11.1	21.9 $\pm$ 6.5	**

*Table 10.* Mean number of staff interactions performed after labour started in the two treatments, with parallel guiding (WP) or no parallel guiding (NP). P-values (t-test) indicating differences between treatments, where \* = ( $p<0.05$ ), \*\* = ( $p<0.01$ ), NS = not significant.

Interactions	NP (Mean $\pm$ STDEV)	WP (Mean $\pm$ STDEV)	P-value
All	28.9 $\pm$ 10.7	19.9 $\pm$ 7.6	**
G1	28.5 $\pm$ 13.3	21.3 $\pm$ 6.6	NS
G2	29.3 $\pm$ 8.0	19.3 $\pm$ 8.7	**

The parallel guiding lowered the number of animals left at staffs first interaction in G2 ( $p=0.04$ ; table 11). Group 2 had more animals left when at staffs first interaction compared to G1 in both NP and WP ( $p=0.0002$  and  $p=0.05$ , respectively). Both the time for staff interaction as well as the number of staff interactions were positively correlated with number of animals left at staffs first interaction ( $r=0.749$ ,  $p<.0001$  and  $r=0.417$ ,  $p=0.0032$ , respectively).

*Table 11.* Mean number of animals left at staffs first interaction in the two treatments, with parallel guiding (WP) or no parallel guiding (NP). P-values (t-test) indicating differences between treatments, where \* = ( $p<0.05$ ), \*\* = ( $p<0.01$ ), NS = not significant.

	NP (Mean $\pm$ STDEV)	WP (Mean $\pm$ STDEV)	P-value
All	21.5 $\pm$ 7.0	18.6 $\pm$ 6.3	NS
G1	16.8 $\pm$ 5.2	16.1 $\pm$ 5.8	NS
G2	26.2 $\pm$ 5.3	21.2 $\pm$ 5.9	*

### 5.2.1 Staff interactions per cow

When the number of animals left at staffs first interaction was taken into account regarding the number of staff interactions (table 12) and time (table 13), no differences were found between the treatments. In treatment NP, G2 needed less interactions per cow (IPC) compared to G1 ( $1.1 \pm 0.2$  IPC and  $1.7 \pm 0.9$  IPC respectively;  $p=0.03$ , table 14). Less IPC was also needed for G2 compared to G1 in treatment WP ( $0.9 \pm 0.4$  IPC and  $1.4 \pm 0.3$  IPC respectively;  $p=0.01$ , table 14).

*Table 12.* Mean number of interactions per cow left at staffs first interaction in the two treatments, with parallel guiding (WP) or no parallel guiding (NP). P-values (t-test) indicating differences between treatments, where \* = ( $p<0.05$ ), \*\* = ( $p<0.01$ ), NS = not significant.

Group	NP (Mean $\pm$ STDEV)	WP (Mean $\pm$ STDEV)	P-value
All	$1.4 \pm 0.7$	$1.1 \pm 0.4$	NS
G1	$1.7 \pm 0.9$	$1.4 \pm 0.3$	NS
G2	$1.1 \pm 0.2$	$0.9 \pm 0.4$	NS

*Table 13.* Mean number of minutes of total time for staff interaction per animal left at staffs first interaction in the two treatments, with parallel guiding (WP) or no parallel guiding (NP). P-values (t-test) indicating differences between treatments, where \* = ( $p<0.05$ ), \*\* = ( $p<0.01$ ), NS = not significant.

Group	NP (Mean $\pm$ STDEV)	WP (Mean $\pm$ STDEV)	P-value
All	$1.2 \pm 0.3$	$1.1 \pm 0.3$	NS
G1	$1.1 \pm 0.2$	$1.2 \pm 0.4$	NS
G2	$1.2 \pm 0.3$	$1.0 \pm 0.2$	NS

*Table 14.* Mean number of interactions per cow left at staffs first interaction in the two groups, G1 and G2, in the two treatments with parallel guiding (WP) or no parallel guiding (NP). P-values (t-test) indicating differences between the groups, where \* = ( $p<0.05$ ), \*\* = ( $p<0.01$ ), NS = not significant.

	G1 (Mean $\pm$ STDEV)	G2 (Mean $\pm$ STDEV)	P-value
NP	$1.7 \pm 0.9$	$1.1 \pm 0.2$	*
WP	$1.4 \pm 0.3$	$0.9 \pm 0.4$	**

### 5.2.2 Focal animals

The majority, 57%, of the staff interactions regarding the focal animals was performed on first parity cows. Further, 50% of the staff interactions was performed on the heaviest animals, weight class III. Weight class II received the least number of staff interactions (21%) and weight class I received 29%. Regarding the days in milk, it was found that higher DIM class resulted in more staff interactions was received. Cows in DIM class I received 9%, DIM class II 7 %, DIM class III 18%, DIM class IV 30 % and DIM class V received 36%.

### 5.3 Time interval analysis

#### 5.3.1 Time in waiting area

No significant difference was found between NP and WP regarding time in waiting area ( $32.2 \pm 1.7$  min and  $33.2 \pm 1.7$  min respectively,  $p=0.1916$ ) and treatment had no significant effect on the time spent in the WA ( $p=0.3758$ ). No significant difference between treatments within each group was found, neither was there any significant differences between the two groups, G1 and G2 ( $33.4 \pm 2.2$  min and  $32 \pm 2.2$  min respectively,  $p=0.6193$ ). The time in waiting area for both groups in the two treatments are presented in table 15. No significant differences between combinations of groups or treatments were found. Days in lactation and body weight had a significant effect on the time spent in the WA ( $p<.0001$  and  $p=0.0330$  respectively); increasing number of days in lactation and higher weight resulted in longer periods of time in the WA.

#### 5.3.2 Total walking and waiting time before milking

No significant difference was found between treatments in total walking and waiting time before milking ( $39 \pm 1.7$  min and  $39 \pm 1.8$  min respectively,  $p=0.9484$ ) and treatment had no significant effect on the total walking and waiting time before milking ( $p=0.3429$ ). No significant difference between treatments within each group was found, neither between G1 and G2 ( $39.2 \pm 2.3$  min and  $38.9 \pm 2.3$  min respectively,  $p=0.9137$ ). The total walking and waiting time before milking for both groups in the two treatments are presented in table 15. No significant differences between combinations of groups or treatments were found. Days in lactation and body weight had a significant effect on the total walking and waiting time before milking ( $p<.0001$  and  $p=0.0167$  respectively), where cows in later lactation and heavier cows had longer waiting times.

#### 5.3.3 Total time for milking

No significant difference was found between treatments, with parallel guiding and no parallel guiding, regarding the total time for milking ( $63.9 \pm 1.6$  min compared to  $64.9 \pm 1.66$  min,  $p=0.2332$ ) and treatment had no significant effect on total time for milking ( $p=0.1076$ ). No significant difference between treatments in either G1 or G2. Further, no difference between G1 and G2 in total time for milking was found ( $63 \pm 2.2$  min and  $65.9 \pm 2.2$  min respectively,  $p=0.343$ ). The two groups total time for milking in the two treatments are presented in table 15. No significant differences between combinations of groups or treatments were found. Days in milk and body weight had a significant effect on the total time for milking ( $p=0.0009$  and  $p=0.0091$  respectively). Cows later in lactation and heavier cows had longer milking times.

Table 15. Least square mean of minutes for the two groups, G1 and G2, in the no parallel guiding treatment (NP) and with parallel guiding treatment (WP) for the three different time intervals; time in waiting area (WA), total walking and waiting time before milking (WT) and time for milking (MT).

	Time intervals (LSMEAN $\pm$ SE)			
	NP		WP	
	G1	G2	G1	G2
WA	33.8 $\pm$ 2.3	32.5 $\pm$ 2.3	33.0 $\pm$ 2.3	31.5 $\pm$ 2.2
WT	39.0 $\pm$ 2.4	39 $\pm$ 2.4	39.4 $\pm$ 2.4	38.6 $\pm$ 2.4
MT	62.6 $\pm$ 2.3	67.4 $\pm$ 2.4	63.4 $\pm$ 2.3	64.4 $\pm$ 2.4

#### 5.4 Order of entrance

The order of entrance was found to be affected by the body weight ( $p=0.0183$ ) and milk yield ( $p<.0001$ ). Cows with a higher milk yield entered the AMR earlier compared to cows with a lower milk yield, and heavier cows entered later compared to lighter cows.

#### 5.5 Milk yield

The milk production differed in both G1 and G2 between the WP and NP treatments (table 16). Overall, the milk production was 0.95 kg higher in the WP treatment ( $15.24 \pm 0.39$  kg and  $14.29 \pm 0.39$  kg respectively;  $p <.0001$ ) and G2 had a higher milk production than G1 ( $15.62 \pm 0.46$  kg and  $13.91 \pm 0.48$  kg respectively;  $p=0.0019$ )

Table 16. Least square mean and significance level for the number of kilogram milk yield in the two groups G1 and G2 in the two different treatments with parallel guiding (WP) and no parallel guiding (NP). Significance level showing the difference in milk yield between the treatments in each group.

	Milk yield (LSMEAN $\pm$ SE)		Significance level
	WP	NP	
G1	14.24 $\pm$ 0.50	13.58 $\pm$ 0.49	0.0016
G2	16.24 $\pm$ 0.47	15.00 $\pm$ 0.49	<.0001

## 6 Discussion

### 6.1 Behaviour

A significant difference between treatments was found regarding the total number of behaviours. Although not significant, the WP treatment resulted in lower numbers in all the specific behaviours. The reduced total number of behaviours in WP could be a result of the gates separating the cows, and preventing cows from as easily blocking the entrance of the AMR. The significantly higher number of total behaviours in G1 and the fact that G1 had a higher frequency of all behaviours (except mounting in the WP treatment) could be a result of heifers being included in G1 before calving. Regroupings have been found to increase aggressive interaction (Bouissou *et al.*, 2001), especially when dominance relationships are being established (Beilharz & Zeeb, 1982).

Another factor affecting the number and types of behaviours in the study may be the crowd gate. The crowd gate keeps the stocking density in the WA close to constant. Because of this, when the crowd gate is started, little to no space is left for the animals to perform some, or any, behaviours. This was noted during the analysis of the video recordings since the behaviour of mounting, which requires space to be performed, was performed almost exclusively at the beginning of the session when the WA was not filled with animals and the crowd gate had not been started yet. Higher stocking density has been found to increase the frequency of agonistic interactions because of competition for resources (Metz & Mekking, 1984; Fregonesi & Leaver, 2002). However, one may argue that this is only applicable until a point where the available space is too small for agonistic behaviours to be performed. Hence, the crowd gate may have had an impact on lowering the number of behaviours in the study. More behaviours were performed in the forward area compared to the backward area. This was expected and most likely a result of the crowd gate pushing the animals forward, leaving less time and space for the animals to perform behaviours in the backward area.

The results of the present study show that multiparous cows performed behaviours on primiparous cows, hence, older cows performed behaviours on younger cows. This supports the findings that parity number as well as age are correlated to dominance value and social rank (Philips and Rind 2002 And O'Connell 1989), since the number of initiated aggressive interactions and dominance value has been found to be positively correlated (Collis, 1976).

The present study did also find that cows later in lactation performed more behaviours. This supports the findings of Ketelaar-de Lauwere *et al.*, (1996) that social rank and days in milk are positively correlated.

Further, several authors have found social rank to be correlated to live weight (Wagnon *et al* 1966; Dickson *et al* 1967; Bouissou 1972; Philips and Rind 2002). But the results of the present study regarding the focal animals are contradictory since the animals in weight class I, the lightest animals, was the performing animal in 40% of the behaviours. Although, the heaviest cows, weight class III, was the animal performing a behaviour in almost as many cases (37%). A reason for the high number of light weight cows performing a behaviour could be that the

animals were at different stages of gestation. Cows later in gestation may avoid such interactions with other cows.

## 6.2 Staff interaction

The parallel guiding lowered both the total staff interaction time and the number of staff interactions needed in total. This is positive for the farmer since the cost of labour is the largest cost in dairy production (Gustavsson, 2009). The parallel guiding did also lower the number of animals left at staffs first interaction ( $21.7 \pm 6.8$  cows resp.  $18.6 \pm 6.3$  cows) but the difference was not significant. However, the fact that fewer animals were left at staffs first interaction as parallel guiding was practised indicate that the treatment results in a lower need of fetching cows. Since fetching of cows requires more labour it results in economic losses (Drach *et al.*, 2017). The parallel guiding could because of this be of interest when reduced labour is desired.

No difference between the treatments was found regarding time for total staff interactions in G1. On the other hand, the WP treatment did have a lower total staff interaction time compared to the NP treatment in G2. The same was found regarding the number of staff interactions. No difference between treatments in G1 but lower number of staff interactions needed in WP compared to NP in G2. Hence, the parallel guiding did have a bigger positive effect on G2, which consisted of both primi- and multiparous cows. This may indicate that groups where primi- and multiparous cows are mixed receive most benefits from the use of the parallel guiding.

The majority of the staff interactions was performed on first parity cows. A reason for this could be that most of these were new to the system since it has been found that one of the top three reasons for fetching is that the cow is new to the system (Rodenburg & House, 2007). As well as it has been found that the voluntarily entering is increasing as days in lactation increases (Jacobs & Siegford, 2012b), which could be interpreted as cows learn to use a system. Another reason may be that they are subordinate animals and therefore not likely to get access to the AMR as fast as the dominant animals. The majority of staff interactions were also performed on cows in weight class III (50%). This contradictory result, that the majority of staff interaction were performed on the primiparous cows as well as the heaviest cows may be explained by the primiparous cows not being the lightest animals despite them probably being the youngest. It was also found that the number of staff interactions increased as days in milk increased. This may be explained by the milk yield decreasing in the mid and late lactation (Sjaastad *et al.*, 2010) and therefore maybe also the motivation to be milked.

## Working safety

The Swedish work environment regulations on animal work stipulate that the work environment should be dimensioned and maintained to offer a safe work environment, as well as it should offer escape routes for the farmer (ASF 2008:17). In a study by Lindahl *et al.* (2012) the farmers mentioned horizontal rails as an important factor in making the facility safer, since it offers escape routes for the farmer. The railings in the present study had vertical rails. This type of railing increases the risk for the staff to get crushed or stuck between a cow and the railing. An



improvement of the present parallel guiding would be to use horizontal railings instead. The fact that the railing was a bit difficult to work with since it did not offer any escape routes was mentioned by the staff in the present study.

### 6.3 Time intervals

The consequences of the parallel guiding on the various time intervals was varying. Overall, the parallel guiding did not have a significant effect on the time intervals. However, the majority of time intervals were shorter when the parallel guiding was practised, indicating that the parallel guiding did not have a negative effect on the efficiency of the milking routine. Rather the contrary, the parallel guiding tended to make the milking routine more efficient. When the waiting time for the whole group was retrieved from the video recording, a difference between treatments was found; the parallel guiding resulted in a quicker emptying of the WA ( $86.6 \pm 10.2$  min and  $84 \pm 8.1$  min respectively;  $p=0.328$ ). Although, the difference were not significant and the result can only be used to indicate a tendency to lower waiting time as a group when parallel guiding was practised.

Dijkstra *et al.* (2012) reported average waiting times of 27-63 minutes in three cowsheds where the cows were gathered in a WA with a crowd gate prior to milking. This is similar to the present study. However, the milking equipment differed which affects the different waiting times. The average waiting time in the WA in the present study was approximately 32 minutes for both with and without the parallel guiding. This time spent in the WA is in the lower range of the three waiting times in the study by Dijkstra *et al.* (2012).

Group 1 had overall longer time intervals, except the time for milking, compared to G2. This could be a result of group dynamic since G1 was more often regrouped and consisted of primiparous cows compared to G2 that consisted of both primi- and multiparous cows. The primiparous cows may not have been as used to the system as the multiparous cows were, resulting in longer time intervals. It should be mentioned that G2 had a longer way walking to milking compared to G1 (not enough to consider in the statistical analysis) but still achieved shorter time intervals.

Cows later in lactation had longer time intervals in all investigated time intervals in this study compared to cows earlier in lactation. Scott *et al.* (2014) did almost the same finding, as the study reports that heifers exited the WA more rapidly than cows later in lactation. The milking time and total walking and waiting time before milking were affected by the body weight of the animal; heavier cows had longer waiting time. Since live weight has been found to be correlated to social rank (Wagnon *et al.*, 1966; Dickson *et al.*, 1967b; Bouissou, 1972; Phillips & Rind, 2002) it can be assumed that heavier cows have a higher social rank. Low ranked and submissive cows have been found to have higher waiting times (Halachmi, 2009; Melin *et al.*, 2006) in both free and guided cow traffic (Thune *et al.*, 2002). According to this, the heavier cows should have had shorter milking time and total walking and waiting time before milking. But the results of the present study indicate that the heavier cows had longer waiting times.

However, analysis regarding the social rank have not been done and no clear results regarding the correlation between social rank and time intervals can be stated.

Previous studies have found high yielding cows to enter the milking unit earlier than low yielding cows (Rathore, 1982; Albright *et al.*, 1992; Phillips & Rind, 2002; Grasso *et al.*, 2007; Berry & McCarthy, 2012). The results of the present study also support this. Previous studies have also found low ranked cows to spend longer time in the WA (Ketelaar-de Lauwere *et al.*, 1996; Phillips & Rind, 2002; Melin *et al.*, 2006), hence, high ranked cows entering the milking unit earlier. If, as assumed before, body weight is positively correlated to dominance order, the present result supports also this.

#### 6.4 Milk yield

The higher milk yield of G2 is probably a result of group arrangement since G1 consisted of mainly primiparous cows which are known for having a lower production level. On the other hand, it could also be a result of regroupings, which have been seen to sometimes lower the milk yield (Collis *et al.*, 1979; Jezierski & Podluzny, 1984). The increased milk yield during the WP treatment may be a result of the reduced number of behaviours performed. Stress, such as aggressive interactions, have been found to activate the sympathetic nervous system which can impede milk ejection in various ways (Sjaastad *et al.*, 2010).

#### 6.5 Study limitations and further studies

The observations of behaviour were performed manually, resulting in a risk of human errors. The behavioural analysis was based on identity numbers painted on the back of each focal animal. Since this paint wears off, making it hard to identify some cows, some interactions regarding the focal animals may be missing. This may have resulted in misleading results regarding the focal animals. However, this error was minimized by frequently painting the animals and should be overlooked in the interpretation by the results. Further, during the analysis of the video recordings, interactions between cows may have been missed due to several interactions happening at the same time or that the identity of the cow could not be seen. The camera angle and/or placement could also have resulted in misinterpretation of the situations, making it hard to see if the cows really did touch each other or which cow that initiated the interaction. This could have resulted in misleading results regarding the behaviour and staff interaction analysis. But since the misleading results should be the same regarding both treatments it should not have an impact on the results of this study. To minimize these kinds of errors, it would have been of interest to reduce the factor of having the interior, such as the crowd gate, blocking the view by having several cameras placed in the back of the WA.

Since the present study was conducted at a research centre, several studies were performed at once as well as educational activities, resulting in several various demands were put on both the staff and cows. This was probably the case when the routine of no staff interaction before 40 minutes had past where not followed. This was solved by prolonging the affected period with an appropriate number of days.

Time intervals for all animals could not be retrieved since data from gates were missing. This could have given misleading results for the different time intervals and the effect of the various factors. To minimize the prevalence of errors of this kind, data from DelPro™ should have been regularly downloaded and checked if most gate passages were registered. But since this is not a common error, it was not a part of the routine.

The distribution of cows in the groups was a limitation to the behavioural analysis. Because of G1 only containing primiparous cows, only G2 suited for analysis. Because of this, there was a small number of cows and behaviours as well as staff interactions to analyse. Hence, it would be of interest to have a different distribution of cows in the groups making it possible to have primi- and multiparous focal animals in both groups. Another approach to this limitation would be to have longer or more treatment periods to achieve more data to analyse. If time and resources were not limited, it would have been of interest to increase the length of the habituation period. The present length of the habituation period might have affected the results and caused carry-over effects in the cow performance between treatments. This was attempted to be minimized by choosing milkings at the end of each treatment period.

It would be of interest to look at the behaviours performed at the entrance of the AMR instead of the whole WA. This would give an indication if the parallel guiding did the cow entrance in the AMR more efficient and if the parallel guiding lowers the number of behaviours performed at the entrance. The behaviour analysis as a tool to investigate the parallel guiding in the present study may have been disturbed by many behaviours happening in other parts of the WA, which is not affected by the parallel guiding.

## 7 Conclusion

The parallel guiding resulted in a lower total number of behaviours as well as it needed less total time for staff interactions and fewer staff interactions per occasion. The majority of behaviours were performed by the lightest or heaviest animals, and multiparous cows. The number of performed behaviours, as well as received behaviours, seems to be increasing with days in milk. The animal receiving a behaviour was in most cases primiparous cows. The majority of the staff interactions were also performed on first parity cows and the heaviest cows. The number of received staff interactions seems to be increasing with days in milk. No difference was found between treatments in total time for milking, total walking and waiting time before milking or time spent in waiting area. Neither was a difference found regarding the time spent in waiting area as a group retrieved from the video recordings. However, the parallel guiding did overall not result in longer time intervals when compared to no parallel guiding. The milk yield during the periods when parallel guiding was practised was found to be higher compared to when no parallel guiding was practised. Regarding the aims of the study, the use of parallel guiding resulted in less staff interactions and less aggressive behaviours. As a result of the reduced staff interactions probably also a better working environment. The use of parallel guiding did not make the milking more efficient regarding the time spent on milking.

The parallel guiding was not found to have any negative effects on either working time, animal behaviour or milk yield. By installing parallel guiding the cows were less aggressive in the waiting area which led to less staff interactions and higher milk production. Further studies are needed to investigate the positive effects of the parallel guiding in more depth.

## Acknowledgements

I would like to thank my supervisor, Jan Olofsson, for the help during this study and for giving me the opportunity to work with this interesting subject. A very big thanks to Cecilia Kronqvist for all the invaluable help with understanding and working with SAS. I also want to thank Asif Maqsood for performing the data collection. Thanks to my friends and family, especially my amazing sister Malin Pettersson, boyfriend Markus Johansson and friends Jessica Vahlberg and Josefin Wingren, for always being there and listening with patience when I have had a hard time with this project, as well as celebrating every small victory during the process.

## References

AFS 2008:17 *Work environment regulations on animal work*.

Albright, J., Cennamo, A. & Wisniewski, E. (1992). Voluntary Entrance into the Milking Parlor. In: Ipema, A.H., Lippus, A.C., Metz, J.H.M., & Rossing, W. (eds) *Prospects for Automatic Milking*. Wageningen: Pudoc, pp. 459–465.

Andersson, J. (2014). *Behaviour and throughput of dairy cows when entering and exiting two types of parallel rotaries*. Diss. Skara: Sveriges Lantbruksuniversitet. [Accessed 2019-05-03].

Bach, A., Iglesias, C., Calsamiglia, S. & Devant, M. (2007). Effect of Amount of Concentrate Offered in Automatic Milking Systems on Milking Frequency, Feeding Behavior, and Milk Production of Dairy Cattle Consuming High Amounts of Corn Silage. *Journal of Dairy Science*, vol. 90 (11), pp. 5049–5055.

Beilharz, R.G. & Zeeb, K. (1982). Social dominance in dairy cattle. *Applied Animal Ethology*, vol. 8 (1), pp. 79–97.

Berry, D.P. & McCarthy, J. (2012). Genetic and non-genetic factors associated with milking order in lactating dairy cows. *Applied Animal Behaviour Science*, vol. 136 (1), pp. 15–19.

Bouissou, M.F. (1972). Influence of body weight and presence of horns on social rank in domestic cattle. *Animal Behaviour*, vol. 20 (3), pp. 474–477.

Bouissou, M.-F., Boissy, A., Le Neindre, P. & Veissier, I. (2001). *The social behaviour of cattle*. Bouissou, Marie-France; Laboratoire d'Etude du Comportement Animal, INRA, 37380 Nouzilly, France, France.: CABI Publishing.

Collis, K.A. (1976). An investigation of factors related to the dominance order of a herd of dairy cows of similar age and breed. *Applied Animal Ethology*, vol. 2 (2), pp. 167–173.

Collis, K.A., Kay, S.J., Grant, A.J. & Quick, A.J. (1979). The effect on social organization and milk production of minor group alterations in dairy cattle. *Applied Animal Ethology*, vol. 5 (2), pp. 103–111.

Cook, N.B. & Nordlund, K.V. (2009). The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics. *The Veterinary Journal*, vol. 179 (3), pp. 360–369.

Dado, R. & Allen, M. (1994). Variation in and Relationships Among Feeding, Chewing and Drinking Variables for Lactating Dairy-Cows. *Journal of Dairy Science*, vol. 77 (1), pp. 132–144.

Dahlgren, I. (2013). *The effect of the shape of the waiting area on the behaviour of dairy cows in an automatic milking rotary system*. Diss. Swedish University of Agriculture Science. Available from: <https://stud.epsilon.slu.se/5906/>. [Accessed 2017-12-01].

Dalemar, E. (2017). *Cow traffic in an automatic milking rotary system - comparing single alley and open waiting area*. Diss. Swedish University of Agriculture Science. [Accessed 2019-05-04].

DeVries, T.J. & von Keyserlingk, M.A.G. (2006). Feed Stalls Affect the Social and Feeding Behavior of Lactating Dairy Cows. *Journal of Dairy Science*, vol. 89 (9), pp. 3522–3531.

Dickson, D., Barr, G. & Wieckert, D. (1967a). Social Relationship of Dairy Cows in a

Feed Lot. *Behaviour*, vol. 29, p. 195-.

Dickson, D.P., Barr, G.R. & Wieckert, D.A. (1967b). Social Relationship of Dairy Cows in a Feed Lot. *Behaviour*, vol. 29 (2/4), pp. 195–203.

Dijkstra, C., Veermäe, I., Praks, J., Poikalainen, V. & Arney, D.R. (2012). Dairy Cow Behavior and Welfare Implications of Time Waiting Before Entry Into the Milking Parlor. *Journal of Applied Animal Welfare Science*, vol. 15 (4), pp. 329–345.

Drach, U., Halachmi, I., Pnini, T., Izhaki, I. & Degani, A. (2017). Automatic herding reduces labour and increases milking frequency in robotic milking. *Biosystems Engineering*, vol. 155, pp. 134–141.

Fernández, M.E., Mariño, R.A. & Carreira, X.C. (2009). Algorithms for dairy barn design: Maternity and milking areas. *Journal of Dairy Science*, vol. 92 (5), pp. 2276–2296.

Flaba, J., Georg, H., Graves, R., Lensink, J., Loynes, J., Ofner-Schröck, E., Ryan, T., Van Caenegem, L., Ventorp, M. & Zappavigna, P. (2014). *The Design of Dairy Cow and Replacement Heifer Housing*. (Section II Working Group No 14).

Forsberg, A.-M. *Factors affecting cow behaviour in a barn equipped with an automatic milking system*. (2008). Available from: <https://pub.epsilon.slu.se/1856/>. [Accessed 2017-11-09].

Fregonesi, J.A. & Leaver, J.D. (2002). Influence of space allowance and milk yield level on behaviour, performance and health of dairy cows housed in strawyard and cubicle systems. *Livestock Production Science*, vol. 78 (3), pp. 245–257.

Galindo, F. & Broom, D.M. (2000). The relationships between social behaviour of dairy cows and the occurrence of lameness in three herds. *Research in Veterinary Science*, vol. 69 (1), pp. 75–79.

Grasso, F., Rosa, G.D., Napolitano, F., Francia, A.D. & Bordi, A. (2007). Entrance order and side preference of dairy cows in the milking parlour. *Italian Journal of Animal Science*, vol. 6 (2), pp. 187–194.

Gustafsson, M. (2009). *Arbetstid i mjölkproduktionen*. Uppsala: JTI-institutet för jordbruks- och miljöteknik. (379).

Gustavsson, A. (2009). *Automatiska mjölkningssystem: så påverkas arbetstid och arbetsmiljö*. Uppsala: JTI - Institutet för jordbruks- och miljöteknik.

Hadley, G.L., Harsh, S.B. & Wolf, C.A. (2002). Managerial and Financial Implications of Major Dairy Farm Expansions in Michigan and Wisconsin<sup>1</sup>. *Journal of Dairy Science*, vol. 85 (8), pp. 2053–2064.

Halachmi, I. (2009). Simulating the hierarchical order and cow queue length in an automatic milking system. *Biosystems Engineering*, vol. 102 (4), pp. 453–460.

Hedlund, S. (2008). *Arbetsåtgång i mjölkproduktion beroende på besättningsstorlek samt mekaniserings- och automatiseringsgrad*. Alnarp. (2008:2).

Hermans, G.G.N., Ipema, A.H., Stefanowska, J. & Metz, J.H.M. (2003). The Effect of Two Traffic Situations on the Behavior and Performance of Cows in an Automatic Milking System. *Journal of Dairy Science*, vol. 86 (6), pp. 1997–2004.

Hurnik, J.F., Webster, A.B. & Siegel, P.B. (1995). *Dictionary of farm animal behavior*. Ames, IA 50014, USA: Iowa State University Press.

Jacobs, J.A., Ananyeva, K. & Siegfurd, J.M. (2012). Dairy cow behavior affects the

- availability of an automatic milking system. *Journal of Dairy Science*, vol. 95 (4), pp. 2186–2194.
- Jacobs, J.A. & Siegford, J.M. (2012a). Invited review: The impact of automatic milking systems on dairy cow management, behavior, health, and welfare. *Journal of Dairy Science*, vol. 95 (5), pp. 2227–2247.
- Jacobs, J.A. & Siegford, J.M. (2012b). Lactating dairy cows adapt quickly to being milked by an automatic milking system. *Journal of Dairy Science*, vol. 95 (3), pp. 1575–1584.
- Jezierski, T. & Podluzny, M. (1984). A Quantitative-Analysis of Social-Behavior of Different Crossbreds of Dairy-Cattle Kept in Loose Housing and Its Relationship to Productivity. *Applied Animal Behaviour Science*, vol. 13 (1–2), pp. 31–40.
- Jordbruksverket. *Antal nötkreatur i december 2016*. (2019). Available from: <http://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/Statistik,%20fakta/Husdjur/JO23/JO23SM1701/JO23SM1701.pdf>. [Accessed 2019-02-03].
- Ketelaar-de Lauwere, C.C., Hendriks, M.M.W.B., Metz, J.H.M. & Schouten, W.G.P. (1998). Behaviour of dairy cows under free or forced cow traffic in a simulated automatic milking system environment. *Applied Animal Behaviour Science*, vol. 56 (1), pp. 13–28.
- Ketelaar-de Lauwere, C.C., Devir, S. & Metz, J.H.M. (1996). The influence of social hierarchy on the time budget of cows and their visits to an automatic milking system. *Applied Animal Behaviour Science*, vol. 49 (2), pp. 199–211.
- King, M.T.M., Pajor, E.A., LeBlanc, S.J. & DeVries, T.J. (2016). Associations of herd-level housing, management, and lameness prevalence with productivity and cow behavior in herds with automated milking systems. *Journal of Dairy Science*, vol. 99 (11), pp. 9069–9079.
- Klaas, I.C., Rousing, T., Fossing, C., Hindhede, J. & Sorensen, J.T. (2003). Is lameness a welfare problem in dairy farms with automatic milking systems? *Animal Welfare*, vol. 12 (4), pp. 599–603.
- Kolbach, R., Kerrisk, K.L., Garcia, S.C. & Dhand, N.K. (2013). Effects of bail activation sequence and feed availability on cow traffic and milk harvesting capacity in a robotic rotary dairy. *Journal of Dairy Science*, vol. 96 (4), pp. 2137–2146.
- Kondo, S., Sekine, J., Okubo, M. & Asahida, Y. (1989). The effect of group size and space allowance on the agonistic and spacing behavior of cattle. *Applied Animal Behaviour Science*, vol. 24 (2), pp. 127–135.
- Lidfors, L.M. (1996). Behavioural effects of separating the dairy calf immediately or 4 days post-partum. *Applied Animal Behaviour Science*, vol. 49 (3), pp. 269–283.
- Lindahl, C., Lundqvist, P. & Norberg, A.L. (2012). Swedish Dairy Farmers' Perceptions of Animal-Related Injuries. *Journal of Agromedicine*, vol. 17 (4), pp. 364–376.
- LRF Mjöljk. *Mjölkrapporten - Nr 1 mars 2017*. (2017). Available from: <https://www.lrf.se/om-lrf/organisation/branschavdelningar/lrf-mjolk/rapporter-och-analyser/mjolkrapporten/>. [Accessed 2017-11-30].
- Main, D.C.J., Barker, Z.E., Leach, K.A., Bell, N.J., Whay, H.R. & Browne, W.J. (2010). Sampling strategies for monitoring lameness in dairy cattle. *Journal of Dairy Science*, vol. 93 (5), pp. 1970–1978.
- Mangalis, M., Jaundzeikars, D. & Priekulis, J. (2014). Cow Traffic Dynamics Using Mechanical Movers. In: Osadcuks, V. (ed) *13th International Scientific Conference on*



- Engineering for Rural Development*. Jelgava: Latvia Univ Agriculture, Faculty Engineering, Inst Mechanics, pp. 85–88.
- Mangalis, M., Jaundzeikars, D. & Priekulis, J. (2015). Cow crowding in waiting yard using mechanical drivers and its influence on productivity of rotary type milking equipment. *Agronomy Research*, vol. 13 (1), pp. 237–244.
- Mathijs, E. (2004). *Socio-economic aspects of automatic milking*. (Meijering, A., Hogeveen, H., & Koning, C. J. A. M. de, eds) Wageningen, Netherlands: Wageningen Academic Publishers.
- Melin, M., Hermans, G.G.N., Pettersson, G. & Wiktorsson, H. (2006). Cow traffic in relation to social rank and motivation of cows in an automatic milking system with control gates and an open waiting area. *Applied Animal Behaviour Science*, vol. 96 (3), pp. 201–214.
- Metz, J.H.M. & Mekking, P. (1984). Crowding phenomena in dairy cows as related to available idling space in a cubicle housing system. *Applied Animal Behaviour Science*, vol. 12 (1), pp. 63–78.
- O'Brien, B., Gleeson, D., Kinsella, J. & O'Donovan, K. (2007). New knowledge of facilities and practices on Irish dairy farms – Fundamental requirements for effective extension. *Proceedings of Association for international Agricultural and Extension Education*, Polson, Montana, USA, May 20 2007. pp. 270–279. Polson, Montana, USA.
- O'Brien, B., Jago, J., Edwards, J.P., Lopez-Villalobos, N. & McCoy, F. (2012). Milking parlour size, pre-milking routine and stage of lactation affect efficiency of milking in single-operator herringbone parlours. *Journal of Dairy Research*, vol. 79 (2), pp. 216–223.
- O'Connell, J., Giller, P.S. & Meaney, W. (1989). A Comparison of Dairy Cattle Behavioural Patterns at Pasture and during Confinement. *Irish Journal of Agricultural Research*, vol. 28 (1), pp. 65–72.
- O'Donovan, K., O'Brien, B., Ruane, D.J., Kinsella, J. & Gleeson, D. (2008). Labour Input on Irish Dairy Farms and the Effect of Scale and Seasonality. *Journal of Farm Management*, vol. 13 (5), pp. 38–53.
- O'Shea, J., Kavanagh, A.J. & Reid, P. (1988). Labour use on Irish dairy farms. *Irish Grassland and Anim. Prod. Assoc. J.*, vol. 22, pp. 112–120.
- Phillips, C.J.C. & Rind, M.I. (2001). The effects on production and behavior of mixing uniparous and multiparous cows. *Journal of Dairy Science*, vol. 84 (11), pp. 2424–2429.
- Phillips, C.J.C. & Rind, M.I. (2002). The Effects of Social Dominance on the Production and Behavior of Grazing Dairy Cows Offered Forage Supplements. *Journal of Dairy Science*, vol. 85 (1), pp. 51–59.
- Pirkelmann, H. (1992). Feeding Strategies and Automatic Milking. In: Ipema, A.H., Lippus, A.C., Metz, J.H.M., & Rossing, W. (eds) *Prospects for Automatic Milking*. Wageningen: Pudoc, pp. 289–295.
- Prescott, N.B., Mottram, T.T. & Webster, A.J.F. (1998). Relative motivations of dairy cows to be milked or fed in a Y-maze and an automatic milking system. *Applied Animal Behaviour Science*, vol. 57 (1), pp. 23–33.
- Rathore, A.K. (1982). Order of cow entry at milking and its relationships with milk yield and consistency of the order. *Applied Animal Ethology*, vol. 8 (1), pp. 45–52.
- Reinhardt, V., Mutiso, F.M. & Reinhardt, A. (1978). Social behaviour and social

- relationships between female and male prepubertal bovine calves (*Bos indicus*). *Applied Animal Ethology*, vol. 4 (1), pp. 43–54.
- Rodenburg, J. (2017). Robotic milking: Technology, farm design, and effects on work flow. *Journal of Dairy Science*, vol. 100 (9), pp. 7729–7738.
- Rodenburg, J. & House, H.K. (2007). Field Observations on Barn Layout and Design for Robotic Milking. *Proceedings of Proceedings from the Sixth Intl. Dairy Housing Conference*, Minnesota, June 17 2007. Minnesota: American Society of Agricultural and Biological Engineers.
- Rushen, J. & de Passillé, A.M. (1999). Environmental design for healthier and more profitable cows. *Advances in Dairy Technology*, (11), pp. 319–333.
- Scott, V.E., Thomson, P.C., Kerrisk, K.L. & Garcia, S.C. (2014). Influence of provision of concentrate at milking on voluntary cow traffic in a pasture-based automatic milking system. *Journal of Dairy Science*, vol. 97 (3), pp. 1481–1490.
- Sjaastad, Ø.V., Sand, O. & Hove, K. (2010). *Physiology of Domestic Animals. 2nd edition*. Oslo: Scandinavian Veterinary Press.
- Sorge, U.S., Cherry, C. & Bender, J.B. (2014). Perception of the importance of human-animal interactions on cattle flow and worker safety on Minnesota dairy farms. *Journal of Dairy Science*, vol. 97 (7), pp. 4632–4638.
- Stal, M., Pinzke, S., Hansson, G.A. & Kolstrup, C. (2003). Highly repetitive work operations in a modern milking system. A case study of wrist positions and movements in a rotary system. *Annals of Agricultural and Environmental Medicine*, vol. 10 (1), pp. 67–72.
- Stefanowska, J., Ipema, A.H. & Hendriks, M.M.W.B. (1999a). The behaviour of dairy cows in an automatic milking system where selection for milking takes place in the milking stalls. *Applied Animal Behaviour Science*, vol. 62 (2), pp. 99–114.
- Stefanowska, J., Tiliopoulos, N.S., Ipema, A.H. & Hendriks, M.M.W.B. (1999b). Dairy cow interactions with an automatic milking system starting with 'walk-through' selection. *Applied Animal Behaviour Science*, vol. 63 (3), pp. 177–193.
- Svennersten-Sjaunja, K.M. & Pettersson, G. (2008). Pros and cons of automatic milking in Europe. *Journal of Animal Science*, vol. 86 (13\_suppl), pp. 37–46.
- Taylor, G., van der Sande, L. & Douglas, R. *Smarter not harder: improving labour productivity in the primary sector*. (2009). Available from: <http://maxa.maf.govt.nz/sff/about-projects/search/05-028/technical-report.pdf>. [Accessed 2017-11-09].
- Thune, R.O., Berggren, A.M., Gravas, L. & Wiktorsson, H. (2002). *Barn layout and cow traffic to optimise the capacity of an automatic milking system*. (McLean, J., Sinclair, M., & West, B., eds) Wageningen, Netherlands: Wageningen Pers.
- Uetake, K., Hurnik, J.F. & Johnson, L. (1997). Behavioral pattern of dairy cows milked in a two-stall automatic milking system with a holding area. *Journal of animal science*, vol. 75 (4), pp. 954–958.
- Wagon, K., Loy, R., Rollins, W. & Carroll, F. (1966). Social Dominance in a Herd of Angus Hereford and Shorthorn Cows. *Animal Behaviour*, vol. 14 (4), p. 474-.
- Wierenga, H.K. (1990). Social dominance in dairy cattle and the influences of housing and management. *Applied Animal Behaviour Science*, vol. 27 (3), pp. 201–229.