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Reactions of dairy cows during the operation of a robotic slat cleaner

During manure removal, robotic slat cleaners move in close proximity to dairy cows. The present study investigated the influence of a robotic cleaner on the animals by video recording and analysing their reactions. As most important influence factors concerning individual animal reactions, the small proportion of 8% of marked reactions by cows to the slat robot as well as the actual distance between the cows and the slat robot, indicated a good adaption of dairy cows to the equipment. Observation of the complete herd of cows demonstrated that animals increased their movement from lying area to feeding area while the robotic slat cleaner was operating.

received 22 July 2014
accepted 5 September 2014

Keywords
Robotic slat cleaner, dairy cows, animal behavior

Abstract
Landtechnik 69(5), 2014, pp. 225–231, 3 figures, 2 tables, 12 references

Automation of German dairy farms progresses continually. In many cases, automatic milking systems (AMS) and robotic slat cleaners are installed at the same time [1]. This concerns a relatively new technology working in close proximity to the animals [2]. The effect of application of such equipment on individual cows and on groups of animals should therefore be examined.

Based on herd hierarchy, individual cows normally maintain a certain distance from one another, behaviour they also demonstrate with humans [3]. Depending on their positions within the herd hierarchy, this distance can be between 0.5 and 3.0 m (between respective heads). Where this distance becomes less, animals react [3]. In the behaviour of cattle towards incomers, postures of impressing, of threatening and readiness for flight lie close to one another [5]. If a cow perceives a threatening situation her metabolism is put on alert and rapid reactions such as flight, or fight too, can then follow [6].

But if cattle perceive a situation or object as unthreatening, exploratory behaviour can be observed. This entails them slowly approaching the object with head lowered and stretched forward. Also possible to be carried out very well in this posture is their main exploratory activities, sniffing and licking [7].

Behaviour of cattle is also influenced by their motivation. The animals choose and regulate their behaviour according to the consequences they expect. In doing so, both internal and external influences play a role. Cattle can learn to show specific behaviour in context with specific objects or noises. Consequently, they are able to adapt to changing environmental conditions [8; 9; 10].

In other studies it could be shown that the use of fixed dung removal systems caused a certain strain [11], or even stress [12], with cows in the barn passageway tending to leave the immediate area of the barn or step into a cubicle [12].

Materials and Methods

Experimental conditions

The trial farm had a four-row cubicle barn. The unheated building featured raised cubicles (cow comfort mattresses) and slats. The floor plan of the barn (**Figure 1**) was split down the middle with the two sides almost the same layout, respectively housing a high yield and a lower yield group of cows. Each group area had an AMS unit (VMS, DeLaval) with a waiting area at the centrally situated milking facilities. Cow traffic was regulated by selection gates according to the “feed first concept”. The cows got their part- mixed ration in the feeding area via automatic feeding system (Pellon).

The robotic slat cleaner used was the type RS250 from DeLaval with a 1.10 m wide scraper, its charging station installed in an incomplete cubicle in the low-yield group area. The scraper started operations about half a year before the video recordings were made. To clean the whole passageway width, the robot had to move along behind each cubicle row and then down the middle of the passageway.

During data collection about 120 lactating dairy cows (Holstein-Friesian and Red-Holstein) were housed in the barn. The video data were taken within the scope of a parallel feeding trial. In two phases the cows got new feed six times or twice daily. Video recordings were made in both lying areas with four cameras (Mobotix MX-D 12). Because of their 180° lens angle, each camera could film a passage with its two adjacent rows of cubicles within one group area.

Individual animal reactions

For analysis of the individual animal reactions two experimental days with six daily feeds and three days with twice-daily feeds were selected on the basis of the robotic slat cleaner's hours of operation and its route configuration. The barn floor plan was divided into small fields (**Figure 1**, example group 2) to achieve precise location of the cows and robotic slat cleaner. Field division was based on cubicle dimensions so that each field was 1.2 m wide. Furthermore, the robot´s sphere of influence was defined with reference to the individual distance from each other required by cattle (0.5–3.0 m between their heads). To cover this area reliably, the chosen sphere of influence included two fields in front of, two fields behind and the current field of the robotic slat cleaner, as well as the adjacent cubicles on the left-hand and right-hand side (**Figure 1**).

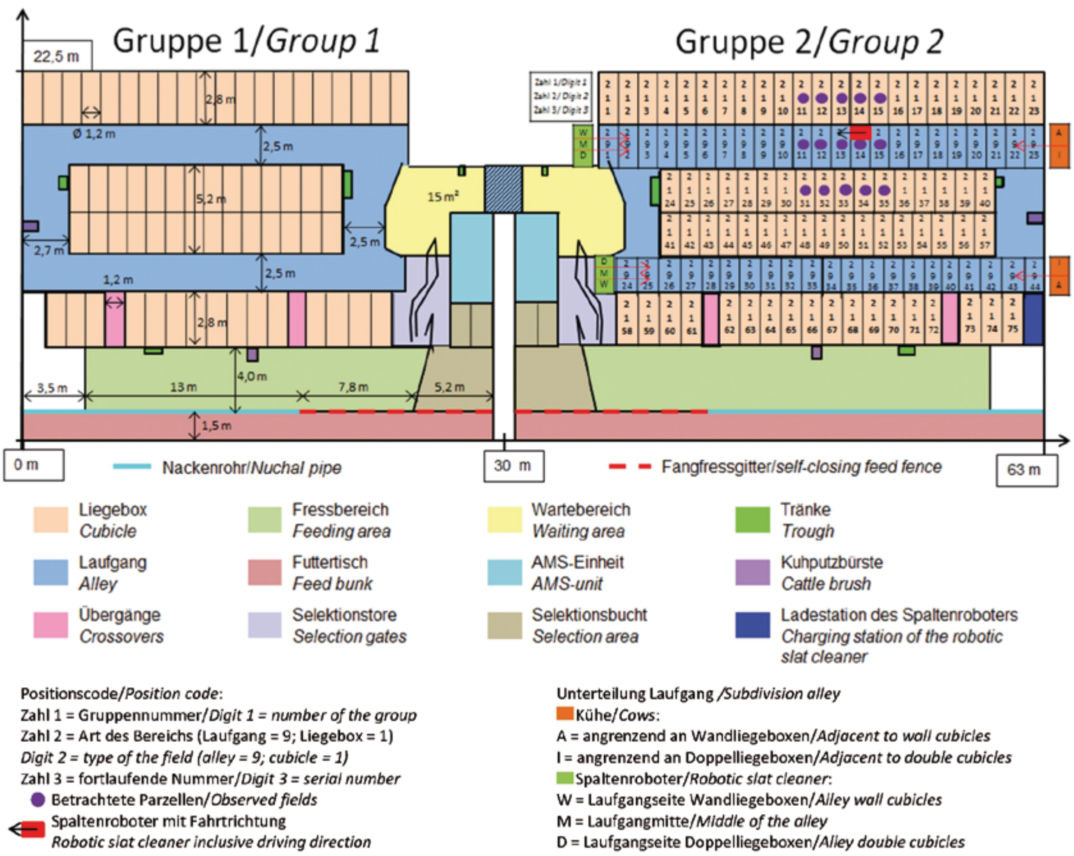
For the analysis, the video was stopped if the robotic slat cleaner was completely inside one field. In the next step, all fields to be observed within the sphere of influence of the robot´s next position were determined. This was followed by the recording of the cows, with their actual position (position code) and their starting posture (e.g. standing or lying), to be found in the, usually, 15 fields. Finally, all reactions of the affected cows during the movement of the robotic slat cleaner to the next field were observed and recorded. Data such as date, time, robot´s position, or presence of staff, were noted too. Following that, the same process took place in the subsequent fields along the direction of robot travel. Altogether, 24352 data sets were recorded for 5439 cows. Thus, each cow was observed an average 4.5 times per robot journey. The acquired reactions were differentiated between 30 possibilities, afterwards divided into six reaction groups (**Table 1**).

With the aid of the chi-square test the influence of five different factors on the results within the individual reaction groups were assessed. The influencing factors were frequency of feeding, yield level of the group, presence of staff, robot´s position in the passageway (same side, opposite side or middle) and distance between animals and robot along the passageway.

Group reactions

In an additional video analysis, the behaviour of two groups of animals with or without moving robotic slat cleaner was observed. The two yield groups were chosen as the experimental groups. Consequently, the observation area restricted itself to the respective group area in the barn. Because of imprecision in the routes followed by the robotic slat cleaner, this was partially inactive during the video recordings. Thus, different days could be chosen during which observation of group behaviour could

Fig. 1



Schematic drawing of the freestall´s floor plan including the dimensions, the division into fields and the defined robotic slat cleaner´s sphere of influence

Table 1

Possible reactions of the cows and their division into six reaction groups

Reaktionsgruppe ***Reaction group***	**Definition** ***Definition***	**Detaillierte Beschreibung der einzelnen Reaktionen** ***Detailed description of the individual reactions***
1	Keine Reaktion (Tiere bewegen sich nicht) *No reaction (animals do not move)*	Keine Reaktion *No reaction*
2	Sonstige Reaktionen (Reaktionen, die nicht eindeutig dem Roboter zugeordnet werden konnten) *Miscellaneous reactions (reactions which couldn´t be clearly assigned to the robot)*	Bewegung des Kopfes (u. a. Roboter anschauen/nachschauen) *Movement of the head (i. a. watching/looking after the robot)*
		Sonstige Bewegungen (vor allem auf der Stelle treten/im Liegen zurechtrücken) *Miscellaneous movements (primarily seesawing/moving while lying)*
		Gehen entgegen der Fahrtrichtung/*Walking towards the robots movement direction*
		Stehenbleiben/*Stopping*
		Sich Ablegen/*Lying down*
		Sich Ablecken/*Licking itself*
		Sozialkontakt (andere Kuh ablecken bzw. sich ablecken lassen) *Social contact (licking another cow resp. being licked of another cow)*
2	Sonstige Reaktionen (wenn diese 4 Reaktionen vor/auf gleicher Höhe des Roboters geschehen) *Miscellaneous reactions (if these 4 reactions happen before the robot has passed/at the level of the robot)*	Bein(e) auf den Laufgang ausstrecken *Stretching one/both hind leg/s out on the alley*
		Mit einem/beiden Hinterbein(en) aus der Liegebox treten *Stepping out of the cubicle with one/both hind leg(s)*
3	Folgereaktionen auf das Ausweichen (wenn diese 4 Reaktionen hinter dem Roboter geschehen) *Consecutive reactions on the evasion (if these reactions happen after the robot has passed)*	Bein(e) ausstrecken *Streching out one/both hind leg(s)*
		In der Liegebox einen Schritt nach hinten gehen (nur 2 Beine innerhalb der Liegebox) *Stepping one step back in the cubicle (only 2 legs inside the cubicle)*
3	Ausweichen (Reaktionen, die dazu dienen, den Kontakt mit dem Roboter zu vermeiden) *Evasion (reactions which serve to avoid the contact with the robot)*	Aufstehen/*Getting up*
		Weggehen in Fahrtrichtung/*Walking away in the robots movement direction*
		Vorbeigehen entgegen der Fahrtrichtung mit geringer Richtungsänderung *Passing the robot against its movement direction with little change of direction*
		In die Liegebox treten (Endposition mit allen 4 Beinen in der Liegebox) *Stepping into the cubicle (end position with every 4 legs in the cubicle)*
		Mit den Vorderbeinen in die Liegebox treten/*Stepping into the cubicle with the front legs*
		Einen Schritt weiter in der Liegebox nach vorne gehen (nur 2 Beine innerhalb der Liegebox) *Moving one step forwards in the cubicle (only 2 legs inside the cubicle)*
		Bein im Liegen vom Laufgang hochnehmen und evtl. anziehen *Pulling up a leg from the alley and maybe drawing it up, while lying*
		Einen Schritt zur Seite gehen (den direkten Fahrtweg des Roboters verlassen) *Moving one step apart (leaving the direct driveway of the robot)*
		Bein(e) anziehen unter den Bauch *Pulling up one/both leg(s) beneath the stomach*
4	Elemente des Erkundungsverhaltens *Elements of the exploratory behavior*	Verfolgen des Roboters/*Following the robot*
		Roboter beschnuppern/*Sniffing at the robot*
		Roboter umkreisen/*Circling the robot*
5	Elemente des Fluchtverhaltens (Tiere fliehen bzw. führen sehr schnelle Bewegungen aus) *Elements of the flight behavior (animals flee resp. make very quick motions)*	Verlassen der Liegebox/*Leaving the cubicle*
		Weggehen in Fahrtrichtung mit massivem Richtungswechsel (> 90°) *Walking away in the robot´s movement direction with massive change of direction (> 90°)*
		In die Liegebox „springen“ (Endposition mit allen 4 Beinen in der Liegebox) *“Jumping” into the cubicle (end position with every 4 legs in the cubicle)*
		Schnelles hin und her treten und den Kopf bewegen *Stepping back and forth quickly and moving the head*
6	Kontakt (Kuh hat einen offensichtlichen Kontakt mit dem Roboter) *Contact (cow has an obvious contact with the robot)*	Keine Reaktion trotz massivem Kontakt (Kuh wird „mitgeschoben“) *No reaction despite massive contact (cow is “sidelined”)*
		Roboter blockieren (Kuh hindert den Roboter am Weiterfahren) *Disabling the robot (cow precludes the robot from going on)*

Table 2

Overview of the significant dependencies of the individual reactions from the different influencing factors, distinguished between the starting positions of the cows

Ausgangsposition *Starting position*	**Einflussfaktor/*Influencing factor***				
	Fütterungshäufigkeit *Frequency of feeding*	**Leistungsstand Gruppe** *Yielding level of the group*	**Personal** *Staff*	**Roboterposition am Laufgang** *Robot´s position on the alley*	**Abstand Tier-Roboter** *Distance animal-robot*
Alle Kühe/*All cows*	n. s.[1)]	*** [4)]	***	***	***
Liegend/*Lying*	n. s.	n. s.	** [3)]	***	***
Im Laufgang/*On the alley*	n. s.	***	***	***	***
Stehend LB[5)]/*Standing c*	n. s.	***	* [2)]	***	***
Halbstehend LB[6)] *Half standing c*	*	**	n. s.	***	***

[1)] n.s. = nicht signifikant abhängig/*not significant dependent*
[2)] * = signifikant abhängig/*significant dependent* (p < 0,05)
[3)] ** = signifikant abhängig/*significant dependent* (p < 0,01)
[4)] *** = signifikant abhängig/*significant dependent* (p < 0,001)
[5)] LB: Liegebox/*c: cubicle*
[6)] halbstehend LB = nur 2 Beine sind in der Liegebox/*half standing c = only two legs are up in the cubicle*

take place always at the same time (robot´s planned hours of operation) with or without the moving robotic slat cleaner. On the basis of a movement profile of the robotic slat cleaner, it could also be reliably determined that, per observation point of time, 2–3 days with and 2–3 days without the moving robot were selected. Thereby, external influences such as feeding time could be neutralised. In addition, data sets showing obvious external influences (e.g. cow in heat or herding staff) were excluded from the evaluation.

The routes of the robot were divided into seven partial routes to ensure that the single partial routes always followed the same route, in the same group area for about the same duration. Only during the partial routes 4 and 7 did the robotic slat cleaner drive in the middle of the passage and in the others it followed the cubicle ends along the passageway sides. In addition, only the data from the partial routes 1 and 4 originated from group 1 (high yield group).

For data collection, the number of cows lying or standing in the cubicles, as well as those who were in the passageway of the respective group area, were recorded at the beginning and at the end of each analysed robot journey. Furthermore, the cows that moved from the feeding area into the lying area, or left the lying area in the direction of the feeding area, were counted during the travel time of the robotic slat cleaner. The determined values were used for the subsequent statistical evaluation. These five parameters were proven with the aid of the t-test to show significant differences ($p < 0.05$) between a moving and a not moving robotic slat cleaner. Thereby it was possible to distinguish between the seven partial routes for each parameter.

Results

Individual animal reactions and distribution of the reaction groups

In the distribution of the six reaction groups all the data sets showed that in most cases (66.1 %) there was no reaction from the cows. With 24.2 %, miscellaneous reactions formed the next most-represented group. In the case of a contact with the robotic slat cleaner (1.7 %) the cows did not show any reaction but let the contact simply take place. Therefore in 92 % of the circumstances no, or no direct, reaction of the cows to the robotic slat cleaner could be determined. From the 8 % of obvious reactions to the equipment by the cows, 6.3 % represented evasion. The remaining two reaction groups were relatively small with 1.0 % (elements of the flight behaviour) and 0.7 % (elements of the exploratory behaviour).

Influencing factors

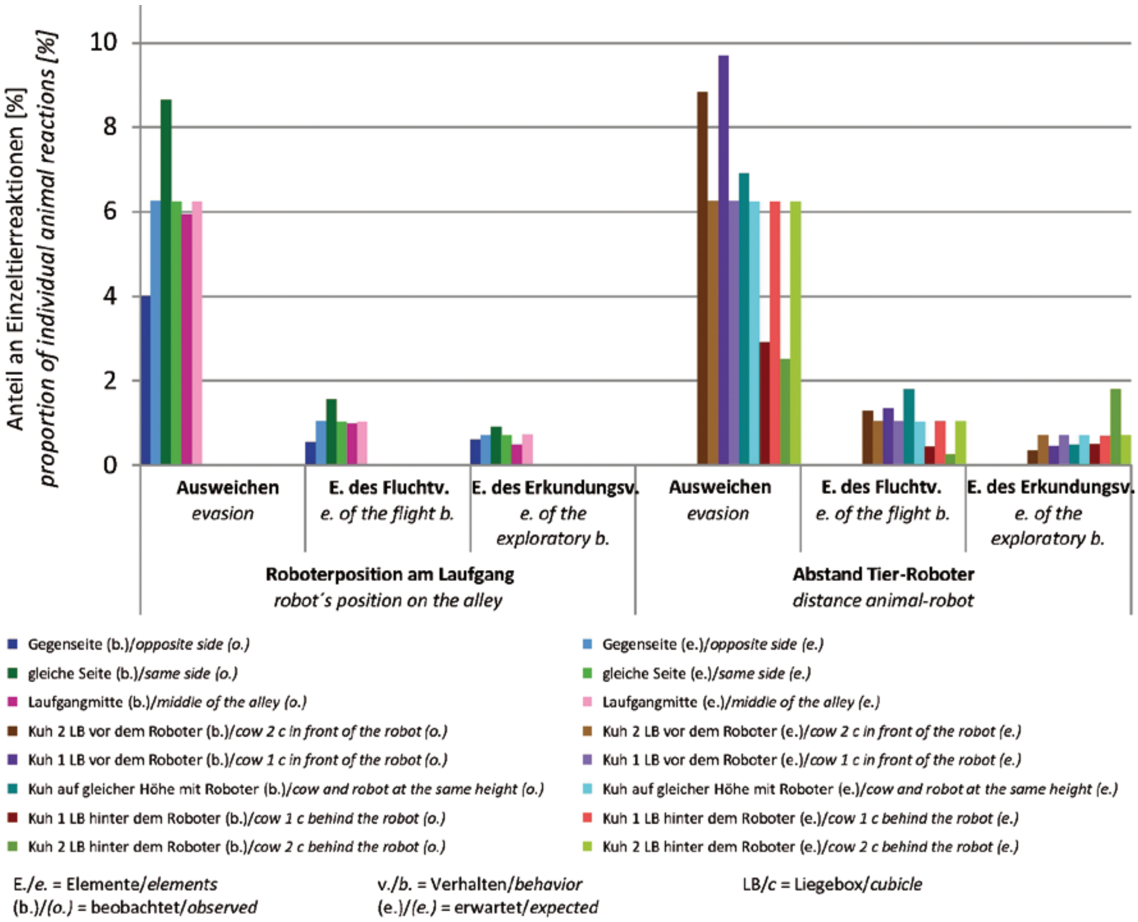
Table 2 shows the significant dependencies related to the five influencing factors determined by the chi-square test. Apart from the total values recorded from all cows, four different starting positions of the animals were also examined.

Overall, it turned out that frequency of feeding had basically no influence on individual animal reactions. With regard to the yield level of the group and the presence of staff, a significant dependency ($p < 0.001$) was found for all cows. Nevertheless, there existed clear differences in the dependencies of the reactions from the starting positions. The robot´s position on the passageway and the distance between the animals and the robot had, in every starting position, a significant dependency ($p < 0.001$) for the individual animal reactions.

What the differences between the observed and the expected values of the chi-square test in the case of a significant dependency ($p < 0.001$) were like is shown in **Figure 2**. Exemplarily in this case, the three obvious reaction groups of all cows (evasion, elements of the exploratory or flight behaviours) were selected with the robot´s position on the passageway and the distance between the animals and the equipment.

The expected values in **Figure 2** express how the cows had to react independently from the respective influencing factor. The observed values represent what reactions were really found in the different distances to the robotic slat cleaner. Overall it

Fig. 2



Relative proportions of the observed and expected values of the chi-square test of the whole values for all cows using the example of the robot´s position on the alley as well as the distance animal–robot for three reaction groups

can be said that, on the same passageway side, considerably more reactions from the cows (especially evasion and elements of flight behaviour) were seen than were expected.

The animal-robot distance showed that the dairy cows waited until late before evading the approaching robotic slat cleaner. If the robot was at the same level as the animals, the elements of flight behaviour occurred to a large extent, whereas elements of the exploratory behaviour could mainly be observed behind the robot.

Group reactions

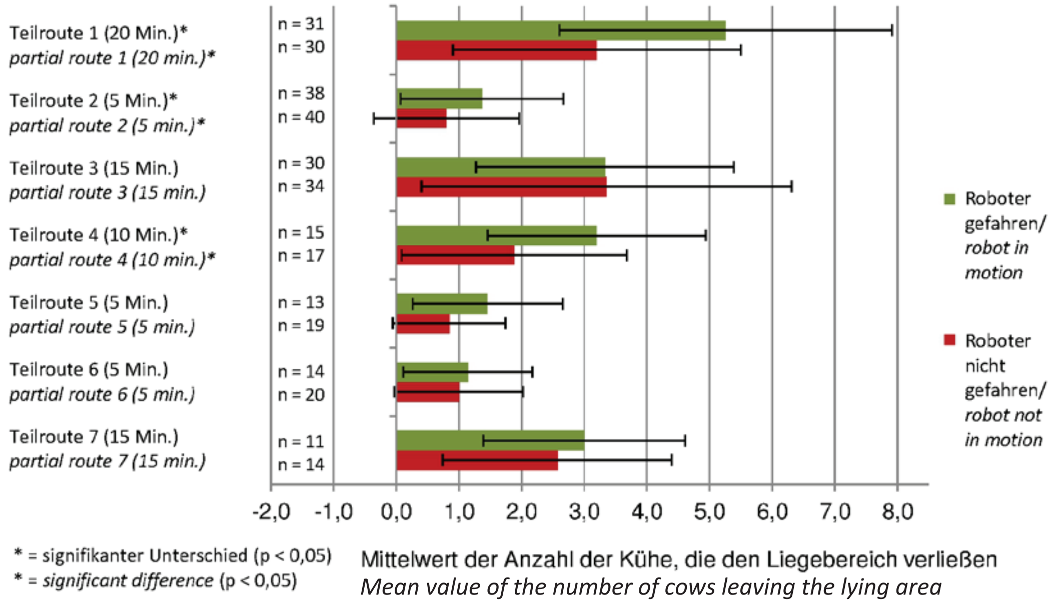
Within the scope of group reactions, significant differences in the partial routes (PR) could mainly be determined in the case of animals moving from the lying area to the feeding area (**Figure 3**). Especially the high yield dairy cows (PR 1 and 4) left the lying area more often in reaction to the moving robot. In such cases the absolute differences between both mean values were about one (PR 4) or two (PR 1) animals. These were thus the greatest differences. The difference of one cow between these partial routes could be ascribed to the longer duration of partial route 1 on the one hand and, on the other, to the different movement routes followed (PR 1: backs of the cubicles; PR 4: middle of the passageway). The low yield dairy cows did not show a significant difference, with the exception of partial route 2. It could only be shown that, with a moving robotic slat cleaner, tendencially more cows left the lying area than in the situation without the robot. The relatively high standard deviations show that the distributions along the values of the single partial routes were relatively high, too.

Discussion

Individual animal reactions

The huge proportion of 92 % of reactions which could not, resp. could not directly, be attributed to the influence of the robot suggested that a good adaptation of the dairy cows to the robotic slat cleaner had occurred. As described at the beginning, cattle can control their behaviour depending on the consequences they expect [8; 9; 10]. The animals seemed to associate only few negative experiences with the robotic slat cleaner. Thus elements of flight behaviour could only be found in 249 cases (1.0 %). The evasion behaviour was rarely present, with 6.3 % (1520 times). However, the elements of the flight behaviour indicate that the cows had assumed a threatening situation and their metabolism was on alert [6]. On the other hand, the discovered elements of exploratory behaviour (0.7 %, 172

Fig. 3



Mean values of the number of cows who leave the lying area depending on the partial routes and the robots motion

times) suggest that the cows perceive the robotic slat cleaner as unthreatening, too [7].

In connection with the five influencing factors, it was shown that, especially the distance between cow and robotic slat cleaner (robot´s position on the alley and distance animal-robot), had a huge influence on the observed reactions. Animals react to a reduction in the accepted individual distance [3]. This was why definitely more cows also reacted the less the actual distance was between them and the robot. Conversely, if the distance increased between the milk cows and the robotic slat cleaner, this resulted in increasingly fewer reactions to the equipment by the animals being observed.

Equally, the determined results can be attributed to adaptation of the cows to their environment [8; 9; 10]. The cows had learned that they only have to react in special cases, for example when their legs were in the passageway while the robot was driving towards them. In this situation the animals have to react and move out of the way in order to avoid contact with the robotic slat cleaner. However, where one of these two factors is not fulfilled one could conclude that the motivation of the milk cow to make a move markedly sinks.

Group reactions

The significantly higher number of cows that left the lying area in the direction of the feeding area agrees with the results of a trial on a farm with a stationary dung removal system [12]. This study showed that mainly cows on the passageway left this area of the barn or searched for a cubicle as haven. In the case of the robotic slat cleaner´s use, more dairy cows changed from the lying to the feeding area. In particular, an increasing number of animals in the high yield group left. Nevertheless, the use of a robotic slat cleaner did not result in a significant difference in animals, or a higher number, in the cubicles. This fact suggests that the animals had the possibility of evading the robotic slat cleaner, with its lesser width, in the passageway in contrast to the situation in the passageway with the wider fixed dung removal system. They therefore did not have to withdraw into a cubicle when the robot neared.

Consequently, it is imaginable that the robotic slat cleaner could be used for motivating the cows to move from the lying area to the feeding area, resp. subsequently to the milking area. This effect could mainly be used during AMS off-peak times.

Conclusions

On the basis of the dairy cow reactions encountered with the application of a robotic slat cleaner, the cow lying area could basically be classified as safe. All in all, the dairy cows paid little attention to the equipment. It can therefore be said that the animals could obviously come to very good terms with the robot. The extent to which there exists real strain for animals through application of slat robots, and how large the animal individual differences are, should be clarified in further investigations.

The results from the group reactions indicate that, to a certain extent, the slat robot could also be applied in controlling the animal traffic towards achieving a more uniform usage rate of the automatic milking system.

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Acknowledgments

The authors thank the Bayerisches Staatsministerium für Landwirtschaft, Ernährung und Forsten for promoting this project.