Norwegian University of Life Science (NMBU),
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Virtual fences for cattle

Studies on heifers 2018

Assignment on behalf of Nofence AS

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Contents

1. Introduction

Nofence AS is a Norwegian entrepreneurial company that has developed a virtual fencing system consisting of a solar-powered GPS collar (the Nofence collar) and a digital map. The grazing area is created by defining GPS coordinates on the map and transferring this information to the collar via the mobile network. Based on GPS data recorded by the collar, a sound warning is emitted when crossing the virtual boundary. The warning is a scale of tones – the higher the pitch, the closer to the electric impulse. The electric shock is only triggered by the highest tone in the defined tone scale.

Virtual fences have been under development for many years. In 1973, Peck (1973) was granted a patent in the United States for a system aimed at dogs and cats. This system is commercially available today under the name of "Invisible Fence". Fay et al. (1998) tested the same system on goats in 1998 and concludes that goats were unable to adapt to the system. Throughout the 1990s, a variation of virtual fencing systems was tried out; Brose (1990), Aine (1992), Rose (1991), Quigley (1995) and Tiedemann et al., (1999). In 1999, Marsh (1999) patented a fenceless system based on GPS technology. The system was designed to control farmed animals, emitting both audio signals and subsequent electric shocks if the animals approached the virtual border. Later, several different patents have been issued for systems based on GPS technology.

Lee et al. (2008) studied the effect of low-energy electric shocks on levels of cortisol and β-endorphin, as well as heart rate and behaviour in cattle. The study concluded that the stress response for cattle exposed to three unpredictable shocks did not deviate from common treatments such as weighing.

There have been several trials on the effects of the strength of the electric shock. In a trial with heifers, Lee et al. (2007) used 600 V and 250 mW for a maximum of 5 seconds. In the same experiment, the authors tested the intensity of the electric shock and found that it does affect the heifers' reaction. They further point out the importance of the method of learning. Umstatter et al. (2015) tested a virtual fencing system (Boviguard) on a herd of 10 cows. The system effectively prevented the cows from crossing the virtual fence and they found no difference in lying behaviour. However, the strength on the electric shock was not specified.

During autumn 2017 there was done an initial study with cattle at The Animal Production Experimental Centre (SHF) at the Norwegian University of Lifesciences (NMBU). The aim of the study was to test if also cattle could learn the Nofence virtual fence system and respond

correctly (Eftang & Bøe, 2017b). Some alternations were also made to the position of the virtual border during the study to see how they responded when their pasture design changed. The six heifers in the study learned to turn on the sound signal within a few days, just like goats, and respected the border to a certain extent. In the beginning of the study there were a few escapes by all the heifers across the border. After 10 days two of the heifers started to cross the virtual border without any hesitations. The two heifers were taken out of the study after exceeding the number of escapes limited by the application to FOTS. No physical tests were carried out afterwards in order to establish whether the collar was giving electric shocks or not. It was concluded that the two heifers didn`t find the electric shock aversive enough when there was better grass on the other side of the border. Therefore, new studies regarding the magnitude of the electric shock was needed.

The main aim of these studies was to determine whether cattle could be kept on a pasture with only virtual fences.

The aim of study 1 was to investigate the cattle's response to three different strengths of electric shocks from virtual fences when grazing on pastures with one virtual fence. The intent was to find the strength of the electrical shock that was aversive enough to keep the animals within the virtual border, and still acceptable regarding animal welfare.

The aim of the study 2 was to investigate how two different methods for adapting to virtual fencing - assisted and unassisted - affected the number of warning sounds, electric shocks and escapes.

2. Materials and methods

2.1 Ethical approval

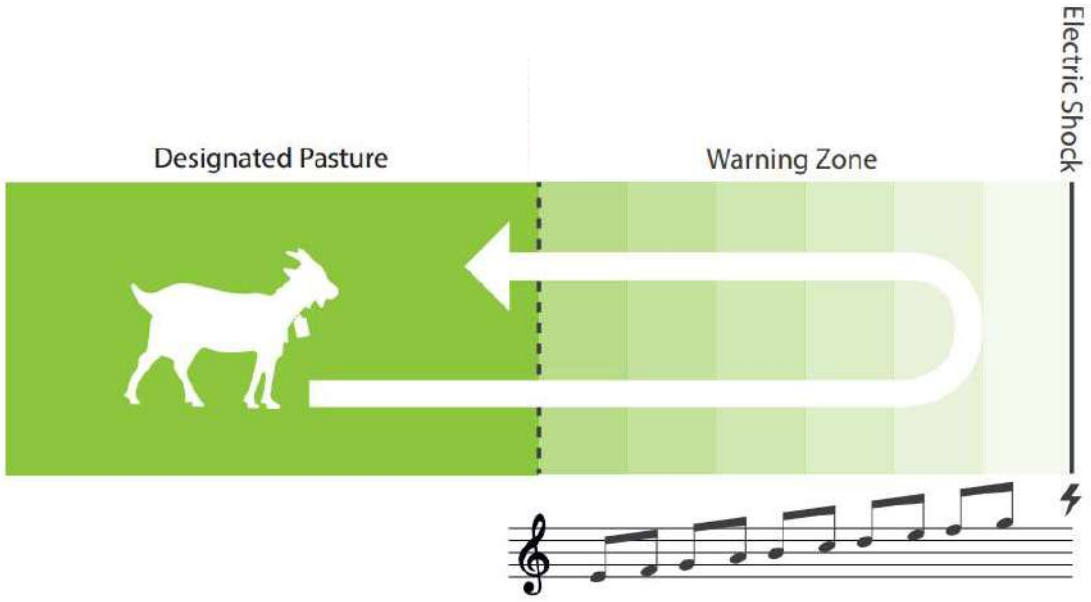
The study was approved by Norwegian Food Safety Authority, FOTS ID 15953.

2.2 The Nofence-system

Picture 1: Heifer with Nofence collar

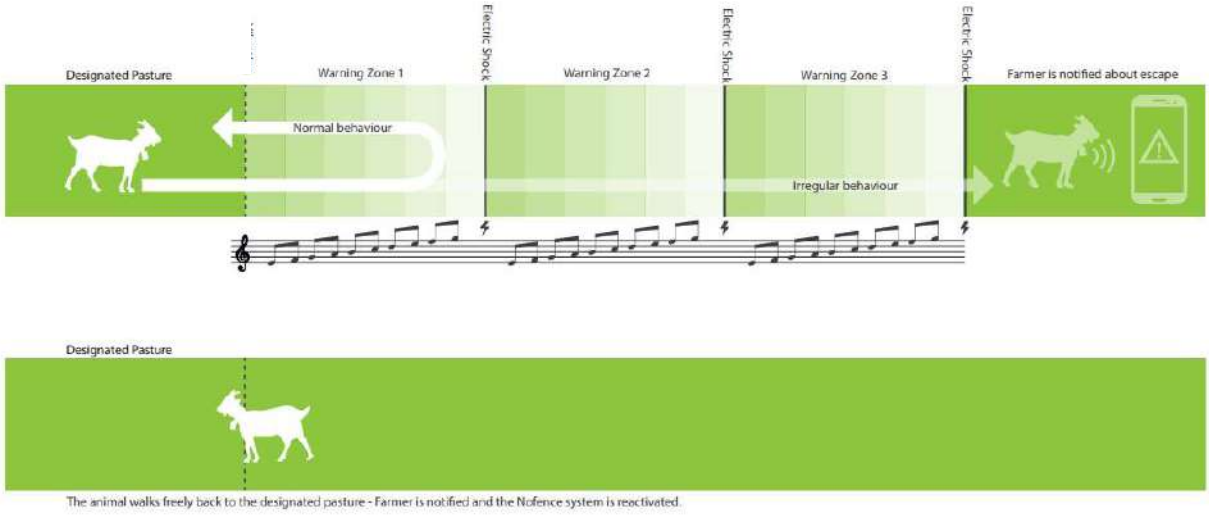
Nofence virtual fencing systems consists of a collar (picture 1) which starts to play a warning sound when the animal crosses a virtual border. The warning sound consist of a tone scale, starting on the lowest tone. The warning sound can never skip a tone, and thus the electric shock always instantly follows the tone with the highest pitch. The warning sound never lasts for shorter than 5 seconds, and never for longer than 20 seconds. The duration of the sound depends on the animals speed across the virtual border.

When the animal responds to the warning sound by turning around, the tone scale plays downward until the animal is back inside the virtual fence, upon which the sound stops playing. If the animal doesn`t turns as a response to the warning sound, it will get an electric shock in the neck region (picture 2). A traditional electric fence has a stored energy of 6 Joule.



Picture 2: Illustration of the Nofence-collars warning system (Nofence AS).

Should the animal continue to walk in the same direction (out of the virtual fence) despite receiving the initial warning sound and a following electric shock, it walks into the second warning zone, where the pattern from warning zone 1 is repeated. The system consists of a maximum of three such warning zones (picture 3). If the animal crosses all three warning zones, it`s reported as escaped and the owner receives a push notification through the mobile phone app. The audio signals are turned off and the electric shock is deactivated, and the collar goes into trace mode. If the animal returns to the grazing area of its own, the system is reactivated, and the owner is notified.



Picture 3: Escape mechanism in the Nofence-system (Nofence AS).

The collar has two function modes: Learning mode and fence mode. During learning mode, the warning sound stops immediately when the animal turns and face the pasture. The purpose is to let desired behaviour get a quick response as the animals is learning to use the system. In fence mode, the experienced animals must move all the way back into the pasture. The collar will change from learning mode to fence mode automatically when the animal has responded by turning 20 times without getting an electric shock. This is appropriate to avoid the experienced animals "pushing the virtual fence" beyond the Nofence boundary.

According to Nofence AS' recommended instructional procedure, learning should take place in an area of good mobile and GPS coverage, where the animals feel safe and where they go behind fixed fences. It`s further recommended to lay the first virtual fence within the fixed fences, so that they can be introduced to warning sounds and electric shocks in a controlled manner.

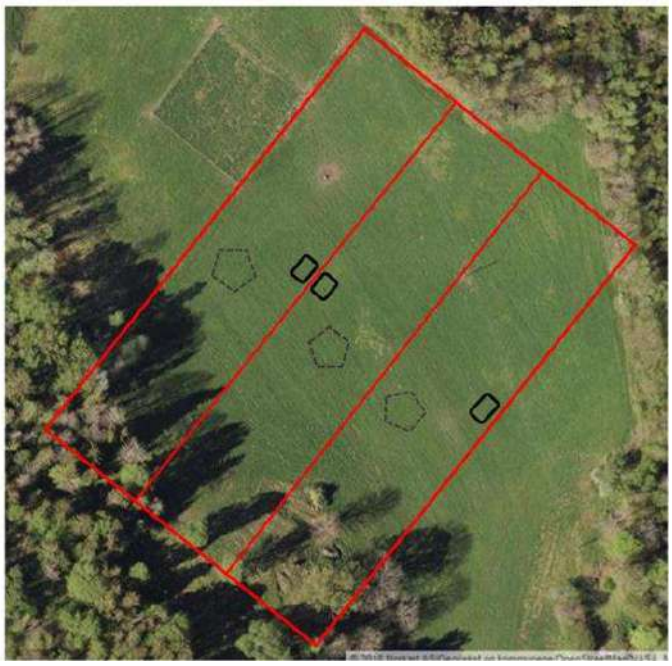
In the Nofence app, information about the animals' position and the number of warning sounds and electric shocks given is reported every 15 minutes. If an animal escapes, the farmer will be notified immediately by a push warning.

The collar used for this study was Nofence` newest version (picture 1), the same version that was used for goats, only with a longer chain and a leather neck piece specially designed for the cattle study.

2.3 Study 1

2.3.1 Animals and pastures

On Monday the 17th of September 2018, eighteen Norwegian Red heifers aged 18 months were randomly selected for this study and transported to the experimental pasture. They all belonged to The Animal Production Experimental Centre (SHF) at NMBU. All of the heifers had been on pasture since May, as part of a larger group. There were three experimental pasture areas next to each other, approximately equal in size: 250 meters long and 50 meters wide (picture 4) and the heifers were divided into three groups (A, B and C). The pastures were surrounded by electric fences. There were moderate levels of grass on the pasture due to the draught period earlier in the summer. In the end of the experimental period there was very little grass left, so the study was finished earlier due to lack of grass.



Picture 4: Pasture area divided into three similar areas

2.3.2 The experimental procedures

In this study, three different strengths of electric shocks tested:

A) * Weakest strength: 1.5 kV, 0.1 Joule loading with 0.5 second duration. Resulting in 2-3 pulses. One pulse delivers approximately 0.1 Joule.

B) Medium strength: 1.5 kV, 0.2 Joule loading with 0.5-1 second duration. Resulting in 1-2 pulses with approximately 0.2 Joule`s strength.

C) Highest strength: 3 kV, 0.3 Joule loading with 1 second duration. Resulting in 1-2 pulses with approximately 0.3 Joule`s strength.

*Strength A is the same strength that was used in the cattle trial in 2017, and the same strength as used for goats on commercial farms.

According to the experimental set-up, animals that escaped more than 6 times over the virtual fences had to be taken out of the experiment. The heifers were inspected several times a day, both by SHF staff and the project manager.

When adjustments had to be made to the collars, or the batteries had to be changed, the heifers were taken into a small paddock for practical reasons. This was also the case when collars had fallen off the animals.

The number of warning sounds, electric shocks and escapes were recorded continuously and for each individual throughout the study.

2.3.3 Adaption period (2 days)

On Monday the 17th and Tuesday the 18th of September the collars were individually adjusted to the neck of each heifer in small pens (picture 5). Then the heifers were released onto the pasture again. They were running around for some minutes, probably because it was the first time they had something around their neck. After some minutes they started grazing and it seemed that they were adapted to the collars. The collars were turned on, but the fence mechanism not activated in this phase of the trial.

Picture 5: Six heifers collected in a pen for collar adjustments.

2.3.4 Experimental period (11 days)

On Wednesday the 19th of September at approximately 10 AM, the virtual fence was introduced in the eastern part of the pasture area (picture 6). This prevented the heifer access to approximately 1/5 of their pasture area. This was similar for each of the three groups.

Picture 6: Pasture area with the virtual border (yellow).

When the virtual fence was introduced, there were five people positioned outside the virtual fence, attracting the heifers to come to the virtual border area. When the heifers crossed the border, the warning sounds started, and they could continue into the warning zone as to expose them to the electric shock. At that point, the animals were carefully chased back by the staff waving their arms. The heifers were then attracted towards the border area once more, and the procedure was repeated. The goal for the training procedure was to teach the animals in what direction they should move when the warning sound started, and to hopefully speed up the learning process. The animals' reaction during these procedures were carefully observed a by a trained person and video recorded.

The heifers' movements were observable through the Nofence app, where the animals' position was updated every 15 minutes. The application also sent a push warning immediately when an animal got an electric shock because of crossing the boundary.

2.3.5 Motivation test

On day 6 of the study (24th of September), each group (A, B and C) where attracted towards and over the virtual border by one of the technician usually taken care of the heifers, using a bucket of concentrates. This procedure was repeated twice.

2.3.6 Behavioural observations

The last two days of the study (29th and 30th of September), there were carried out observations of the behaviour and position within the pasture of the heifers for 2 hours each day, with an interval of five minutes. There were two observers, one doing scan sampling on all the individuals in all the three groups, the other did focal sampling on the four heifers with a heart rate monitor on. The observers were located outside the electric fence on the part of the pasture with the virtual border, approximately 40 meters away from the border (picture 7). The activities in the ethogram were lying, grazing, standing/walking and running.

Picture 7: One of the observers doing behavioral observation.

The pasture was divided into three zones (1, 2, 3) and the zone closest to the virtual border (zone 1) were split into two (a. close to/at the border, b. second half) (picture 8). Cones were placed out on the field in order to mark the different zones, and hence to make the zones visible for the observers on a distance.

Picture 8: Pasture area divided with number 1, 2 and 3 indicating the three different observations zone, placement of the cones (¤) and the observers (Δ). The shaded area in zone 1 indicates zone 1a, while the unshaded part of zone 1 indicates zone 1b.

2.3.7 Heart rate measurements

The heart rate was monitored, on 14 of the heifers for a total of 36 hours and 49 minutes, by using four Polar Equine heart rate monitor belts and activity watches, which also included an accelerometer.

Before the belt was put on, the heifers were shaved on the left side to increase contact between the skin and the heart rate monitor. In addition, obstetric gel was used to increase and maintain the contact. For the Polar system to work the watch was attached to the belt and switched on (picture 12).

Picture 12: Heifer with a Polar equine heart monitor belt on.

To collect the data from the watches, they needed to connect with a computer and synchronized to a Polar account. Each of the measurement session were saved in the workout diary in Polar Flow.

Due to technical issues, some of the data had to be removed from the dataset. Any observation value below 57 bpm was defined as "invalid" and some inexplicable peak values were removed.

Examples of issues could be the equipment lost contact with the skin of the animal, most prominent at fast movements or speed. There were also some episodes where animals had switched off the watches inside the pen just when getting in contact with another animal.

In the end, there were representative data for a total of 21 hours and 54 minutes. There were six incidences of electric shocks during this period with valid data.

2.4 Study 2

2.4.1 Animals and pastures

On the 8th of October, twelve Norwegian Red heifers aged 18 months from SHF/NMBU were randomly selected for this study. All the heifers had been on pasture since May, as part of a larger group. The heifers were separated into two equal experimental pastures (picture 9), six in each group. There pasture areas were next to each other and approximately equal in size: 150

meters long and 30 meters wide. The pastures were surrounded by electric fences. There was moderate of grass on the pasture due to the draught period earlier in the summer.

Picture 9: Pasture area divided into two similar areas.

2.4.2 The experimental procedures

In this study, collars with medium strength of the electric shock (1.5 kV, 0.2 Joule loading with 0.5-1 second duration, resulting in 1-2 pulses with approximately 0.2 Joule strength) were used. Choice of strength was based on the results of study 1, where strength B was considered most suitable.

According to the experimental set-up, animals that escaped more than 6 times over the virtual fences should be removed from the experiment. The heifers were inspected several times a day, both by people from SHF and the project manager.

When there had to be adjustment of the collars, battery changes or the collars had fell of, the heifers were taken into a small paddock for practical reasons.

The number of warning signals, electric shocks and escapes were recorded continuously and for each individual throughout the study.

2.4.3 Adaption period (2 days)

On the 8th of October, the heifers were confined in smaller pens (picture 5) and the collars were individually adjusted to the neck of each heifer. Then the heifers were released into the pasture again. They were running around the first minutes, since this was the first time they had something around their neck. After some minutes, it seemed that the heifers were adapted to the collars. The collars were turned on, but the fence mechanism was not activated during the adaption period. The GPS in the collars gave indication about the GPS condition in the pasture.

2.4.4 Experimental period 1 (5 days)

On Wednesday the 10th of October at approximately 11 AM, the virtual fence was introduced in the northern part of the pasture area (picture 10). This prevented the heifer access to approximately 1/5th of their pasture area. This was similar for both groups.

Picture 10: Pasture area with the virtual border (yellow).

When the virtual fence was introduced to the assisted group (A) there were five people positioned outside the virtual fence attracting the heifers to come to the virtual border area. When the heifers came to the border, the warning sounds started, and they were let to go so near the border that some of the heifers got an electric shock. At that point, the animals were

carefully chased back by the present people waving their arms. The heifers were again attracted to the virtual border area and the procedure were repeated. The goal of the training procedure was to teach the animals what direction they should move when the warning sound started, and hopefully also get a faster learning process. The reactions of the animals during these procedures were carefully observed by a trained person and video recorded. During this procedure, the unassisted group (U) was kept inside a small paddock inside their pastures, so that they didn`t got influenced and attracted to their border.

When the assisted group was finished with their introduction, the unassisted group was let out from their paddock. They could now experience the virtual border by themselves.

During the next five days, the animals were observed several times a day. In addition to the access to all the heifers in the Nofence application, were the animal position was updated every 15 minutes. The application also sent a push warning immediately when an animal got an electric shock at the border.

2.4.5 Experimental period 2 (7 days)

On Monday the 15th of October at approximately 9 AM, the physical fences surrounding the experimental pastures were removed. The virtual border was expanded so that the experimental field covered a larger section of the total pasture area (picture 11). The heifers were now only fenced in by virtual fences and both groups (A and U) were united on the same pasture. The coordinates were set approximately 30-40 meters inside an already existing electric fence that surrounded the whole field where the experiment was taking place.

Picture 11: Pasture area with the virtual border in yellow.

2.5 Technical and practical issues

Prior to fitting the collars on the animals in study 1, their function (sound and electric shock) was tested at Nofence` office. All collars were functioning. During the study, two of the C-collars stopped giving electric shocks, and the animals started to cross the virtual boundary as a result.

Due to uncertainty as to which time they stopped working, these collars and the corresponding data were taken out from the study. The collars were replaced with new ones (as soon as the issue was discovered).

A last, third collar (group B) was also removed from the data due to a firmware update that was done the last three days of the study. This was not detected before we analysed the data, since the animal stayed inside the virtual fence.

In addition, there were a few incidents of battery loss (battery falling out of the collar), collars falling off and one case where the battery ran empty. There have been no changes made to the data set because of the collars felling off or battery issues. This was due to the time span between incidents and when the issue has been resolved was considered insignificant for the study.

Due to technical issues, the results are based on data from six collars with weakest strength of the electric shock (group A), five collars with medium strength (group B) and four collars with the highest strength (group C) of the electric shock.

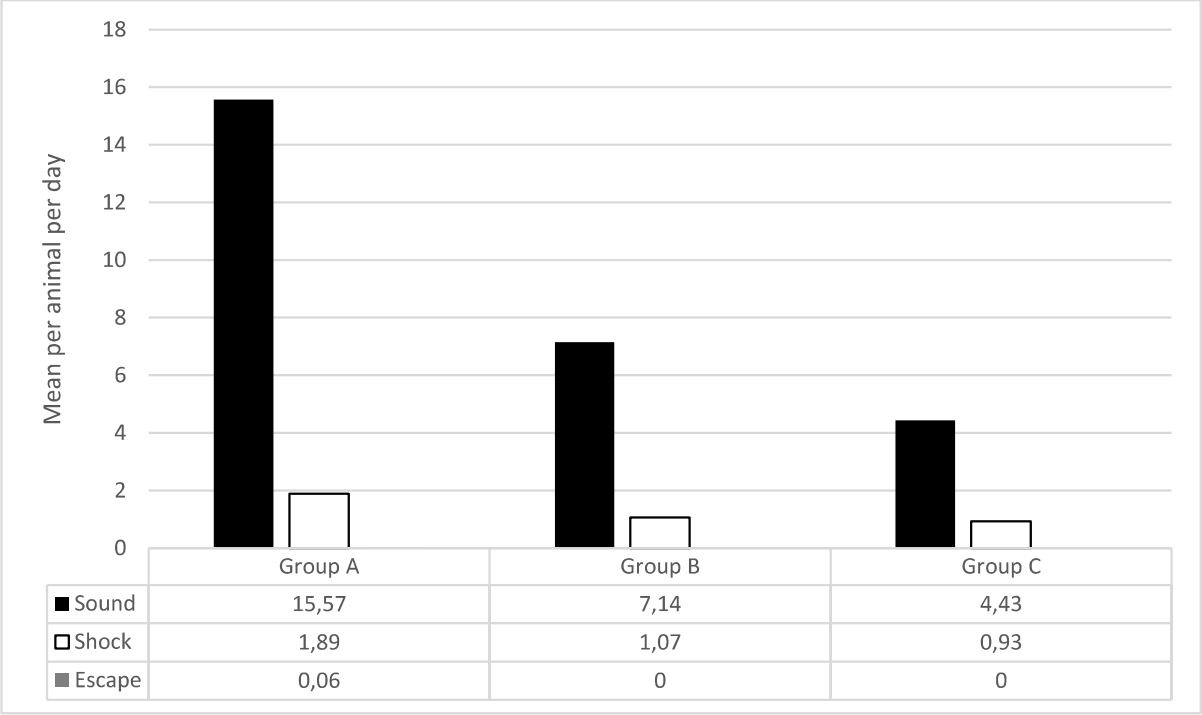
In study 2, the collars were tested at the pasture site, and all the collars were functioning well. Because some collars had fallen off during study 1, there was a new design of the locking mechanism of the chain. During the first night, there was loss of one collar because of the attachment around the neck being too loose. After that, there was none issues with the collars.

3. Results

3.1 Study 1

3.1.1 Warning sounds, electric shocks and escapes

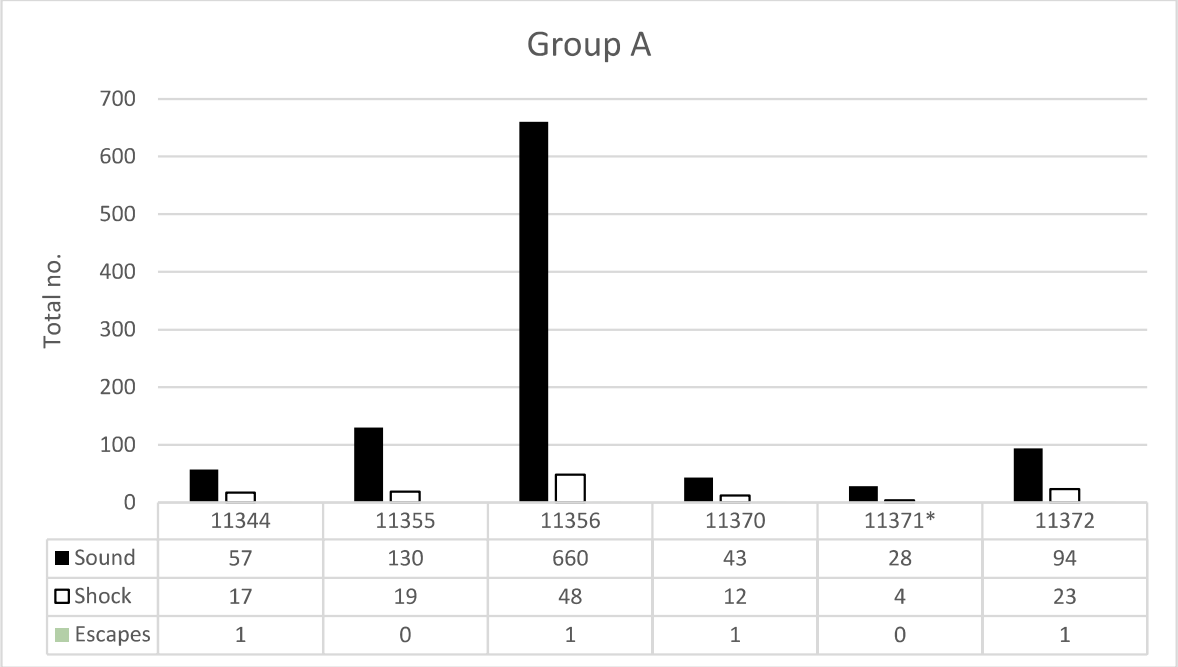
During the 11-day study, there were no escapes across the virtual fence for group B and C, while in group A four animals escaped across the virtual fence on day 2. Mean numbers of warning sounds and electric shocks were highest for group A, medium for group B and lowest for group C (figure 1).



	Group A	Group B	Group C
Sound	15,57	7,14	4,43
Shock	1,89	1,07	0,93
Escape	0,06	0	0

Figure 1: Mean numbers of warning sounds, electric shocks and escapes for each animal per day, for 11 days.

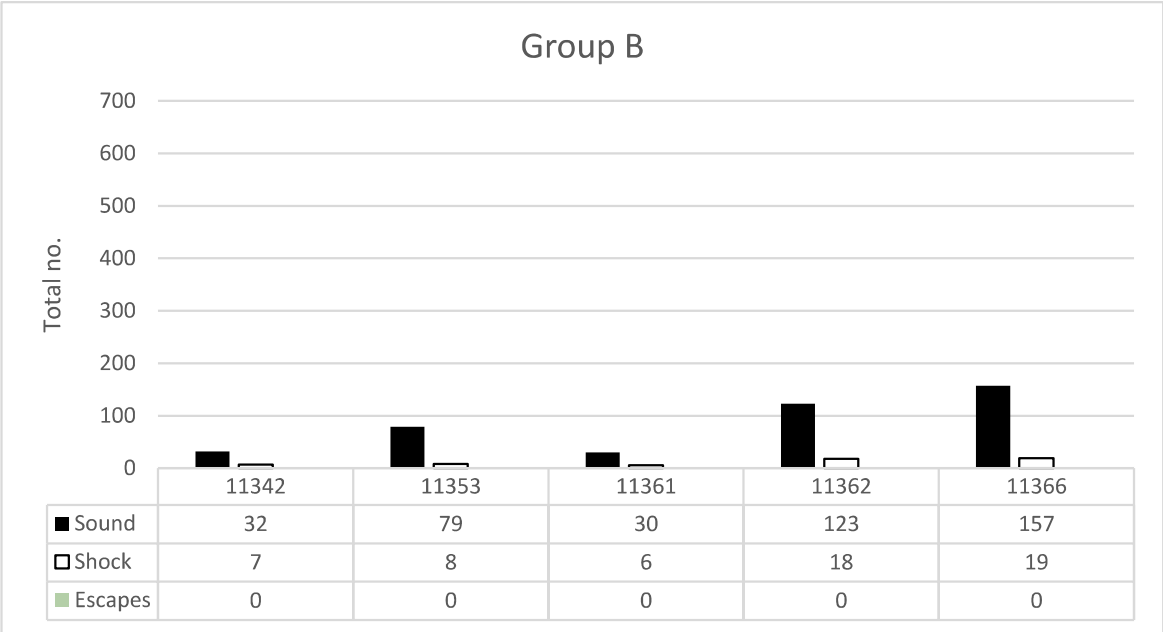
The total number of warning sounds in group A was 1.012. Total number of electric shocks was 123 and the number of escapes was 4 (figure 2). The individual with lowest number of warning sounds got 28 warning sounds and 4 electric shocks, compared to the individual with the highest number that got 660 warning sounds and 48 electric shocks. The latter animal stood out from the rest of the group.



	11344	11355	11356	11370	11371*	11372
Sound	57	130	660	43	28	94
Shock	17	19	48	12	4	23
Escapes	1	0	1	1	0	1

Figure 2: Individual data for group A collected for 11 days. *Collar run out of battery the last 24 hours and hence has one day less of data collection.

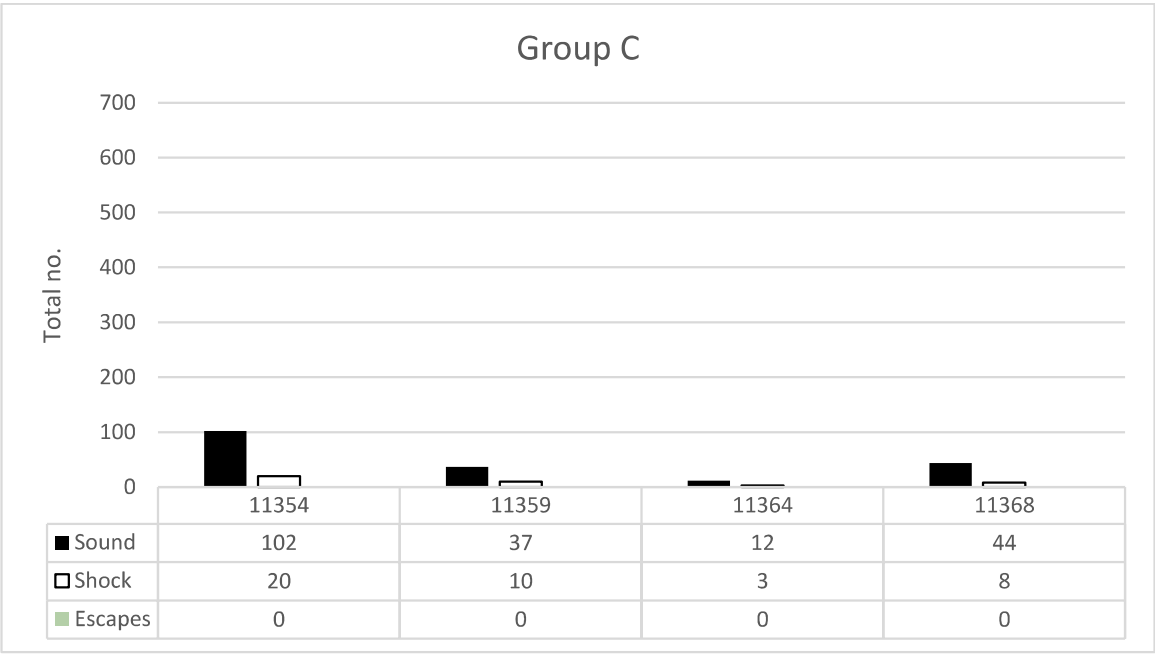
The total number of warning sounds in group B was 421 and the total number of electric shocks was 58 (figure 3). The individual with lowest number of warning sounds got 30 warning sounds and 6 electric shocks, compared to the individual with the highest number which got 157 warning sounds and 19 electric shocks. The individual variation was less for this group than for group A.



	11342	11353	11361	11362	11366
Sound	32	79	30	123	157
Shock	7	8	6	18	19
Escapes	0	0	0	0	0

Figure 3: Individual data for group B collected for 11 days.

The total number of warning sounds in group C was 195 and the total number of electric shocks was 41 (figure 4). The individual with lowest number of warning sounds got 12 warning sounds and 3 electric shocks, compared to the individual with the highest number that got 102 warning sounds and 20 electric shocks. The latter animal stood out from the rest of the group, but the variation was less for this group than for group A.



	11354	11359	11364	11368
Sound	102	37	12	44
Shock	20	10	3	8
Escapes	0	0	0	0

Figure 4: Individual data for group C collected for 11 days.

3.1.2 Motivation test

In group A, two out of six animals were attracted and followed the technicians to the virtual border. One heifer got two warning sounds and one electric shock, while the other heifer got one warning sound. In group B, two out of six animals followed the technician to the virtual border. One heifer got three warning sounds and one electric shock, while the other heifer got two warning sounds. In group C, none of the six heifers were tempted to follow the technician. After receiving warning sounds and/or electric shocks, only two heifers were interested to follow the bucket of concentrate the second time. None of the animals crossed the virtual border.

3.1.3 Behavioural observations

In all three groups, the heifers spent approximately 70 % of the observation period in sector 1b (figure 6), thus near to but not very close to the virtual border. The heifers also spent some time, up to 10 % of the observation period, in zone 1a, close to the border. The data indicate that the heifers in group C spent less in this zone than the other two groups. The heifers were approximately 18% of the time in zone 2, while less than 5% in zone 3.

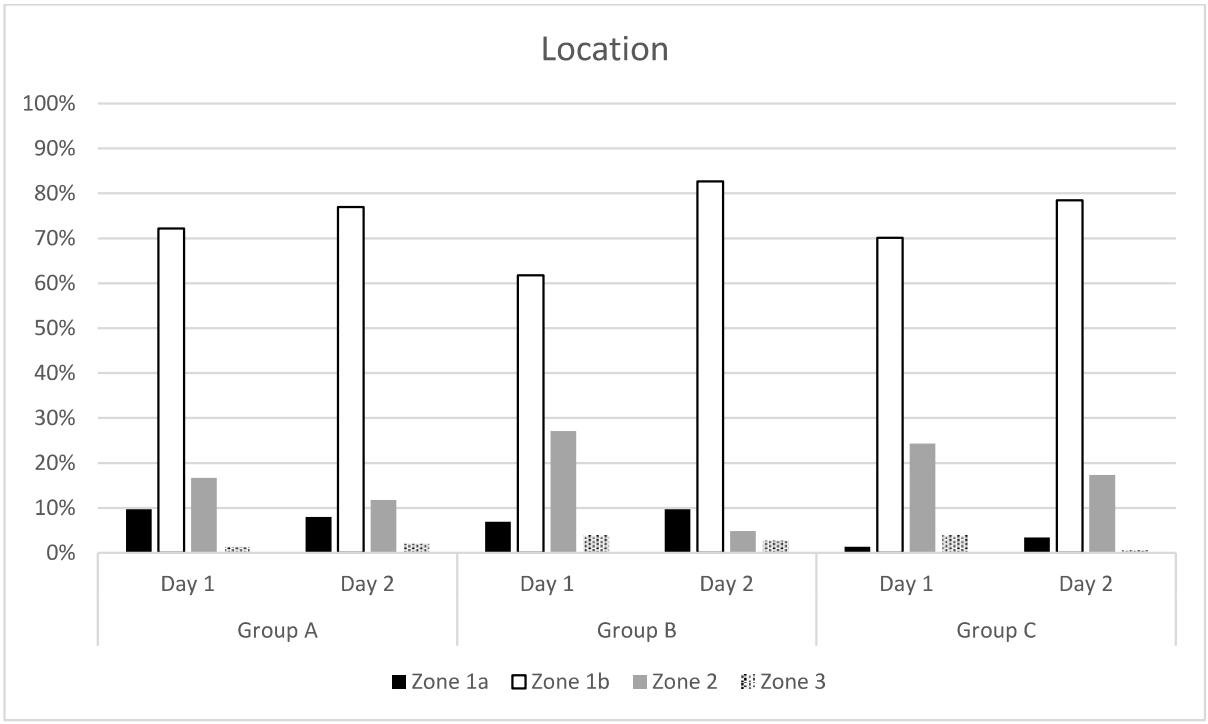


Figure 5: The heifers' location in the pasture area for all groups (A, B and C) for both observation days.

Lying and grazing were the most commonly observed behaviours for all three groups (figure 6). It was observed least lying in group A compared to group B and C. All the animals in all the three groups were observed to be lying in zone 1b. There were observed least standing/walking in group B. None of the heifers in any of the three groups were observed running.

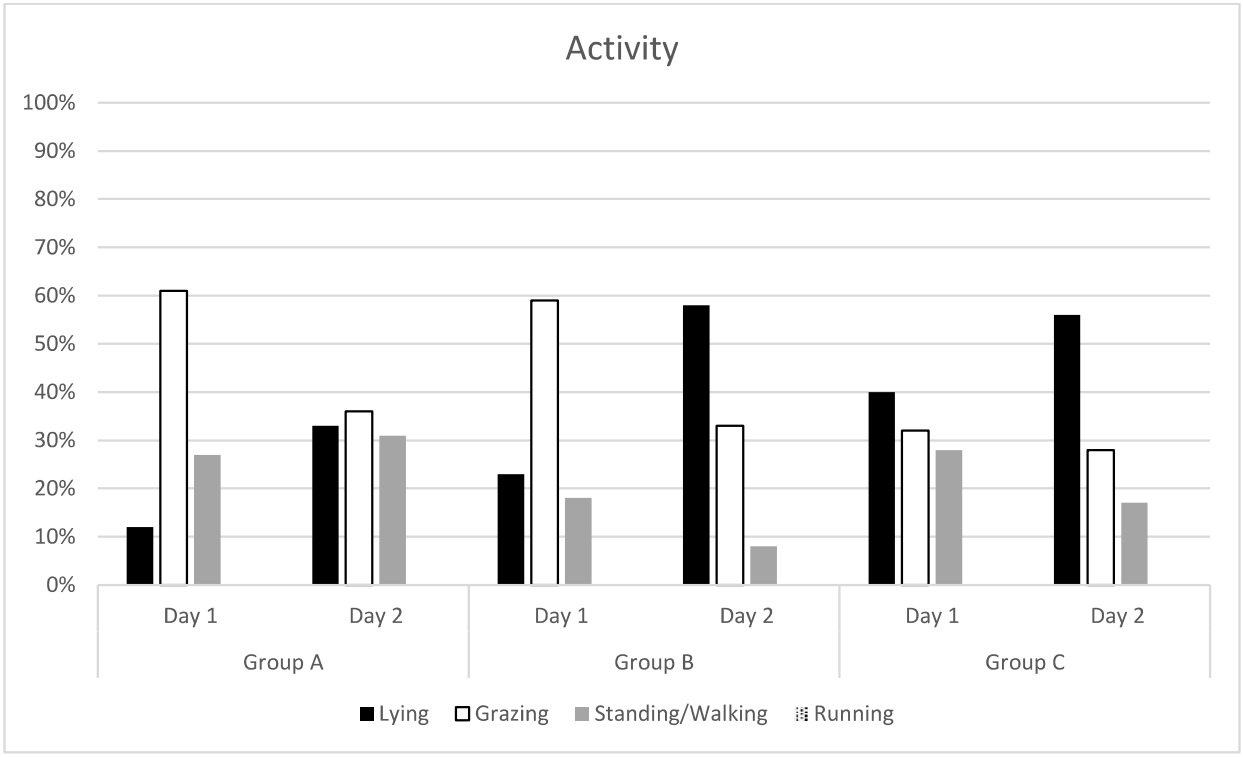


Figure 6: Behaviour (% of observations) of the heifers in the three experimental groups.

3.1.4 Heart rate measurements

One example of a sequence of heart rate data was selected to illustrate a session (2.5 hours) without any warning sound or electric shocks, but still with several increases in heart rate (figure 12). There are five peaks shown in the first part of the period, and several peaks at the end of the session. The peaks at the end of the session was due to the technicians trying to come close to the animal to take the pulse belt off.

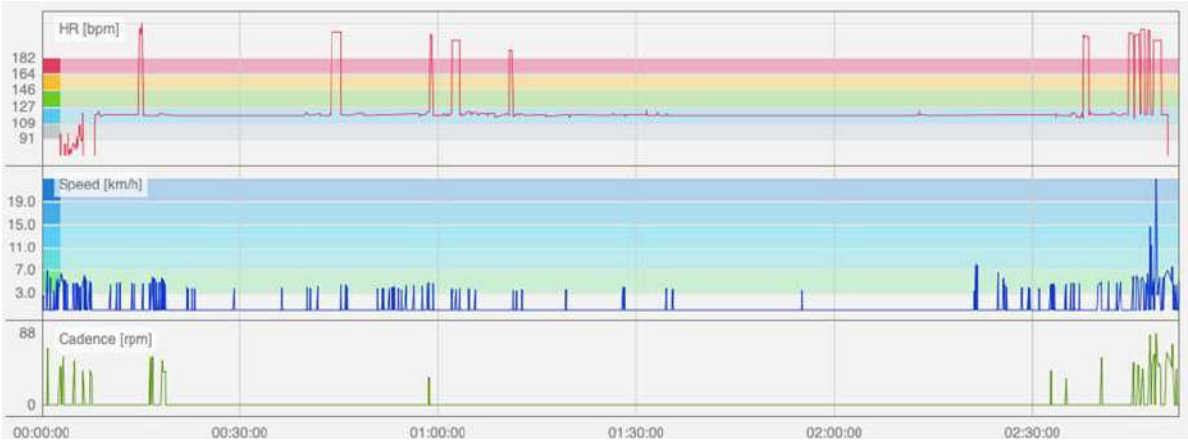


Figure 12: An individual during a 2.45 hours monitoring session. No warning sounds or electric shocks were given.

Three examples of sequences of heart rate data was selected to illustrate the impact of electric shocks and warning sounds on heart rate.

Heifer 11344, from group A, getting her first electric shock during the assisted learning procedure (figure 13). The figure shows a 25-minute sequence out of a 1.15 min session to show more details. The heart rate increases immediately after the electric shock is given, with a HR peak showed in the top row as 143 bpm. It is also clear that the HR decreases within a few minutes to a normal level.

Figure 13: Heifer 11344 getting her 1st electric shock during learning, indicated with the marker.

Heifer 11354, from group C, getting her first electric shock during the assisted learning procedure (figure 14). The figure shows a 20-minutes sequence, were the heart rate increases immediately after the electric shock is given, with a HR peak showed in the top row as 134

bpm. It is also clear that the HR decreases within a few minutes to a much lower level, but still higher that before the electric shock. Reason for this can be that there are more movement in the group.

Figure 14: Heifer 11354 getting her 1st electric shock during learning, indicated with the marker.

Heifer 11344, from group A, getting an electric shock during the motivation test on day 6 (figure 15). The heart rate increases immediately after the electric shock is given, with a HR peak showed in the top row as 155 bpm, within this 25-minute sequence. There is a decrease in the HR within a few minutes, to a much lower level, but it increases again. The reason for this is probably due to the bucket of concentrates.

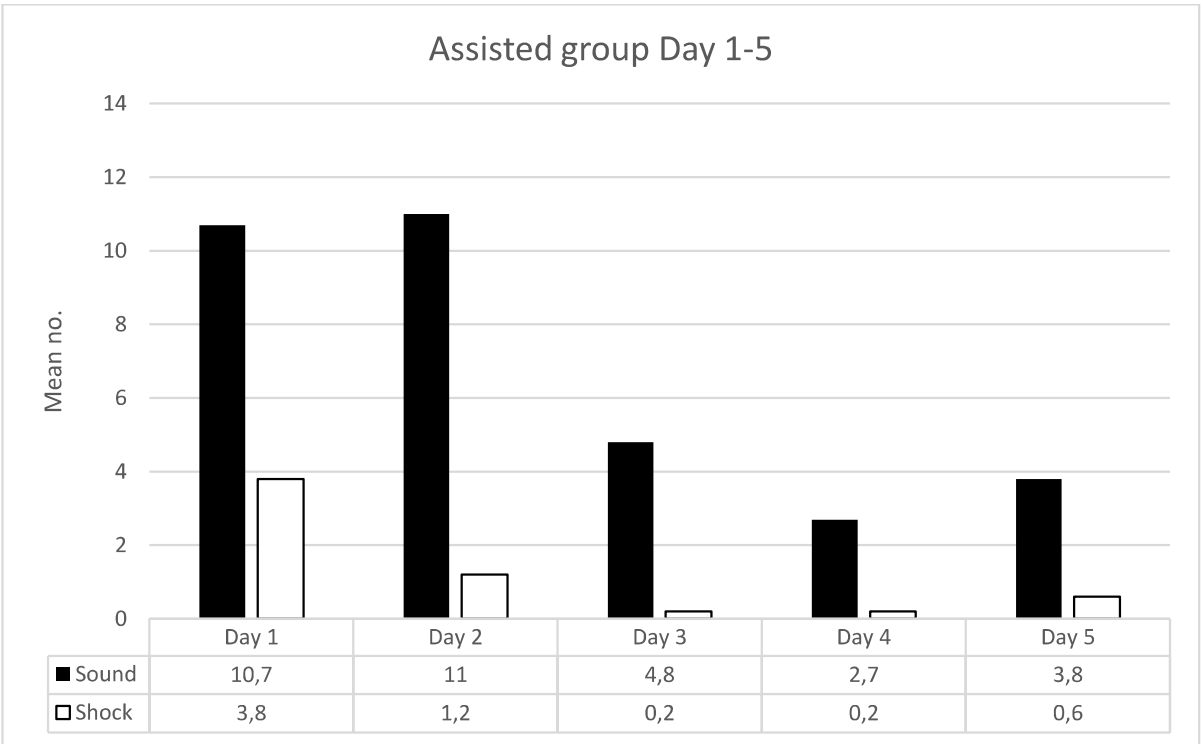
Figure 15: Heifer 11344 getting an electric shock, indicated with the marker, during the motivation test.

3.2. Study 2

3.2.1 Experimental period 1 (learning period)

During the first five days of study 2, there were no escapes over the virtual border in either of the groups.

In group A (assisted group) the mean number of warning sounds were reduced from 10.7 per animal/ day at day 1 to 3.8 per animal/ day at day 5 (figure 7). Further, the mean number of electric shocks were reduced from 3.8 per animal/ day at day 1 to 0.6 per animal/ day at day 5. Likewise, in group U (unassisted group) the mean number of warning sounds were reduced from 12.2 per animal/ day at day 1 to 3.3 per animal/ day at day 5 (figure 8). Further, the mean number of electric shocks were reduced from 4.7 per animal/ day at day 1 to 0.5 per animal/ day at day 5. Hence, in both groups the number of warning sounds and electric shocks markedly decreased from day 1 to day 5, and there were no clear differences between the groups.



	Day 1	Day 2	Day 3	Day 4	Day 5
Sound	10,7	11	4,8	2,7	3,8
Shock	3,8	1,2	0,2	0,2	0,6

Figure 7: Mean numbers of warning sounds and electric shocks for the five first days of learning for the assisted group.

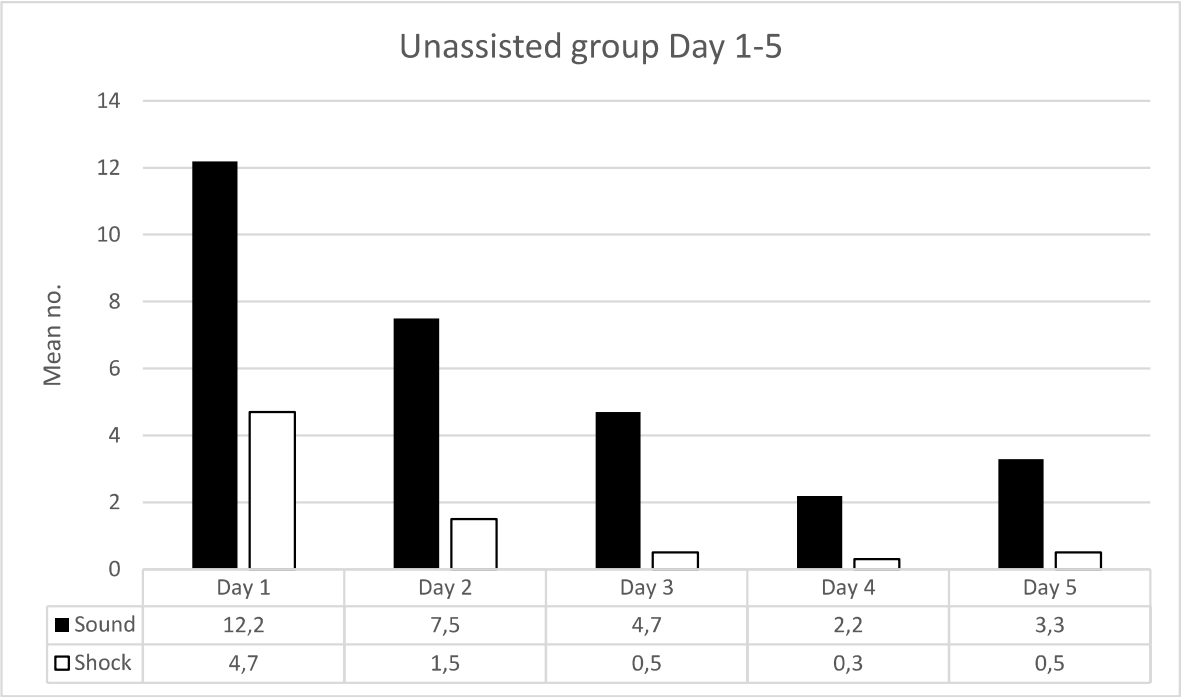


Figure 8: Mean numbers of warning sounds and electric shocks for the five first days of learning for the unassisted group.

The individual data show a variation ranging from 16 to 48 warning sounds per animal, and a range in total number of electric shocks from 3 to 11, during the five-day period of learning.

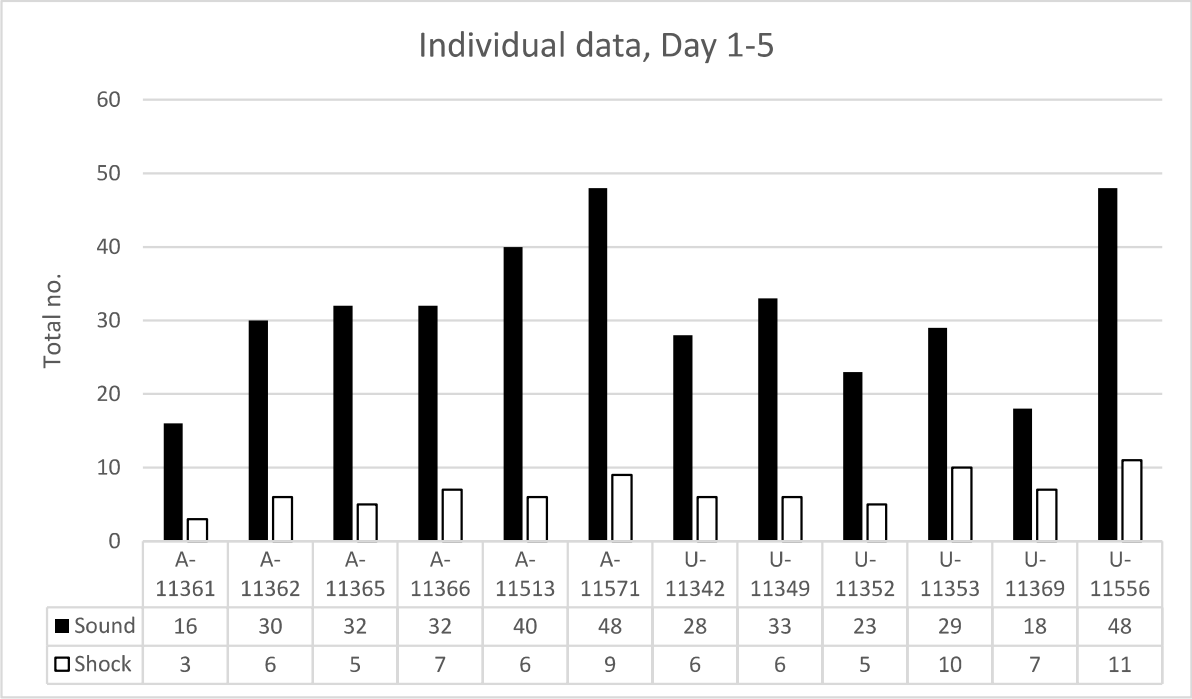
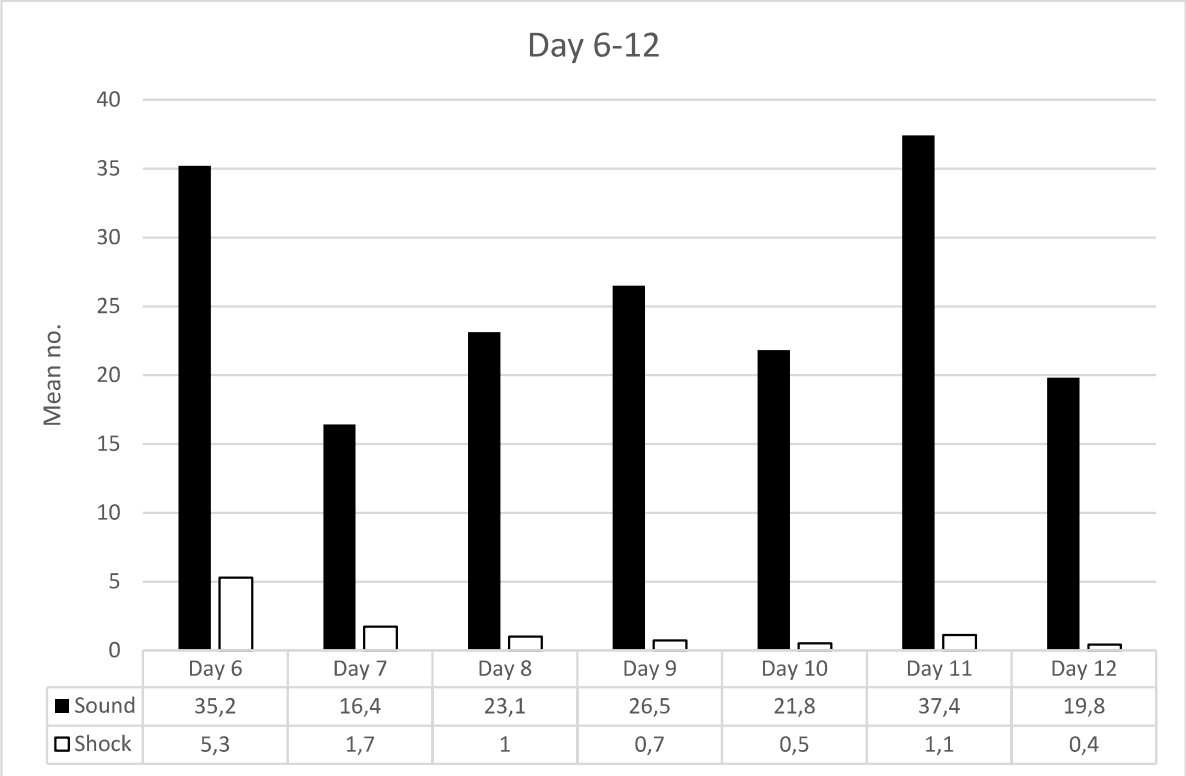


Figure 9: Total amount of warning sounds and electric shocks given during the first five days, both assisted (A) and unassisted (U) individuals.

3.2.2 Experimental period 2

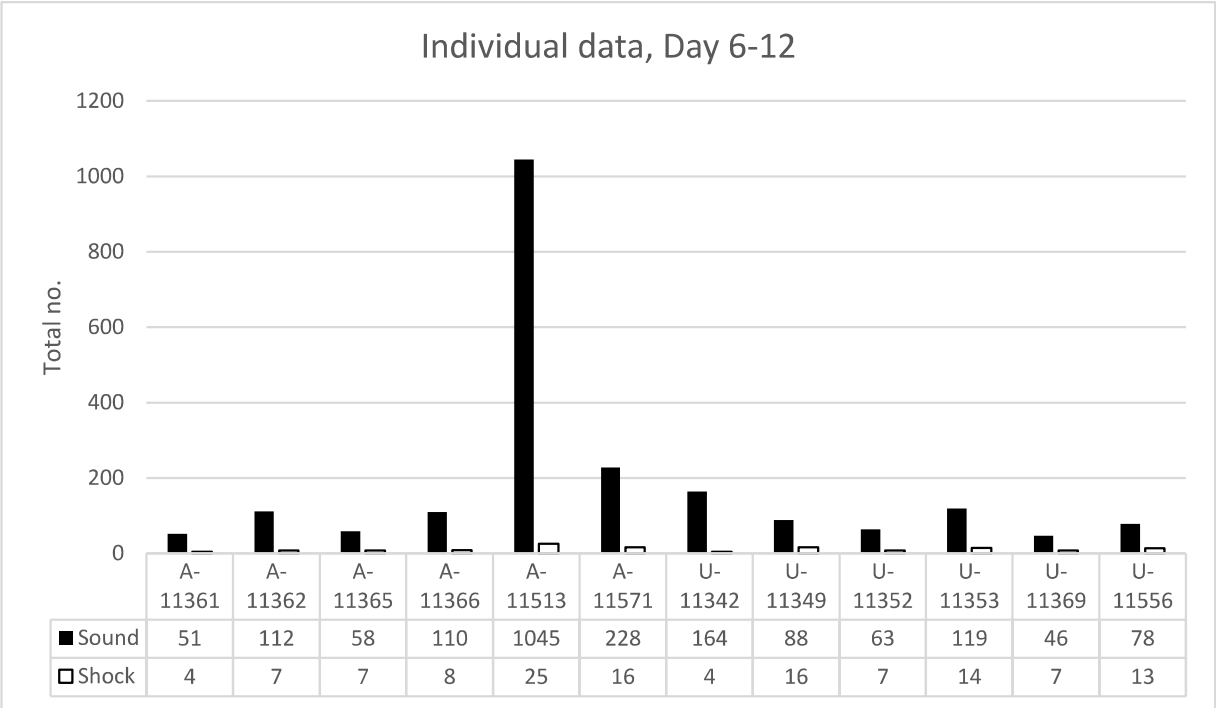
At day 6, when the heifers were given access to a larger pasture area with only virtual borders, the mean number of warning sounds per animal increased from 3.6 at day 5 to 35.2 at day 6. Likewise, the mean number of electric shocks per animal increased from 0.6 to 5.3 (figures 8 and 10). The number of electric shocks decreased gradually, and already at day 8, the mean number was down to 1.0. Two heifers, A-11513 and U-11349, escaped in the morning at day 7.



	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12
Sound	35,2	16,4	23,1	26,5	21,8	37,4	19,8
Shock	5,3	1,7	1	0,7	0,5	1,1	0,4

Figure 10: Daily mean of warning sounds and electric shocks for both groups during the last seven days of study 2.

In spite of the decline in numbers of electric shocks, the number of warning sounds however, remained high, mainly because of heifer A-11513 (figure 11). This individual got more than 1000 warning sounds from day 6 to 12, which represents 42 % of the total number of warning sounds in this period.



	A-11361	A-11362	A-11365	A-11366	A-11513	A-11571	U-11342	U-11349	U-11352	U-11353	U-11369	U-11556
Sound	51	112	58	110	1045	228	164	88	63	119	46	78
Shock	4	7	7	8	25	16	4	16	7	14	7	13

Figure 11: Total amount of warning sounds and electric shocks given during the last 7 days, both assisted (A) and unassisted (U) individuals.

4. Comments by the technicians

The technicians at the dairy unit at the Animal Production Experimental Centre were asked to give their comments regarding the use of the virtual fencing system in this study. They commented that they had not observed any changes in the habits of the animals, except when the collars were put on for the first time, were the heifers were running around for some minutes. They had observed drinking-, resting- and grazing behaviour comparable to what would be considered being normal during the grazing period when using conventional fences. They were pleased that the heifers quickly learned the system and they seemed to tolerate the virtual fence system well. The heifers reacted at the electric shock as they would have reacted on a shock given by a traditional electric fence. A practical comment was that it would have been easier to put on the collars if the heifers had been fixated. They observed no change in behaviour of the heifers after returning to the rest of the flock, when the study was finished.

5. Discussion

Over all, regardless of different treatments, the number of escapes over the virtual border were low. Further, the number of electric shocks were also low, and the number of warning sounds were much higher than number of electric shocks. All this suggests that the heifers quite fast associated the warning sound with the electric shock, and hence learned the system with virtual borders. This was also our expectation when considering the positive results with virtual fencing for goats in commercial herds (Eftang and Bøe, 2017a). At the end of study 1, little grass was left on the pasture inside the virtual fence, and still there were few escapes.

In group A, having the collars with the weakest electric shock, 4 heifers escaped out of the virtual fence, whereas in group B and C no animals escaped. Further, the number of warning sounds and electric shocks were much higher for heifers in group A compared to group B and C. These findings suggest that the weakest electric shock was too low. The virtual fence with the strongest electric shock (group C) was probably regarded as most aversive by the heifers since these heifers received the lowest number of both warning sounds and electrical shocks, and spent least time in the zone nearest to the virtual border (zone 1a). The time spent in this zone did not differ between group A and B. Based on these results it was decided to continue the further studies with the virtual fence with medium strength of the electric shock (strength B).

A lot of effort was put into getting reliable heart rate data. The data showed that the heart rate generally peaked immediately after the electric shock was given. However, the heart rate returned to normal within a few minutes. There is no standards regarding how to interpret variation in heart rate in animals. It is however interesting to observe that the heart rate also peaked in situations that were not related to the virtual fences.

The fact that the heifers were lying in zone 1b indicate that they felt confident in that area, and hence they were not stressed of being close to the border. The observations of grazing/walking/standing heifers in zone 1a further supports this. There were not observed any animals running during the behavioural observations.

There was apparently only small differences in the number of warning sounds and electric shocks between the assisted and unassisted group. We had expected to see a lower number of both these parameters in the assisted group.

Even though a few heifers escaped the second day of the second part of study 2, the other data indicate that heifers can be kept within pastures surrounded by virtual fences only. It seems that when heifers had learned how to respond correctly to one virtual border, it was easy to adapt to new virtual borders.

We conclude that heifers can learn to associate warning sounds with the electric shocks, and hence can be kept on pastures with virtual fences. The minimum strength of the electrical shock at the virtual border must be 1.5 kV, 0.2 Joule loading with 0.5-1 second of duration. There was no obvious effect of assisted learning when introducing virtual fences to heifers. The fact that the heifers were lying in zone 1b indicate that they felt confident in that area, and hence they were not stressed of being close to the border.

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