# Effects of virtual fence monitored by global positioning system on beef cattle behavior

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## INTRODUCTION

In modern agricultural systems, multiple types of fences are used to contain and manage livestock. The containment of cattle in grazing systems uses mainly barbed wire or electric fences, which are time-consuming to build and maintain, and are very costly (Bishop-Hurley et al., 2007). Recently developed technology, virtual fence (VF), which uses behavioral modification based on global positioning systems (GPS), may offer a less expensive and logistically challenging alternative to traditional fencing.

The VF can be defined as a structure serving as an enclosure, a barrier, or a boundary without a physical barrier. Usually, animals in VF are fitted with GPS-monitored collars, which provide an auditory warning stimulus followed by an electric stimulus (ES) if the animals trespass a determined boundary (Umstatter, 2011). A study conducted in Europe (Campbell et al., 2018) demonstrated that VF is highly effective at keeping cattle at designated locations after being trained to respond to the VF. However, it has been observed in other studies (Lee et al., 2009) a high variation in how individual animals respond to cues, with some animals demonstrating non-desirable behaviors.

We hypothesized that the use of VF collars would be an effective method to contain cattle in a specific area or/and prevent cattle from entering a designated area. Furthermore, we hypothesized that the use of VF collars would not negatively impact cattle behavior. Thus, the objective of this study was to evaluate the efficacy of VF as well as the behavior of naïve cows when fitted with VF collars for the first time.

## MATERIAL AND METHODS

The study was conducted during summer 2020 at the Northern Great Basin Experimental Range (NGBER, Riley, OR; 43°29′37″N to 119°42′30″W), Eastern Oregon Agricultural Research Center (EOARC; Burns, OR). All procedures were approved by the Institutional Animal Care and Use Committee of Oregon State University (no. 2020-0074).

### *Animal Selection and Handling*

A total of 11 mature Angus × Hereford cows were randomly selected from the EOARC herd. Cows were familiar with each other and were also familiar with the working facilities where the study was conducted. Cows selected for this study were never fitted with VF collars and, therefore, were considered naïve to the technology. For behavioral evaluation, each cow was fitted with a unique VF collar (Vence Corp. Inc. San Diego, CA) for the duration of the study.

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### *Virtual Fence and Testing Arena*

A VF was used to create a testing arena, where all behavioral variables were collected. The testing arena was created using Herd Manager (Vence Corp. Inc. San Diego, CA) according to GPS coordinates. The VF was built in a pen adjacent to cattle working facility, allowing to move cows easily in and out of the testing arena. The VF contained two management zones: one where the auditory stimulus (AS) was applied and another one where the ES was applied. The management zones, within the VF, were set at the back end of the pen and were approximately 5 × 35 m for the auditory management zone and 10 × 35 m for the electric management zone (both management zones followed the length of the pen, approximately 35 m; Fig. 1). Briefly, when a cow moved into a management zone, the stimuli begin with sound-only with a 0.5-s tone followed by 1.5 s pause. This pattern repeated for 60 s, followed by a cool-down period (no stimuli) of 180 s. From this point on, a combination of auditory and electric stimuli was applied due to location (if the cow moves forward into the management zone) or due to timing into the management zone. The electric stimuli differed depending on the trigger for the stimuli (timing or location) and were 0.5 s in duration followed by either a 1.5 or 2.5 s of pause.

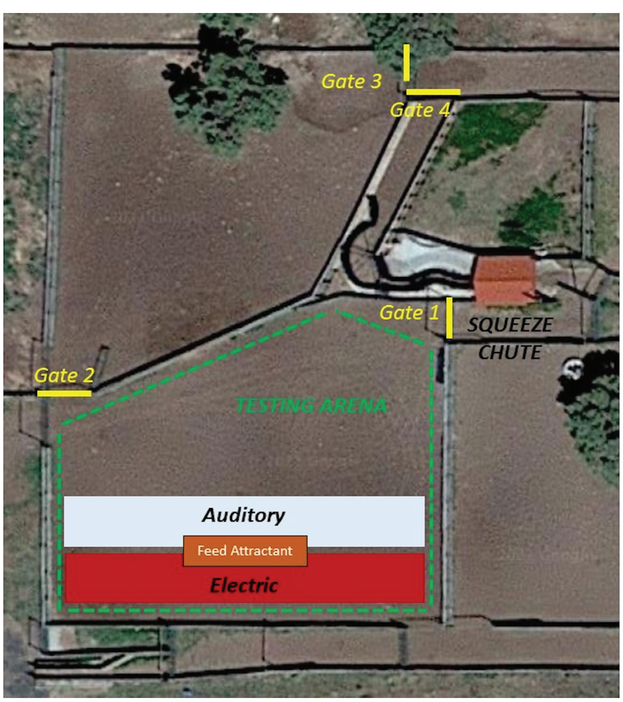


**Figure 1.** Schematic representation of the testing arena depicting two management zones: auditory and electric, and gates allowing cows to be moved in and out of the testing arena.

### *Data Collection*

Data were collected over three consecutive days, where four cows were used in the first 2 d and three cows were used on the third day of the study. Data were collected individually for each cow over five runs of 10 min each. A bale of alfalfa (*Medicago sativa*) hay was placed approximately in the middle of the VF management zone, to serve as a feed attractant, to stimulate cows to move into the VF management zone. Run 1 was used to allow cows to become familiar with the testing arena; thus, cows were not fitted with collars, and therefore auditory and electric stimuli were not collected at the first run. The testing time (10 min) began as the cow entered the testing arena passing through gate one. When the testing time was over, the cow was moved out of the testing arena to an adjacent pen, through gate two, and would later be moved to the squeeze chute through gates three and four (Fig. 1). Cows were fitted with VF collars at the beginning of run 2 and remained collared until the end of run 4; collars were removed at the beginning of the last run (run 5).

Chute score was collected by three trained technicians, following procedures of Arthington et al. (2008), where 1 = calm, no movement; 2 = restless shifting; 3 = constant shifting with occasional shaking of the chute; 4 = continuous movement and shaking of the chute; and 5 = violent and continuous struggling. Chute exit velocity was achieved by determining the speed of the cow exiting the squeeze chute by measuring the rate of travel over a 1.6-m distance with an infrared sensor (FarmTek Inc., North Wylie, TX).

Collar fit score was collected by three trained technicians immediately after cow left the chute upon 30 s of observation, where 1 = unalarmed and unexcited, walking slowly; 2 = slightly alarmed and excited, moving moderately quickly; 3 = moderately alarmed and excited, moving quickly; 4 = very alarmed and excited, moving quickly, and shaking head; and 5 = extremely alarmed and excited, moving quickly, shaking the head, and jumping. The collar fit score was developed by the authors of the present study, upon observation of several other cows being collared for a different study. Although cows were not fitted with collars during runs 1 and 5, collar fit scored was collected in both runs to evaluate cow's fit to the collar. Time to approach feed attractant was recorded for all cows in all runs by one individual using a stopwatch (Versa, Fitbit; San Francisco, CA). Cow behavior while in the testing arena, as well as cow location (in or out of the VF management zones), was collected by three trained technicians. Cow location and behaviors were collected using focal point observations every 1 min. Behaviors were collected based on a pre-established ethogram (Table 1). Cow location while in the testing area was established by visual marks in the testing arena (only visible to technicians) and is presented as time spent in the VF management zone. Each run was recorded (DJI Pocket 2; DJI, Shenzhen, CN) for further confirmation of live data collection. The VF collar logged the date, time, GPS location, and any cues applied. All these data were available to be downloaded for later analysis (Vence Corp. Inc. San Diego, CA).

### *Statistical Analysis*

All data collected by technicians (chute score, collar fit score, behavior, and location) were averaged among technicians for each cow in each run.

For repeated measures data, cow was considered the experimental unit. Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC; version 9.4). The model statement included the effects of runs and all variables. Run was included in the repeated statement with cow as subject. Correlation between the number of AS and ES was analyzed using the CORR procedure with Pearson statistical analysis option. Data were separated using PDIF when a significant *F*-test was detected. Results are reported as least squares means. Significance was set at $P \leq 0.05$, and tendencies were determined if $P > 0.05$ and $P \leq 0.10$.

**Table 1.** Category and behavioral descriptions of behaviors collected from naïve cows fitted with VF collars

| Category | Behavior | Behavior description |
|---|---|---|
| Feeding | Eating | Cow eats attractant (hay) |
| | Browsing | Cow eats grass/shrubs present in the testing arena |
| Locomotion | Idling | Cow does not perform any behavior—Standstill |
| | Walking | Cow walks/wanders in the testing arena |
| | Head shaking | Cow shakes head while standstill |
| Agonistic, non-desirable[†] | Walking; head shaking | Cow walks and moves head—nonnatural movement |
| | Running/trotting | Cow runs/trots in the testing arena |
| | Running/trotting; head shaking | Cow runs/trot and moves head—nonnatural movement |
| | Jumping | Cow jumps in the testing arena |
| | Jumping and head shaking | Cow jumps and shakes head simultaneously |
| | Bucking and running | Cow bucks and runs |

[†]Some of the listed behaviors considered as agonistic/non-desirable in this study might be considered play behavior or social interaction in different literature. However, for this study, these behaviors were considered non-desirable responses for cows when fitted with VF collars.

## RESULTS AND DISCUSSION

No differences were observed across runs for chute score ($P = 0.85$) or chute exit velocity ($P = 0.37$; Table 2), implying that both variables were not affected by the collar use.

Collar fit score was greater ($P < 0.001$) in run 2 when compared with all other runs (Table 2). Cows were fitted with VF collars at run 2 explaining the increase in collar fit score when compared with the other runs. During run 2, collar fit score was 3.95 where cows were classified as very alarmed and excited, moving quickly, and shaking head (score 4). Interestingly this response was only observed at run 2, suggesting that cows became quickly adapted to VF collars.

Although no differences ($P = 0.12$) were observed for latency to approach the feed (Table 2), cows took a longer time to approach the feed attractant during runs 3 and 4 when compared with run 5, suggesting that cows did not lose interest in the feed attractant; however, they were cautious when proceeding to the respective area. Such rationale is supported by the time spent in the VF management zones (Table 2), whereas cows spent the greatest ($P < 0.01$) time in the VF management zones during run 1 followed by run 5, with runs 2, 3, and 4 with the least amount of time spent in the VF management zones, implying that cows did not develop a negative association with VF management zones and the feed attractant placed in this area.

Auditory and electric stimuli applied to cows during runs 2, 3, and 4 followed that same pattern and were positively correlated ($r = 0.88$; $P < 0.001$). Cows received the greatest ($P \leq 0.01$) number of stimuli during run 2, which decreased over runs 3 and 4 (Table 2), implying that cows have quickly learned to avoid the VF area as similarly observed by Lee et al. (2009).

Among the behaviors observed during each run, there were no differences ($P \geq 0.15$) between runs for browsing, walking, head shaking, walking and head shaking, and running and trotting (Table 3). As expected by study design, cows engaged in eating behavior at the greatest ($P < 0.001$) percentage of time

**Table 2.** Count of AS and ES applied, chute score and exit velocity, collar fit score, latency to approach feed, and time spent in the VF area in each run

| Item | Run 1 | Run 2 | Run 3 | Run 4 | Run 5 | Largest SEM | *P*-value |
|---|---|---|---|---|---|---|---|
| Chute score† | 1.40 | 1.25 | 1.30 | 1.30 | 1.40 | 0.109 | 0.85 |
| Chute exit velocity‡, m/s | 2.10 | 1.45 | 1.80 | 1.85 | 1.90 | 0.244 | 0.37 |
| Collar fit score‖ | $1.45^{b}$ | $3.65^{a}$ | $1.60^{b}$ | $1.30^{b}$ | $1.25^{b}$ | 0.197 | <0.001 |
| Latency to approach feed$, s | 287 | 283 | 455 | 511 | 418 | 73.20 | 0.12 |
| Time spent in VF¶, % | $62.7^{a}$ | $22.7^{b}$ | $18.6^{b}$ | $12.2^{b}$ | $33.6^{a,b}$ | 8.766 | <0.01 |
| AS applied** | N/A | $11.9^{a}$ | $7.95^{a,b}$ | $2.14^{b}$ | N/A | 2.108 | <0.001 |
| ES applied** | N/A | $6.55^{a}$ | $4.7^{a,b}$ | $0.545^{b}$ | N/A | 1.395 | <0.01 |

†Chute score was collected by three trained technicians following procedures of Arthington et al. (2008).

‡Chute exit velocity was achieved by determining the speed of the cow exiting the squeeze chute using an infrared sensor (FarmTek Inc., North Wylie, TX).

‖Collar fit score was collected by three trained technicians immediately after the cow left the chute upon 30 s of observation using a scoring system (1 to 5) developed by the authors.

$Time to approach feed attractant was recorded by one individual using a stopwatch (Versa, Fitbit; San Francisco, CA).

¶Cow location (in or out of the VF area) was collected by three trained technicians using focal observations in a 1-min interval for 10 min.

**Dataset containing AS and ES applied to cows in each run was obtained from VF collars and provided by the VF collar manufacturer (Vence Corp. Inc. San Diego, CA).

a,bMeans within rows with different superscripts differ.

**Table 3.** Activity budget as the average percentage of time spent engaged in each behavior in each run

| Behavior† | Run 1 | Run 2 | Run 3 | Run 4 | Run 5 | Largest SEM | *P*-value |
|---|---|---|---|---|---|---|---|
| Eating, % | $47.7^{a}$ | $3.85^{b}$ | $0.955^{b}$ | $1.34^{b}$ | $24.0^{a,b}$ | 6.943 | <0.001 |
| Browsing, % | 10.8 | 5.60 | 12.0 | 6.65 | 19.9 | 5.09 | 0.30 |
| Idling, % | $21.9^{c}$ | $52.3^{a}$ | $54.9^{a}$ | $57.8^{a}$ | $36.6^{a,b,c}$ | 6.95 | <0.01 |
| Walking, % | 15.9 | 17.8 | 24.9 | 26.0 | 18.8 | 4.01 | 0.30 |
| Head shaking, % | 0.466 | 3.50 | 0.970 | 1.70 | 0.250 | 1.0184 | 0.17 |
| Walking; head shaking, % | 0.485 | 4.01 | 0.888 | 2.83 | 0.252 | 1.2401 | 0.15 |
| Running/trotting, % | 0.00 | 1.14 | 0.92 | 0.88 | 0.00 | 0.9622 | 0.85 |
| Running/trotting; head shaking, % | $0.00^{b}$ | $5.54^{a}$ | $1.60^{b}$ | $0.800^{b}$ | $0.00^{b}$ | 0.8152 | <0.001 |
| Jumping, % | $0.00^{b}$ | $1.08^{a}$ | $0.232^{b}$ | $0.235^{b}$ | $0.00^{b}$ | 0.2404 | 0.01 |
| Jumping and head shaking, % | $0.00^{b}$ | $1.86^{a}$ | $0.927^{a}$ | $0.00^{b}$ | $0.00^{b}$ | 0.4050 | <0.01 |
| Bucking and running, % | $0.00^{b}$ | $1.25^{a}$ | $0.232^{a,b}$ | $0.00^{b}$ | $0.00^{b}$ | 0.3074 | 0.02 |

†Behavior was collected by three trained technicians using focal observations in 1-min intervals based on a pre-established ethogram.

a–cMeans within rows with different superscripts differ.

during run 1 when compared with runs 2, 3, and 4 with no differences observed when compared with run 5, implying that eating behavior was not negatively affected by VF collar use. In fact, the use of VF collars prevented cows from engaging in eating behavior during runs 2, 3, and 4 (as desired) while eating behavior return to a level similar to the initial run during run 5. Similarly, Campbell et al. (2018) reported that number of cows reaching a feed attractant when evaluating cattle behavior using VF collars reduced with trial progression. However, in that study, the authors have not reported if cows would resume feeding activity in the previous established VF, as observed in this study. Cows engaged in idling behavior at greatest ($P < 0.01$) percentages during runs 2, 3, and 4 likely to avoid stimuli.

A similar pattern was observed among some of the behaviors categorized as agnostic or non-desirable (running/trotting and head shake, jumping, jumping and head shaking, and bucking and running). These behaviors were absent during run 1, peaked ($P \leq 0.02$) during run 2, and were reduced or absent during runs 3, 4, and 5, implying that cow's engagement in non-desirable behaviors was likely due to VF collars; however, this response was transient, only present immediately after cows were collared.

In summary, the use of VF collars was effective at preventing cows from entering the VF management zones and, therefore, consuming the feed attractant. Additionally, the use of VF collars did not negatively impact the cow behavior, as observed by the resumption of behaviors upon removal of collars. Further, cows did not develop a negative association with the VF management zone; in fact, cows quickly learn to avoid the VF management zone upon stimuli.

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*Conflict of interest statement*. T.P. is an employee of Vence Corp. Inc. T.P. collaborated on the development of this study but has not contributed to the data analysis.

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