**An investigation of the impact of virtual fencing technology on sheep welfare and behaviour**

**Application –** Virtual fencing use is being advocated for a range of cattle and sheep grazing systems. This technology is promoted as enhancing grazing management. However, important knowledge gaps remain regarding its application. This study investigated the impact of virtual fencing on the welfare and behaviour of lowland and hill breeds of sheep.

**Introduction –** Virtual fencing (VF) is a novel technology which enables grazing livestock management without the need for physical fences. It offers flexibility and may deliver benefits for farm productivity and environmental sustainability, particularly conservation grazing. Real-time GPS monitoring of animal location may also be beneficial for animal welfare and management (Umstatter, 2011). The technology typically uses a GPS-enabled neck collar coupled with a mobile phone application through which the user sets the VF boundary. When the animal approaches the boundary, it receives an audio warning to turn around. This is followed by an electric pulse if it continues beyond the VF. Through associative learning after a short training period, the animals learn the correct response to the audio cues (Lee *et al.*, 2009). However, an electric pulse may cause stress for an animal, raising concerns on the impact of VF systems on welfare and behaviour (Animal Welfare Committee, 2022). Therefore, this study aimed to determine the behaviour and welfare effects of VF across different breeds of sheep.

**Material & methods –** Ninety-six dry ewes (average 4.5 years old) were split into 3 cohorts in a 2x2 factorial design experiment (breed: lowland or hill, fencing: physical or virtual). Each cohort comprised 4 treatments: lowland control (LC), lowland VF (LVF), hill control (HC) and hill VF (HVF) (ngroup = 8, ncohort = 32). Groups were balanced on breed, bodyweight and temperament. All ewes were fitted with Nofence collars (Nofence, Norway). The experimental period lasted 38 days, including an initial 10-day training period for the VF groups followed by a 28-day grazing period where groups were moved to fresh pasture weekly. The training of the VF groups was done with a single VF line in their pasture and two VF lines for the remainder of the study. On days 0, 10, 24 and 38 ewes were weighed, assessed for temperament, reactivity in isolation and flight response using the isolation box method (based on Atkinson *et al*., 2022). Temperament, vocalisations, 180° head turns, number of jumps, single feet lifted, headbutts and ground scratches were recorded (Hero Session 5, GoPro,USA) over a 2-minute period in the weighing crate (1.25\*0.5m). Flight response was measured as the time taken for the ewe to leave the weighing crate and cover 1.70m distance. An attention bias test (based after Monk *et al*., 2020) was performed at the end of the study, using an umbrella as the ‘threat’ for 10 seconds, and behavioural reactions were recorded for 2 minutes. Vocalisations, number of zones crossed, latency to eat, time spent looking at the ‘threat corner‘ and time spent at entry/exit doors were recorded. Activity data (unitless) reported from the VF collars provided information on overall movement patterns, based on an accelerometer registering along 3 axes. Statistical analyses were conducted using R (version 4.2.2) and the package “rstatix” with the individual variables analysed according to their distribution and homogeneity of variances: ANOVA (post-hoc student t-test), Kruskal-Wallis (post-hoc Dunn test), Welsh ANOVA (post-hoc Games-Howell). The data reported are presented as mean±standard error.

**Results –** Preliminary results (cohort 1) showed that VF did not have an effect on bodyweight. There was a difference in the activity data between breeds and treatments, with higher activity levels recorded in hill ewes than lowland ewes, and higher activity in LC than LVF (on average 33,800.98 ± 2,717.43 (LC), 26,243.74 ± 3,370.09 (LVF), 35,5862.13 ± 4,332.35 (HC), 33,984.01 ± 3,567.42 (HVF) [F=59.319. *P*<0.001]). Regarding the isolation box test, no differences were observed between breeds or treatments (Table 1). Attention bias test results showed no behavioural differences between breeds or treatments. On average across treatments, vigilance behaviour was 32.04 ± 3.38s, attention to the ‘threat’ corner was 4.07 ± 0.74s, number of eating bouts was 0.57 ± 0.14, latency to eat was 82.89 ± 8.93s, number of zones crossed was 10.07 ± 1.78, time spent standing at the entry door was 4.18 ± 0.85s, and time spent standing at the exit door was 5.75 ± 1.07s.

Table 1 - Isolation box parameters by date & by treatment (Mean ± standard error)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | LC | LVF | MC | MVF | p-value |
| ***Prior training (Day 0)*** |
| Vocalisations | 0.25 ± 0.25 | 0 | 0 | 0 | 0.39 |
| Jumps | 0 | 0.71 ± 0.53 | 0 | 0.13 ± 0.13 | 0.25 |
| Single feet  | 9.29 ± 3.28 | 13.14 ± 4.11 | 10.71 ± 1.95 | 12.25 ± 3.42 | 0.62 |
| Headbutts | 3.71 ± 1.81 | 1.43 ± 0.91 | 0.71 ± 0.44 | 5.63 ± 3.46 | 0.69 |
| Scratching | 0 | 0 | 0 | 0 | NA |
| 180° head turns | 0.50 ± 0.33 | 0.25 ± 0.25 | 1.00 ± 0.50 | 0.50 ± 0.50 | 0.37 |
| Temperament | 2.00 ± 0.38 | 1.88 ± 0.40 | 2.75 ± 0.37 | 2.88 ± 0.58 | 0.28 |
| ***End training (Day 10)*** |
| Vocalisations | 5.75 ± 1.81 | 1.50 ± 1.05 | 2.00 ± 0.76 | 2.29 ± 0.44 | 0.077 |
| Jumps | 0.25 ± 0.16 | 0.13 ± 0.13 | 0.14 ± 0.13 | 0 | 0.62 |
| Single feet  | 8.63 ± 1.67 | 14.25 ± 3.32 | 6.86 ± 3.05 | 9.67 ± 1.58 | 0.13 |
| Headbutts | 1.13 ± 0.99 | 1.50 ± 1.05 | 0.57 ± 0.40 | 0.17 ± 0.14 | 0.94 |
| Scratching | 1.00 ± 0.76 | 0.25 ± 0.16 | 0.14 ± 0.13 | 0.67 ± 0.58 | 0.92 |
| 180° head turns | 1.25 ± 1.00 | 0.50 ± 0.33 | 0.29 ± 0.17 | 3.29 ± 1.79 | 0.37 |
| Temperament | 3.13 ± 0.30 | 2.50 ± 0.27 | 3.00 ± 0.29 | 3.29 ± 0.17 | 0.25 |
| ***2 weeks in (Day 24)*** |
| Vocalisations | 1.13 ± 0.85 | 1.38 ± 0.89 | 1.00 ± 0.61 | 0.63 ± 0.38 | 0.99 |
| Jumps | 0 | 0 | 0 | 0 | NA |
| Single feet  | 5.63 ± 1.59ab | 14.25 ± 3.94b | 5.14 ± 3.21a | 7.00 ± 2.88ab | 0.047 |
| Headbutts | 0.38 ± 0.38 | 0.13 ± 0.13 | 0 | 0 | 0.58 |
| Scratching | 0.25 ± 0.25 | 0.13 ± 0.13 | 0 | 0 | 0.58 |
| 180° head turns | 0.63 ± 0.42 | 1.50 ± 0.53 | 1.00 ± 0.65 | 1.50 ± 0.42 | 0.26 |
| Temperament | 2.25 ± 0.16 | 2.38 ± 0.18 | 1.57 ± 0.19 | 2.25 ± 0.41 | 1.00 |
| ***End (Day 38)*** |
| Vocalisations | 1.25 ± 0.82 | 0.71 ± 0.53 | 0.50 ± 0.30 | 0.63 ± 0.32 | 0.99 |
| Jumps | 0 | 0 | 0 | 0.25 ± 0.25 | 0.45 |
| Single feet  | 7.63 ± 2.23 | 14.86 ± 4.48 | 4.50 ± 1.20 | 6.38 ± 1.53 | 0.087 |
| Headbutts | 0.25 ± 0.25 | 0 | 0 | 0.13 ± 0.13 | 0.64 |
| Scratching | 0.88 ± 0.52 | 0.67 ± 0.43 | 0 | 0 | 0.12 |
| 180° head turns | 0.25 ± 0.25 | 1.29 ± 0.34 | 1.17 ± 0.41 | 1.88 ± 0.64 | 0.10 |
| Temperament | 2.50 ± 0.27 | 2.71 ± 0.17 | 2.00 ± 0.00 | 2.38 ± 0.26 | 0.13 |

**Conclusion –** Preliminary results indicate that VF did not negatively impact ewe behaviour or welfare, yet it seems that breeds behave differently to the technology. These results need to be confirmed with the bigger data set, combined with cortisol analysis. However, these preliminary findings give confidence that the technology works for containing both hill and lowland sheep within a set boundary which should encourage the uptake of the technology.

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**References -** Animal welfare committee, 2022. ‘AWC opinion on the welfare implications of using virtual fencing for livestock*’,* Available at: *https://www.gov.uk/government/publications/awc-opinion-on-the-welfare-implications-of-using-virtual-fencing-for-livestock*

Atkinson *et al*., 2022. ‘Behavioural reactivity testing in sheep indicates the presence of multiple temperament traits’, *Behavioural Processes,* 201(2022):104711. Available at: https://doi.org/10.1016/j.beproc.2022.104711

Lee *et al*., 2009. ‘Associative learning by cattle to enable effective and ethical virtual fences', *Applied Animal Behaviour Science,* 119(1-2), pp. 15-22. Available at: https://doi.org/10.1016/j.applanim.2009.03.010

Monk *et al.,* 2020. ‘Attention bias test measures negative but not positive affect in sheep: a replication study’, *animals,* 10(8):1314. Available at: https://doi.org/10.3390/ani10081314

Umstatter, 2011 'The evolution of virtual fences: A review', *Computers and Electronics in Agriculture,* 75(1), pp. 10-22. Available at: https://doi.org/10.1016/j.compag.2010.10.005