Electric shock control of farmed animals

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Ethical critique of electric shock control of farmed animals

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Abstract

The available methods of electric shock control or containment of farmed animals are increasing and potentially include: i) fixed and movable electric fencing; ii) cattle trainers; iii) prods or goads; iv) wires in poultry barns; v) dairy collecting yard backing gates; vi) automated milking systems (milking robots); and vii) collars linked to virtual fencing and containment systems. Because any electric shock is likely to cause a farmed animal pain, any such control or containment must, to be ethically justifiable, bring clear welfare benefits that cannot be practicably delivered in other ways. Associated areas of welfare concern with ethical implications include the displacement of stockpersons by technology, poor facility design, stray voltage, coercive behavioural change and indirect impacts on human society and values.

Keywords: animal welfare; automated milking system; collar; electric fencing; electric shock; ethics

1. Introduction

When electricity is used on farms to transmit power to generate outputs such as light, heat or motion, a basic safety expectation is that animals are protected from current by appropriate distancing or insulation. If a current of sufficiently high energy passes through an animal, its negative welfare effects may include pain, discomfort, distress, injury or death. These negative effects may be intentionally harnessed and developed for control and containment purposes.

Over the past ninety years, the uses of electricity to control and contain farmed animals by aversive stimulation have gradually increased, with successive new applications being found. Intentionally causing animals pain is ethically problematic because the experience of pain is intrinsically bad (Tannanbaum 1999, 97–101). This is the earliest modern grounding of animal ethics and is supported by the argument that if causing humans unnecessary pain is ethically unjustifiable, causing sentient animals unnecessary pain is also ethically unjustifiable (Grumett 2018, 34–6). Where such animals are under direct human control, including in farming contexts, the ethical requirement not to cause them unnecessary pain is even greater because humans are responsible for them. In some states this is legally codified (e.g., *Animal Welfare Act 2006*, 9(2)(e)) and enforceable.

This article will address electric shock control applications in which animals subjected to control retain consciousness and retain the capacity for voluntary bodily movement. Other potential uses include stunning, which is used to render an animal unconscious and therefore insensate to pain prior to slaughter, and immobilization, which has sometimes been used to prevent voluntary muscular movement while mutilations such as castration or dehorning are performed. Stunning and immobilization fall outside the scope of this paper.

The objectives of this paper are to provide an overview of the different forms of electric shock control potentially used on farmed animals, to identify their welfare implications and to offer ethical assessment of these. As part of the research for this paper we have conducted a comprehensive survey of manufacturer specifications for energizers available for online purchase. The anonymized dataset resulting from this survey accompanies this paper. The first section of the paper will review potential control and containment applications, which include: i) fixed and movable electric fencing; ii) cattle trainers; iii) prods or goads; iv) wires in poultry barns; v) dairy collecting yard backing gates; vi) automated milking systems (milking robots); and vii) collars linked to virtual fencing and containment systems. In the second section, the ethical implications of each of these uses of electricity on animals will be considered in turn. It will be shown that, while some applications may potentially bring welfare benefits in particular situations, because they all have certain negative welfare impacts they require ethical evaluation. The third section will offer an overall ethical assessment of the electric shock control of farmed animals, extending to issues such as the displacement of stockpersons by technology, facilities design, discretionary versus rational control, stray voltage, behavioural change and indirect effects on human society and values.

2. Overview of applications

i) Fixed and movable electric fencing

Electric fencing was developed during the 1930s in the United States and then in New Zealand. In Wisconsin, Edwin Gengler (1934) created an electrically charged stock enclosure and patented it. Early fences were sometimes powered by home generators or mains supply. Due to the high current, these were more dangerous than fences supplied by batteries. By the later 1930s, electric fencing was in use across the United States to protect farmed animals from predatory wild animals such as bears and racoons, and to keep wild animals including antelope, buffalo, deer and elk off crops (McAtee 1939). In New Zealand later in the same decade, William Gallagher developed electric fencing, apparently after connecting his car to a generator so that if a horse rocked the car, it would receive an electric shock (Goldsmith 2013). Following installation and use on his own farm, Gallagher gained his first patent in 1939, by which time he was marketing his device to neighbours.

Conventional electrical fencing was further developed during the 1960s as a cheaper alternative to traditional wooden fencing, requiring fewer materials and reduced setup time and labour (McKillop and Sibly 1988, 91–3). Electric fencing delivers either a pulsed direct current or an alternating current to an animal that touches one of two or more horizontal wires running between wooden or metal posts fixed in the ground. This causes the animal to experience discomfort or pain and, in response, to move away. The number, height and spacing of wires used typically varies according to species. The wire spacing varies according to the animal size, with small animals requiring narrower spacing. Because an animal usually touches only one wire at a time, the number of wires used for each species is less critical than their spacing and height, which constitute the physical fenced barrier (Kubik 2014). Typically 1–3 wires are sufficient for cattle, 3–4 for pigs, 4–6 for sheep and goats and nine for chickens (Rutland Electric Fencing (UK) n.d.). Energizers are usually identified as suitable for one or more species. The energy ranges (Joules) and voltage (Volt) provided for energizers with published species and energy specifications are shown in Table 1.

Table 1: Energizer specifications by species

Species	Minimum	Maximum	Average	

	Energy (J)	Voltage (V)	Energy (J)	Voltage (V)	Energy (J)	Voltage (V)	Sample size
cattle	0.07	5000	25	16800	4.23	9779	128
sheep	0.07	6900	20	16800	4.83	9995	85
goats	0.07	6900	20	16800	3.93	10058	82
pigs	0.12	7000	18.5	16800	3.42	10350	45
poultry	0.20	7900	5.0	13000	1.77	9663	26

Based on a comprehensive survey of manufacturer specifications for energizers available for online purchase. Minimum energy stated to be potentially deliverable (Joules); maximum energy stated to be potentially deliverable (Joules); minimum stated voltage (Volt); maximum stated voltage (Volt); average energy (Joules); average voltage (Volt); number of energizers marketed as appropriate for the species (sample size). Details are provided in the accompanying anonymized dataset. (Note: five energizers specified for poultry were excluded from the poultry comparison because the high energy levels delivered suggest that they would be used to protect birds from predators rather than for containment purposes.)

The wide range of parameters is due to diverse practical considerations related both to external factors and to species. The actual current that may flow to an animal varies according to the resistance of the hair, skin, body tissues and electrical circuit (McKillop, Pepper, Butt and Poole 2003, 6), which includes wires and any leakage of current to earth through wet insulators or vegetation in contact with the fence wire. Dew, rain, moist soil and wet animals are all likely to increase conductivity and thus the current delivered (Campbell, Mowry and Hartstock 1956). However, vegetation in contact with the fence is likely to result in energy loss as the fence ‘shorts’ through the vegetation to the ground, reducing the potential difference (voltage) of the circuit (ibid.). In general, the greater the length of the fence, and the closer to vegetation that the conducting wires are, the higher the likelihood of variation in the current delivered. Moreover, the energy levels given in specifications are maxima that might be attained under ideal conditions: in real situations the actual current and energy delivered will probably be lower than the maximum possible and, for the reasons just discussed, will be variable.

The high upper-end energies for cattle may be required to control large breeds with hairy coats, and cows with calves, which will overcome significant barriers to protect or retrieve a calf (Lalman, Highfill, Barnes, LeValley, Gill, Wallace and Strasia 2010, 1). Goats are normally curious and are likely to investigate and test a fence regularly, especially by attempting to push under it (Hart 2001, E174). Pig skin is mostly hairless and is exposed, and pigs are likely to touch a fence with their nose, which is a sensitive body part (Kubik 2014, 128, 143–8). If sheep have thick wool, this is likely to limit conductivity (Cholewińska, Iwaszkiewicz, Łuczycka, Wysoczański, Nowakowski, Wryostek and Bodkowski 2019), which, in combination with insulating hoof material (collagen), is likely to result in poor return of the electrical pulse. In poultry, feathers, scaly legs and feet have poor conductivity (also due to collagen), which is also likely to result in poor return of the electrical pulse (Ashokkumar and Ajayan 2021, 176). The thickness of an animal's hair, wool or feathers (Tesfaye, Sithole, Ramjugernath and Mokhothu 2018) is a further variable according to breed, season and management practices. With cattle, electric fencing may, like a traditional fence, be used as a 'creep', with wires fixed high enough to allow calves to pass under but low enough to impede the passage of adults (Miles 1951, 230). This allows calves to remain with their dams but also permits them to access additional pasture unavailable to their dams or to any mature bulls running with the dams, promoting weaning and a degree of independence within the herd.

From the 1990s, portable electric fencing has been in use (Morgan 2016). This consists of stainless-steel wire woven into plastic mesh strips that attach to plastic posts that are pushed into the ground by hand. The fence is usually powered by a portable solar or battery energizer unit. Portable systems may be quickly transported, erected, dismantled and moved to manage animal access to land for grazing and other purposes, including temporary or seasonal hazards.

ii) Cattle trainers

In cow sheds, the cubicles or stalls in which cattle are housed are designed so that faeces and urine produced by an animal drop into the channel or passage that runs the length of the barn behind the cubicles or stalls. (This is often called the scraper passage, because it is lower than the cubicle beds and is scraped by a tractor or track-based automated scraper to remove manure.) However, a standing animal may sometimes defecate or urinate into the rear part of the lying area and bedding within the cubicle or stall, rather than into the passage further back. Waste may then accumulate on the hind feet, legs, hind quarters or udders of the animal, increasing the risk of disease. From a welfare perspective, cubicles need to have sufficient depth to allow for forward lunging on rising, which is a normal species behaviour (Dirksen, Gygax, Traulsen, Wechsler and Burla, 2020). Waste accumulation may be an increased problem where this welfare need is met.

Cattle trainers were developed to encourage cattle to deposit their waste in the channel running behind the cubicle. A trainer is a retractable and height-adjustable electrified rod passing across the stall about one third of the way from the front and just above the animal's shoulders (Hultgren 1991, 291–3). When an animal is preparing to expel faeces or urine, it typically arches its back. If it does so whilst standing forward in the cubicle or stall, it receives an electric shock. However, if the animal steps backwards to avoid being shocked, its position results in the waste being deposited into the channel. Due to differences in size and body movement between individuals, trainers need adjusting for each individual if they are to be effective. This means that, whenever an animal returns to a different stall, the trainer in that stall may need repositioning. Following adjustment, the trainer needs to be firmly secured to avoid any possibility of it falling onto an animal's back. A range of energizers marketed as usable with cattle trainers are specified as 2.5–8kV and 0.02–0.09J. However, a published advice source states that they should not exceed 2.5kV (Midwest Rural Energy Council (USA) 2005, 4).

iii) Prods or goads

A cattle prod or goad is a narrow battery-powered rod of widely varying length held by a stockperson at one end and with two electrodes at the other, which shock an animal touched by them. Although some manufacturers suggest that these ‘coax’ an animal, goading means provoking or annoying in order to stimulate an action or reaction (Pearsall 1998, 784). The prod produces a short-duration shock aimed at causing discomfort or pain and a consequent movement response in an animal. When the prod is activated an alarm may sound, primarily for operator safety (Robinson, Brooks and Renshaw 1990, 286–7, 293). Prods are designed for use by stockpersons to encourage animals to move, or to continue moving, during operations such as walking to and from the milking parlour and loading into or unloading from transportation such as for market or prior to slaughter. In situations such as these, if a prod is at hand a stockperson may decide to use it. A comprehensive survey of prods available for online purchase identified 13 for which specified voltage was available (see accompanying dataset). These voltages were in the range 3.8–5kV. The large majority were at the top of this range, as indicated by the mean average voltage of 4.9kV. Application of a prod is likely to produce significant pain, especially in sensitive body locations, as evidenced by aversive behavioural responses such as leg lifting, kicking and swaying and by increased heart rate (Lefcourt, Kahl and Akers 1986; Lefcourt, Akers, Miller and Weinland 1985).

iv) Wires in poultry barns

Within open barn poultry housing, single-strand electrified wires may be used in several areas to influence bird location, nesting and behaviour. First, for laying hens and broiler breeders in barn systems, wires may be set up to influence where eggs are laid. ‘Floor eggs’ are those laid in barns outside of the designated nesting area or nesting boxes, typically around the edges of housing where the wall provides some similar protection. These eggs are at increased risk of contamination and moisture and require greater labour to collect. By installing an electrified wire around the barn perimeter, the farmer may stop young hens forming the habit of laying in this zone (Vroegindeweij, Kortlever, Wais and van Henten 2014, 2). Such a wire may also help reduce the frequency of one or more hens smothering another in corners. Use of an electrified wire for this purpose is seen in the Netherlands, Germany and France.

A second use of electrified wires is egg protection. In either caged or open laying systems, laid eggs roll down from the laying area into the egg conveyor running in front (Hartung, Briese and Springorum 2009, 316). In some countries, wires may be fixed along the front of the nesting box to deter birds from leaning forwards to peck the eggs that have rolled down and are passing in front of them. A third use of wires in some countries, in barns housing either laying hens or broilers, is to prevent hens sitting on feeder and water lines (Appleby 1984, 243) and soiling the feeder pans and drinkers and their surrounding area. To do this, a wire may be run immediately above the feeder and water lines. Our survey of commercially available energizers (see accompanying dataset) was unable to identify any energizers specified for electrifying wires inside poultry barns. Where such wires are in place it is likely that a lower voltage multi-species fence energizer will be used.

v) Dairy collecting yard backing gates

In the area outside a milking parlour entrance, where cows are gathered prior to milking, a long slow-moving motorized backing (or crowding) gate may be in use. This system is sometimes known as an 'electric dog'. It encourages animals to enter the parlour by gradually reducing the size of the waiting area. This eliminates the need to chase or handle animals in the collecting yard, which would be likely to cause them stress. The metal gate runs the width of the concreted yard and is mounted on tracks that run along either the yard floor, the top of the wall enclosing the sides of the yard or on girders above the yard. A single milker can operate the gate while supervising milking without needing to leave the milking pit, although a herdsman is still likely to be required to round up stragglers (Paranhos da Costa and Broom 2001). This system increases milking efficiency and reduces milk contamination risks resulting from dirt being brought into the parlour by the milker and transferred to equipment. The gate sometimes has a scraper attached and so may also be used to clean the yard. When the gate is activated, a bell or buzzer precedes forward movement. The successive auditory and visual cues alert animals to the movement. However, some gates may include an energized wire running along their length, which will shock any animal that touches them. The energizers used are of the same types as those used for short, low-current electric fences, although they are typically powered from the mains to avoid the need to replace or recharge batteries. Because animals that are stressed or in pain may be difficult to milk, the energizers used are likely to be low power. A rare published advice source states that, like cattle trainers, they must never exceed 2.5kV (Midwest Rural Energy Council (USA) 2005, 4). However, in our comprehensive survey of energizers available for online purchase (see accompanying dataset), the only energizer found that was explicitly identified as suitable for use in backing gates was specified as 7.5kV/0.3J.

vi) Automated milking systems (milking robots)

Milking robots were first commercialized in the Netherlands. Since the early 1990s they have been most widely used there and in Denmark, Sweden and Iceland, although have also become common in Norway, Belgium, Switzerland and Canada (Eastwood and Renwick 2020, 3). There is some usage elsewhere, including Germany and the UK. Animals entering the machine are individually identifiable by means of a microchipped ear tag, a transponder in a rumen bolus (a sensor that is swallowed and remains in the animal's rumen or reticulum) or a transponder contained in a collar. Cows may approach the machine for milking when they wish and may be encouraged by a food incentive. They may also be automatically prevented from entering if they have recently been fed, or sufficiently milked. Following entry, a robotic arm detects the teats and cleans them, attaches the cluster unit, milks the animal, detaches the cluster unit and washes it. The machine measures the quantity of milk delivered and may also analyse its composition to monitor both product quality and individual cow health. If, following milking, the cow fails to leave the unit promptly (e.g. within 20 seconds: Wenzel, Schönreiter-Fischer and Unshelm 2003, 240), an electric shock is administered by a 'tickler' to make her do so. A tickler is a wire rope hanging down above the cow and touching her back. The energy and power delivered are not included in published specifications and in some systems this feature may be deactivated (Schewe and Stuart 2015, 207).

vii) Collars linked to virtual fencing and containment systems

Virtual fencing was first developed in the United States for the purpose of companion animal confinement (Anderson 2007). Equipment for use with livestock was first manufactured in 1987 although full virtual fencing systems became commercially available only in 2017. There are currently four significant providers worldwide. In Australia, Agersens marketed the eShepherd brand for cattle and Halter did so in New Zealand. The Norwegian company NoFence began to sell collars for sheep and goats, and then for cattle, on the European market. In the United States, Vence has launched a cattle system.

From a technological viewpoint, virtual fencing systems are a logical development of the movable electric fencing described in 2. i). Whereas a traditional fence is either fixed in position or requires a farmworker to move it, a virtual fencing system is intended to keep animals within a potentially shifting demarcated area. The animal wears a neck collar that emits a signal captured by global positioning system satellite technology and allows its position, and sometimes body surface temperature, to be recorded. Via a software application, a moveable virtual boundary is programmed into the system's geographic information system. When an animal approaches this boundary an audio cue is emitted to encourage it to move away. If an animal persists towards the boundary, or through it, this is followed by an electric shock delivered to the top of the neck (Anderson, Hale, Libeau and Nolen 2003). One provider specifies the audio cue as 82dB and the shock as 0.2J and 1s duration for cattle (NoFence Grazing Technology n.d.a) and 0.1J and 0.5s duration for sheep and goats (NoFence Grazing Technology n.d.b). Others do not publish these specifications.

An advantage of virtual fencing over traditional electric or other physical fencing is that, because the system registers the direction of animal movement towards and across the boundary, it may permit any escaped animal to return into the containment zone unimpeded, whereas animals that break through traditional fencing are typically stranded until returned to the enclosure by a farmworker. Moreover, the NoFence specifications state that no animal will be automatically shocked. A shock will not be applied if an animal moves very slowly or very quickly, because such movement may indicate injury or flight from harm. Neither will an animal be shocked if it has already received a specified number of shocks within a defined time period.

Virtual fencing may in principle be used for a range of purposes. These include the elimination of poaching (the churning of wet ground by cattle and subsequent solidification as an uneven hard surface) and the protection of animals from non-lethal hazards. However, because of the significant initial investment required and ongoing running costs, the most likely use on farm is as part of a precision grazing system for beef or, most commonly, for dairy cattle grazing. Stocking density and fresh pasture access may be remotely controlled, and if the pasture height, quality and composition are measured or predicted by other methods (e.g. assumptions based on rainfall, temperature and daylength), virtual fencing may form part of a sophisticated intensive grazing system (Verdon, Horton and Rawnsley 2021).

Virtual fencing is also increasingly used in free-ranging settings, including in conservation grazing contexts (Unstatter, Morgan-Davies and Waterhouse 2015). In these locations, conventional fencing may be impractical due to the high cost of the fence length required, or because of difficulties accessing remote locations. Animals nevertheless need containing for their own safety, road safety and to prevent them grazing crops or rare plant species (Umstatter 2011, 11–12) or polluting water courses. Nevertheless, because virtual fencing works by modifying behaviour, which is not entirely predictable, it cannot reliably deliver containment in situations where it is highly important for safety reasons that animals do not access an area (Anderson, Hale, Libeau and Nolen 2003, 843), such as adjacent to a busy highway or high-speed railway line.

Electronic collars may also be used to help manage breeding, such as by influencing mating preference in paddocks where males and females run together (Lee, Prayaga, Fisher and Henshall 2008). However, we consider that they would be unlikely to provide an effective means of gender segregation for breeding control purposes as an electric shock is unlikely to deter males in heat from seeking mating opportunities.

3. Ethical analysis

i) Fixed and movable electric fencing

From a containment perspective, the purpose of a hedge or traditional fence is to establish a physical barrier through which the farmed animals being contained are unable to pass. An electric fence, in contrast, while also visible, is usually in itself an ineffective physical barrier, able to be walked over or through, or pushed under, by animals unless it is live (McDonald, Beilharz and McCutchan 1981, 101). In order to serve as an effective boundary, an electric fence causes discomfort or pain and is designed to do so. This is a significant welfare issue. Indeed, in some publicity descriptions, these are stated operating objectives. Terms such as 'punching', 'packing a punch', 'kicking', 'jolting' and 'zapping' are among those used to describe functioning, suggesting that shock by a larger current is preferable to shock by a smaller current regardless of the level of discomfort or pain caused to an animal.

However, from an ethical perspective, animals under human control should, as far as is practicable, be kept free from pain and discomfort (Grumett 2018, 34–6). This ethical principle is a legal requirement in some jurisdictions. For example, in the United Kingdom it is an offence for a person to fail to take reasonable steps to avoid or reduce the suffering of an animal for which they are responsible (*Animal Welfare Act 2006*, 4). The ethical principle suggests that the current delivered in a shock should be only as high as is needed to contain the animal. As discussed in 2. i), regulation of the current is in practice difficult due to environmental and operating contingencies. For example, even if the fence area is well maintained, such as by being kept clear of vegetation, to ensure that the fence operates effectively in worst-case conditions an energy level will be required that may be unnecessarily high for typical conditions. In practice it is unlikely that the energizer output will be adjusted to allow for such contingencies. Contained animals that are shocked will therefore sometimes experience levels of discomfort and pain that are above those required for the purpose of containment on that occasion.

Moderate discomfort or pain of limited duration may be ethically justified if necessary to enable a greater harm to be avoided. However, in situations in which a boundary is protecting an animal from potential harm, the harm is likely to be sufficiently great to justify traditional fixed fencing. Such harms might include a steep incline, falling debris, deep water, a busy highway or a fast railway line. Because a fixed electric fence may occasionally lose power or be broken through by a herd member, its use cannot be ethically justified in instances where failure may result in severe injury or death to animals or humans.

In other instances, a movable electric fence may protect animals from lower-level harms, such as grazing or browsing harmful flora or accessing waterlogged ground and becoming lagged in mud. (Environmental factors may be ethically significant, although will only fall within a farm animal ethics assessment in so far as environmental protection or degradation impact on farm animal welfare.) However, it needs to be considered whether the discomfort and pain that result from shocking are proportionate to the potential harm being avoided, and if the harm could be avoided in other ways, such as by moving animals to other land, improving drainage or taking steps to eradicate potentially harmful flora. Moreover, as discussed in 2. vii) below, domesticated animals, if afforded sufficient individual and group learning opportunities, have the ability to avoid some lower-level harms.

ii) Cattle trainers

As described in 2. ii), cattle trainers are designed to preserve the physical hygiene and comfort of the bovine animal in the stall, which if delivered is a welfare benefit. However, clear evidence is lacking that cattle controlled by trainers are any cleaner than those that are not, and the use of trainers sometimes disrupts normal lying behaviour as animals seek to avoid being shocked (Hultgren 1991). In a large Swedish study of over 15,000 animals, the incidence and seriousness of several serious health conditions was higher among animals controlled by trainers than in animals housed without them. Rates of silent heat, clinical mastitis and ketosis increased, silent heat changed from a neutral disease to a major culling risk and reproductive performance fell (Oltenacu, Hultgren and Algers 1998). The lack of clear benefits combined with likely negative health and comfort impacts suggests that the use of trainers is ethically unjustifiable.

Moreover, trainers can contribute to the wider welfare problem of ‘stray voltage’ by creating an electric field that induces a potential difference across equipment with metallic parts running in parallel to the trainer lines, such as water lines and milk pipelines (Appleman and Gustafson 1985, 1556–7). As farms become larger and more mechanized, stray voltage problems are likely to increase, especially where financial challenges discourage equipment maintenance and replacement. On dairy farms, signs and symptoms of stray voltage include periodic and unexplained falls in production, slower or incomplete milking, increased incidence of mastitis, nervousness and reluctance to use water bowls or metallic feeders (ibid.). A meta-analysis of 22 studies has indicated that behavioural responses can occur with currents as low as 3mA (Erdreich, Alexander, Wagner and Reinemann 2009). The risk that trainers will contribute to the negative health and comfort impacts caused by stray voltage is a second reason why they are ethically unjustifiable.

iii) Prods or goads

In research on beef cattle, use of cattle prods during the day prior to slaughter resulted in increased stress as indicated by meat that was perceived to be tougher (Warner, Ferguson, Cottrell and Knee 2007). Among pigs, repeated shocking immediately prior to stunning and slaughter has been shown to increase levels of the stress indicators epinephrine and magnesium in blood plasma (D'Souza, Warner, Leury and Dunshea 1998). In another study, which replicated potential normal practice, pigs loaded and unloaded for transport to the abattoir with the use of prods exhibited significantly increased levels of cortisol and lactose in their blood plasma, which also indicated stress (Ludtke, Silveira, Bertoloni, de Andrade, Buzelli, Bessa, and Soares 2010). The use of electric prods is likely to cause animals avoidable suffering with no welfare benefit and is therefore ethically unjustifiable under the conditions described.

On farm, the movement operations described in 2. iii) are likely to be stressful for animals. Stress at loading or during movement is recognized as occurring when handling races are poorly designed (e.g. straight rather than curved), or when animals are allowed to see movement through the race, pen or loading ramp fence rather than these having high solid sides to give a sense of containment, or if animals experience shadows, contrasting light and dark areas, reflections or loud or high-pitched noise (Grandin 1997). Prods or goads are sometimes used repeatedly on animals that are unable to move easily away, such as a tightly bunched group in a pen or race, in order to break up the group. Loading and unloading situations that require animals to walk up or down a sloping ramp are also likely to be stressful (ibid.). Animals in these situations are less likely to cooperate and the response of the farmworker moving them may be to shock them using a prod. The availability and use of prods is likely to be an indicator of poor facility design and poor management. For this reason the responsibility for their use does not lie solely with the farm workers directly dealing with the animals. The designers and owners of facilities have an ethical duty to operate facilities in which the distress experienced by animals during necessary handling operations is minimized. They should not add to this by placing farmworkers in a situation where, in order to move animals, they need to deploy external aversive stimuli in response to behaviours resulting from distress.

iv) Wires in poultry barns

Electrified wires impede the normal behaviour of perching and limit the ability of birds to exercise choice over their location. Within a given barn configuration their use may reduce the risk of harm to birds resulting from smothering and from contamination by soiling of the feed and water lines, and so may be viewed as ethically justified in order to prevent a greater harm. However, a more strategic and more ethically justifiable way to reduce these problems would be to design accommodation that promotes normal behaviour by taking account of nesting preferences (Lentfer, Gebhardt-Henrich, Fröhlich and Borell 2013). Although hens nest gregariously, especially at younger ages, they may prefer boundary locations because these provide some enclosure and are easier to locate than boxes in the centre of a barn (Riber 2010, 28–30). Increasing space allowances, allowing outdoor access for exploration and perching, and expanding opportunities to exercise choice may each also contribute to reducing or eliminating the need for electrified wires by extending opportunities to exercise normal behaviours.

A poultry barn is likely to contain a variety of metal building materials, housing and equipment. These increase the risk of harm to birds due to stray voltage resulting from both electrified wires and other electrical equipment such as heating and lighting. Stray voltage is likely to be exacerbated by moisture, which may be at high levels in winter (Halvorson, Noll, Bergeland, Cloud and Pursley 1989, 585). As described in 2. iv), electrified wires may be installed in order to influence bird location. However, when hens choose to avoid nesting areas and lay floor eggs, this may be in an attempt to avoid stray voltage in the nesting area (Worley and Wilson 2000). The use of electrified wires to prevent perimeter nesting is, in turn, likely to increase stray voltage levels and the incidence of smothering, which typically occurs at barn perimeters and in corners. For at least some voltage types, stray voltage may lead to increased mortality, reduced feed and water intake, hyperexcitability and reduced fertility (Vidali, Silversides, Boily, Villeneuve and Joncas 1996, 99–100; Halvorson, Noll, Bergeland, Cloud and Pursley 1989). Although stray voltage may be reduced and even eliminated by ongoing monitoring, investigation and maintenance, electrified wires increase the risk of stray voltage and these associated welfare problems. As with trainers, the risk that poultry barn wires will contribute to the negative health and comfort impacts caused by stray voltage is a second reason why they are ethically unjustifiable.

v) Dairy collecting yard backing gates

As described in 2. v), a backing (or crowding) gate enables cows to be directed into the milking parlour by a milker working inside the parlour by encouraging them to move as a group, which is part of their normal behaviour, towards the parlour and into it. Moving cows to and from the parlour once, twice or sometimes three times per day can be labour-intensive, and an automated gate eliminates the need for a herdsman to be routinely stationed in the collecting yard to manage animal movement. However, when cattle are electrically shocked, they display agitation by hoof lifting, muscle contraction, sudden jerks, shoulder shaking, mouth opening and arching the back (Reinemann, Stetson, Reilly and Laughlin 1999). Any such agitation is likely to reduce the efficiency of the milking process as well as to be an indicator of pain and distress. Electrified backing gates can therefore only be ethically justified if any agitation that they cause is necessary for avoiding greater negative welfare impacts. No such benefits are apparent.

The development of automated backing gates to gather cows for milking has had the effect of reducing the frequency of use for this purpose of electric prods, which have been observed to lengthen the training period duration for new milkers (Albright, Cennamo and Wisniewski 1992). However, the tradition of electric shock control in the collecting yard exercised by an individual herdsman has probably contributed to its ethical acceptance in some quarters as one of the functions of backing gates. The electrification of these automated gates makes them no longer a simple physical barrier but adds the function of producing, or potentially producing, an aversive stimulus in animals. However, although parlour entry order is generally consistent within a herd, it is influenced by both milking side choice and health. Individuals with a strong milking side preference are likely to prefer to enter a herringbone configuration on one side rather than the other (Paranhos da Costa and Broom 2001). A crowding system in which individuals may be discouraged or prevented from waiting their turn or moving to their preferred side of the yard is therefore likely to inhibit the normal behaviour of individuals and herd synchrony and is therefore ethically questionable. Moreover, animals with sub-clinical mastitis, reduced locomotion due to lameness, or other pain or discomfort, which might be exacerbated by milking, are likely to retreat to the end of the milking order (Polikarpus, Kaart, Mootse, De Rosa and Arney 2015, 23–4) and so be more frequently subject to any electric shock control function of a backing gate. However, these individuals are likely to require careful and humane handling and stockperson attention.

vi) Automated milking systems (milking robots)

In early research into automated milking, it was recognized that the time cows lingered followed automated milking, and the frequent need for a herdsman to move them on, were potential barriers to commercialization. In one project the average voluntary exit time from the milking system was 3.3 minutes, although this ranged from 6 seconds up to, for the oldest cow, over 16 minutes (Winter and Hillerton 1995, 8–10). The average wait time of 3.3 minutes was 30% of the average 11 minute total visit time per cow. Another early study simply reported that, following milking, 38% of cows remained in the milker and had to be pushed out (Metz-Stefanowska, Huijsmans, Hogewerf, Ipema and Keen 1992, 282). It is likely that cows require physical recovery time following the intensive process of automated milking; indeed, the full reversion of teats to their normal dimensions takes several hours (Stádník, Louda, Bezdíček, Ježková, and Rákos 2010). Inherent in AMS is therefore a trade-off between cow exercise of normal behaviour, which from an ethical perspective should be promoted, and maximizing the rate of milking by an expensive machine for commercial reasons.

An electric tickler is a means of coercion designed to move animals out of an automated milker quickly (Stuart, Schewe and Gunderson 2013, 214). As described in 2. vi), very little time is allowed for the animal to move out of the milker before the device activates. Because of this, any animal that chooses to remain in the milker will receive an electric shock (Bear and Holloway 2014, 214). However, an animal may be prevented from leaving the milker by crowding outside or by an individual dominant animal. In any case, automated milking requires a large change to normal group synchrony. Whereas in traditional milking systems, cows will move, be milked and feed as a group, within AMS animals move, are milked and receive their feed reward following milking individually. A tickler is part of a system that coerces cows into behaviour that is abnormal for them at both individual and group levels and its use is therefore ethically questionable.

The behaviour of cows that have been electrically shocked suggests that they experience discomfort and sometimes considerable pain. One experiment investigating the likely effects of shocks at milking showed that, at lower currents, animals shocked biweekly became tense and displayed limited movement. As the current increased, so did agitation. The experiment was terminated due to the extreme behavioural responses presented by some individuals, which at 10 and 12.5mA included back arching, pawing the ground and jumping (Lefcourt, Kahl and Akers 1986). An alternative means of encouraging animals to exit an automated milker may be an air puff (Holloway, Bear and Wilkinson 2014, 138). AMS are frequently presented in positive ethical terms as 'voluntary' and as delivering cow freedom (Driessen and Heutinck 2015, 10–11). If these claims were true, a cow would be permitted to remain in the milker for an extended period before stockperson investigation of her unwillingness to move, and perhaps for as long as she wished. From an ethical perspective, there is a concerning gap between the highly positive claims made for AMS and the reality of the actual or potential automated coercion on which they depend.

vii) Collars linked to virtual fencing and containment systems

Following the long research and development phase described in 2. vii) and recent commercialization, significant claims are currently being made for virtual fencing and containment systems. One overview states that such systems have the 'potential to revolutionize management of the livestock industries', with benefits including 'reduced labor, improved herd management, and protection of environmentally-sensitive areas' (Campbell, Lea, Keshavarzi and Lee 2019, 1–2). Moreover, it is affirmed that, in commercialization, animal welfare is a 'priority consideration'. An advantage of virtual fencing systems over traditional electric fencing is that virtual systems shock a known individual on a particular body part with a measurable current. This avoids the problem discussed in 2. i) that a traditional electric fence will deliver a current that varies according to uncontrollable external factors, the breed and condition of the animal and the body location of the shock. Virtual fencing is therefore better able to satisfy the ethical requirement that the discomfort or pain experienced by the shocked animal is no greater than that required to deliver the welfare benefit.

The ability of animals to learn a virtual system, especially when visual cues are absent, has been extensively discussed. The removal of all visual cues is likely to be problematic for learning (McSweeney, O'Brien, Coughlan, Férard, Ivanov, Haltone and Umstatter 2020), and therefore ethically problematic. With virtual fencing, when the boundary is moved there is no visual cue. However, if cows are unable to see that a physical object causing an aversive stimulus has been removed, they are normally significantly more likely to avoid a location where they have previously experienced such stimulus, even if this entails walking a greater distance to access food (ibid.). In one experiment it took four days for cattle to readjust after virtual fencing was deactivated, in contrast to reportedly 'no time' following the removal of physical electric fencing (Markus, Bailey and Jensen 2014). However, in a precision grazing system a boundary may be moved daily or even several times a day.

It may be argued that the audio cue resolves ethical issues by reducing the likelihood that an animal will experience the discomfort or pain resulting from subsequent shocking (Lee, Henshall, Wark, Crossman, Reed, Brewer, O'Grady and Fisher 2009). Moreover, a cumulative learning effect has been observed, with herd members hearing the audio cues of closely adjacent conspecifics and thereby heeding the virtual boundary without themselves interacting with it (Campbell, Lea, Farrer, Haynes and Lee 2017). When a goat herd is first introduced to virtual fencing, group learning probably also increases (Keshavarzi, Lee, Lea and Campbell 2020). Virtual fencing may therefore be viewed as promoting herd socialization, which is part of normal behaviour. However, among cattle wide variation in learning speeds between individuals has been noted. These depend on a range of factors such as temperament, early environment and socialization (Campbell, Lea, Haynes, Farrer, Leigh-Lancaster and Lee 2018). Slow learners will receive more shocks than fast learners. In one virtual fencing experiment involving 12 dairy cows, three animals received on average more than three electrical shocks per day (3.3, 4 and 6.3) whereas others were subjected to an average of just one (Lomax, Colusso and Clark 2019). The animals receiving the greatest number of shocks also experienced many more of the audio cues that preceded the shock (between 8.7 and 35.8). Within virtual fencing systems, some animals thus experience a disproportionately high number of shocks, meaning that the penalties for any benefits that virtual fencing might deliver to each group member equally (e.g. improved grazing management) are unevenly distributed among members. This is ethically problematic because some animals will gain the benefit for little or no penalty, while for others the benefit may be to a large extent offset by the ongoing penalties experienced.

At its best, virtual fencing promotes associative learning, identifying and rewarding behavioural change (e. g. stopping, turning or backing-up) rather than simple location. However, for associative learning to be more effective, systems need to apply different current levels to individuals depending on their subjective response to being shocked, which may range from ear movement through vocalization to pressing forward or running (Lee, Prayaga, Reed and Henshall 2007, 235). Systems at this level of sophistication, although ethically desirable, are currently unavailable and may be commercially unviable.

It may not always be necessary to control all herd members directly. Partial direct control may have some use in promoting mob grazing or keeping groups together on common land. Given the significant financial investment that virtual fencing requires, partial control may be viewed as delivering insufficient benefit. Yet with sheep, directly controlling two-thirds of a flock has been found to be equally effective in regulating location as directly controlling the whole flock (Marini, Kearton, Ouzman, Llewellyn, Belson and Lee 2020). However, this is in the context of virtual fencing being difficult to operate for sheep, especially those with young, with high escape levels having been observed (Brunberg, Bergslid, Bøe and Sørheim 2017; Brunberg, Bøe and Sørheim 2015). When dominant cattle herd members are directly controlled with collars and other members that are not directly controlled follow them, these other cattle may benefit from any resulting gains without experiencing the discomfort or pain of any electric shocks. This synchrony is potentially possible because cows are herd animals that are gregarious and live in structured groups (Correll, Schwager and Rus 2008). Goat herds exhibit similar synchronicity (Fay, McElligott and Havstad 1989). Such partial direct control, when it delivers the required degree of containment, is ethically beneficial because it is likely to reduce the total number of shocks experienced by a herd and slow learners may be exempted from direct control. Even so, although partial direct control brings some welfare benefits, it is ethically problematic in situations where a duty of care needs to be exercised over all individuals in order to protect from harm (e.g. keeping them off a railway track or busy highway).

Some important welfare implications of virtual fencing are unclear and require further research. Dairy cattle that are virtually fenced for more than about four days may display reduced activity, grazing time and ruminating time and experience increased stress (indicated by milk cortisol levels) (Verdon, Langworthy and Rawnsley 2021). It might be possible to replace the electrical shock that a collar delivers to the top of the neck with a tactile stimulus produced by a vibrating motor (Acosta, Barreto, Caitano, Marichal, Pedemonte and Oreggioni 2020). However, it is unclear at present how effective this would be in controlling the movement of all individuals in a herd, nor if it would reduce or eliminate welfare concerns. At present a precautionary principle is justified that permits commercial development in the context of ongoing research to understand and limit potential negative impacts on health and behaviour.

4. Overall ethical assessment

In any situation where welfare may be compromised, the primary ethical concern needs to be the immediate discomfort or pain caused to the animal. Turning first to fencing, a well-constructed physical barrier of appropriate height and materials can contain animals as well as, or better than, fixed, movable or virtual electric fencing, even though such a barrier may well be more difficult and more costly to construct. In a situation where electric (including virtual) fencing is being considered, one or more probable welfare benefits to animals that could not practicably be delivered by a physical barrier would need to be identified to justify the likely discomfort and pain caused. The settings to which this applies include conservation grazing, where ecological considerations may be stronger than welfare.

Prods and goads, and electrified wires in poultry barns, are likely to be resorted to where there is suboptimal facility design. Poorly configured races, pens, ramps and housing may produce management and welfare problems to which electric shock control is a short-term response that adds another serious welfare issue. A far more appropriate response would be to reassess and redesign facilities so that the factors leading to movement or location challenges are reduced or eliminated.

Dairy collecting yard backing gates and ticklers in automated milking systems are striking instances of the evolution of electric shock control technology. Whereas a prod or goad might previously have been applied as a result of stockperson decision, the electric shock is now mechanically caused. From a welfare perspective this is an ambiguous development. The application of a shock by a mechanism, perhaps according to a rational algorithm, may be viewed as preferable to similar application by a human. This is because mechanistic or algorithmic operation eliminates the possibility of the intentional mistreatment of individual animals by a gratuitous stockperson, such as by frequently shocking the same individuals or by shocking body parts that are highly sensitive to pain. However, the distancing of the stockperson from the animals that these technologies encourage leads to a reliance on electric shock control, or the prospect of it, and its normalization. In many situations, what is needed, and what is far preferable to either discretionary or automated shocking, is intervention by a caring and competent stockperson. Cows at the end of the milking line and those that are reluctant to exit a milker may well require compassionate human attention.

In cattle and poultry barns, the use of trainers and electrified wires may, in combination with other electrical equipment, suboptimal configuration and poor maintenance, contribute to stray voltage and the welfare problems associated with it. This shows that, especially indoors, the potential welfare impact of any electrical shock equipment needs to be considered in the context of all the electrical equipment installed, used and maintained in a facility.

The use of automated milking system ticklers requires animals to change their normal behaviours for the farmed setting quickly and significantly if they are to avoid repeated electric shocks. Automated milking systems require cows to exit the milker many times more quickly than if the system was truly voluntary. The normal behaviour of resting in a standing position immediately that milking is completed, which includes the early period of teat recovery, is thus severely restricted for the purely commercial reason of maximizing milk yield per machine. Animals face a choice between having standstill time and avoiding electric shocks.

In addition to the discomfort or pain that electric shocking is likely to cause an animal, the changing relationship with humans, to which electric shock control technologies have contributed, also needs to be evaluated. Over a period of about ninety years, the development, commercialization and use of the electric shock technologies surveyed in this paper has contributed to a shift away from the direct human control of farmed animals to automated control methods that are becoming increasing sophisticated. With good reason, automated control is sometimes viewed as replacing interaction with humans, such as in the description of virtual fencing as an ‘electronic shepherd’ (Langworthy, Verdon, Freeman, Corkrey, Hills and Rawnsley 2021; Campbell, Lea, Keshavarzi and Lee 2019). It reduces the reasons for stockperson interaction with animals and therefore limits the opportunities for identifying welfare issues that automated monitoring may not detect.

Because humans are also animals it is appropriate to end with brief reflection on the current impacts of the imagined and actual electric shock control of animals on society. Surveying some available technologies, Terry Whiting (2016) presents a continuum between the control of animals and humans. At the group level, cattle prods and goads may be used against crowds that are easily depicted in animalized terms as requiring herding, corralling and containing (Scotton 2019, 364, 369–72), as well as against individuals in contexts of political and other criminal torture (Hillman 2003). Cattle prods and goads are thus used to control both human and nonhuman animals in a context of ongoing technology transfer. Another important instance, this time of imaginative creation for use against animals and humans but then subsequent development and deployment principally for use against humans, is a TASER (Tom. A. Swift Electric Rifle). In the science fiction novel by Victor Appleton (1911), from which its real-life inventor Jack Cover took its name, a TASER was deployed by American ivory hunters while hunting elephants in Africa to immobilize both wildlife and native persons. This weapon, which is essentially a highly portable energizer, shoots two electrode darts attached to copper wires across several metres between the operator and the victim. During travel the darts diverge, and as they approach and penetrate the victim's body at least 10cm apart an electrical circuit is completed and the victim is immobilized by the pulsed DC current. Dangers include high risk of injury resulting from falling onto a hard surface, especially in the urban locations where TASERs are typically deployed by law enforcement personnel, because the immobilized individual is unable to extend their arms to brace against the fall. Electric shock control technologies conceived, developed and used on animals are thus ready to hand for use on groups of humans that may be 'animalized' on such grounds as ethnicity, religion or migration status. This is partly a matter of the simple availability of equipment and knowledge of its use, but also the result of a social acceptance of the use, and potential use, of such technologies for control purposes.

This ethical analysis has shown several reasons for serious concern about the development and use of electric shock control technologies on animals. Instances of these technologies being used to control humans provide further reasons to reduce and replace their use on animals.

5. Animal Welfare Implications

There is currently a high level of tolerance in animal agriculture for diverse methods of electric shock control. Because these cause animals pain they should only be employed if necessary, and to the level required, to avoid greater pain or suffering to animals. By reducing the use of electric shock controls on animals, and, where possible, replacing them with alternative control methods, welfare is likely to be improved. Cattle trainers, prods or goads, electrified wires in poultry barns and electrified backing gates in dairy collecting yards are unlikely to be justifiable on these grounds, and have been shown to cause welfare problems. Fixed and moveable electric fencing is likely to be justifiable in some situations if its welfare purpose is clear and its operation is carefully managed. The ticklers in automated milking systems and collars linked to virtual fencing and containment systems require further welfare assessment because they coerce animals into rapid changes in their normal behaviours and modes of learning.

Declaration of Interest

AB and DG are members of the Animal Welfare Committee, Defra

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