Animal 18 (2024) 101191

Contents lists available at ScienceDirect

Animal
The international journal of animal biosciences

Dairy farming technologies and the agency of cows

K. Kramer [1,*], B. Bovenkerk

Department of Communication, Philosophy, Technology and Education, Wageningen University, Hollandseweg 1, 6706 KN Wageningen, the Netherlands

ARTICLE INFO

Article history:
Received 18 December 2023
Revised 6 May 2024
Accepted 7 May 2024
Available online 16 May 2024

Keywords:
Animal agency
Dairy cattle
Ethical technology design
Multi-species ethnography
Technological mediation

ABSTRACT

Studies on animal cognition, emotion, language, culture, and politics have shown that non-human animals are agents who engage in self-willed actions and have an interest in shaping their own lives. In today's world, however, animals' lives are affected significantly by circumstances that humans have created, including animal farming systems. The current paper explores how the agency of cows relates to technology by reporting on fieldwork performed in the Dutch dairy sector. Multi-species ethnography was used as a flexible methodology that allowed readjusting questions and methods as our research developed. In the first research phase, observations and informal talks were held on six farms which had been recruited on the basis of convenience sampling and which were each visited for one full day. In the second research phase, five more farms were selected for 1-day visits through theoretical and snowball sampling, and one farm was visited repeatedly for in-depth observations. The observational strategies used included following individual actors (farmers, cows or technologies) and documenting their interactions with other actors; participating in daily routines such as feeding cows roughage and scraping manure; witnessing cows' responses to non-routine events such as the introduction of new technologies or new cows; and sometimes waiting for notable occurrences by just 'hanging out' with cows. Observations and informal talks were in this research phase complemented by a small number of interviews with farmers, cow shed designers, and technology developers. Our main conclusion is that the agency of dairy cows is presupposed and mediated by dairy farming technologies. Dairy farming technologies presuppose cow in the 'scripts' and 'programs of action' which they enforce: they require cows to act in specific ways, anticipate some ways in which cows could disrupt technological routines, and (successfully or unsuccessfully) attempt to ensure cows' cooperation by appealing to their wants and desires and their ability to learn. Dairy farming technologies thus assign to cows not only the ability to perform 'metabolic labour' but also the capacity to act purposively and learning abilities. Technologies mediate cow agency by (co–)shaping how cows express agency in relation to other entities, including other cows, humans, other non-human animals, material entities including technologies, and the world at large. That technologies can be relevant for animal agency in various ways raises the question of how technologies can be designed for agency – although the concept of animal agency also challenges us to reconsider animal agriculture more fundamentally.

Implications

Studies have shown that animals have agency: they engage in self-willed actions and have an interest in shaping their own lives. We performed multi-species ethnographic fieldwork in the Dutch dairy sector to explore how animal agency relates to technology. We conclude, firstly, that dairy farming technologies presuppose cow agency: they require cows to act in particular ways and attempt to secure cooperation by appealing to cows' wants and desires. Secondly, technologies mediate cow agency: they affect how cows act towards other cows, humans, other animals, etcetera. Cows' agency should be considered in ethical technology use and design.

Introduction

The agency of (farmed) animals in contemporary society

The lives of many domesticated animals are to a great extent managed by humans. Laboratory animals, pets and farmed animals are often bred and raised according to human preferences, dwell in artificial surroundings, and die or stay alive depending on human

* Corresponding author.
E-mail address: k.kramer@uu.nl (K. Kramer).
[1] Present address: Department Population Health Sciences, Utrecht University, Bolognalaan 50, 3584 CJ Utrecht, the Netherlands.

https://doi.org/10.1016/j.animal.2024.101191
1751-7311/

decisions. In dairy farming, for example, humans breed cows based on specific goals, decide in what social groups cows live during different phases of their lives, house them among a range of technologies, and subject them to routines such as milking.

Today's anthropogenic impact on the lives and deaths of animals is increasingly considered an ethical problem. The problem is not merely that many human activities directly or indirectly cause animal suffering. Studies on animal cognition, emotion, language, culture, and politics have shown that animals have more complex capacities than previously assumed; a main conclusion drawn from such studies is that non-human animals are agents who can shape their own lives and have an interest in doing so (Donaldson and Kymlicka, 2011; Meijer and Bovenkerk, 2021). But if animals' lives are affected significantly by circumstances that humans have intentionally or unintentionally created for them, then this raises an important ethical question: to what extent should we change animals' living conditions to (re-)enable them to live according to their own choices?

Animal welfare scientists have shown that having choices, handling moderate environmental challenges, and developing competences is necessary for animals to experience positive welfare (Špinka and Wemelsfelder, 2011; Webber et al., 2022). The importance of granting animals more agency can thus be grounded in the concept of animal welfare, the ethical significance of which is widely recognised. Moreover, respect for animal agency can arguably be understood as ethically appropriate in itself. The concept of agency is on this perspective similar to that of autonomy (Thomas, 2016; Sebo, 2017), which on various ethical theories deserves respect even aside from its connection to wellbeing or welfare. The fundamental ethical idea here is that agents who have their own perspective on life – including both human and non-human animals – should be allowed or even enabled to pursue their own designs (at least within certain boundaries).

Animal agriculture raises particular concerns about animal agency. The human purposes behind animal agriculture seem to allow farmed animals little scope for exercising agency on a macro-level: to make decisions about basic aspects of their lives, such as where to live and with whom (Donaldson and Kymlicka, 2013; Meijer and Bovenkerk, 2021). This is unlikely to change in the near future, given the extent to which current practices are 'locked in' (Bruijnis et al., 2015), and because many consider farming animals efficiently necessary for feeding a growing human population. Striving to improve farmed animals' agency in smaller steps, although perhaps non-ideal from an animal ethics perspective, may be more realistic and effective on the short term. This raises questions about the extent to which farmed animals already do exercise agency in their day-to-day affairs, how this is affected by the context in which they find themselves, and how this context could be adapted to grant them more agency. The current paper, which reports on a multi-species ethnographic study, addresses the agency of cows living on dairy farms, focusing on how this agency relates to the technologies used in the context of dairy farming. In doing so, it also confronts conceptual questions about what it means to ascribe agency to animals. Such questions have been addressed by animal ethicists and other scholars but have not been settled.

The concept of animal agency in literature

Agency has traditionally been associated with being capable of higher-order thought, in particular with the capacity to think propositionally (Sebo, 2017; Glasscock and Tenenbaum, 2023). The basic idea is that action proper, unlike mere behaviour, involves acting for a reason and thus requires the ability to deliberate on reasons for acting. But propositional accounts of agency have been criticised for their anthropocentrism – arbitrarily setting human agency as the norm for agency as such – and for failing to recognise that even human agency is often non-deliberative (Steward, 2009; Donaldson and Kymlicka, 2011; Sebo, 2017). Object-oriented accounts, on the other hand, model agency on the capacity of objects to make a perceptible difference to other agents' actions (Latour, 2005; Law and Mol, 2008). Proceeding from the methodological assumption that humans, animals, artifacts, and other entities have the same kind of agency, these accounts address how agency is distributed across heterogeneous networks of entities. Both human and non-human agents are on this account comparable to actors, who each play designated roles in specific 'programs of action' and thus perform socio-technical 'scripts' together, but who can also refuse to play their part (Latour, 1992). This account of agency helps to analyse how society is co-shaped by the more-than-human but does not explain why animal agency is ethically relevant (Sayes, 2014): such an explanation requires that animal agency differs from artifactual agency in some significant respect. According to Meijer and Bovenkerk (2021), this difference is that animals engage in self-willed actions: they act out of some will or desire. These authors explain that the intentional agency that animals thus display does not necessarily require propositional thinking. Agency can instead consist in responding to normative perceptual experiences: perceptions in which certain objects of experience "call out" to be treated in particular ways and which thus motivate acting accordingly (Steward, 2009; Sebo, 2017). Such perceptions are shaped by mental states like memories, anticipations, beliefs, and desires, and enable deliberating about how to act in ways that do not require higher-order thoughts about reasons for acting. For example, an animal may be motivated to obtain an apple, which perceptually appears to the animal as to-be-eaten, and then consider how to acquire it on the basis of mental images (Sebo, 2017). This perceptual type of agency is indispensable in both human and non-human animals, whether or not they are capable of propositional thought (Sebo, 2017; Blattner et al., 2020; Glasscock and Tenenbaum, 2023).

The differences between theoretical accounts of animal agency are not exhausted by distinguishing between propositional, objected-oriented, and perceptual accounts, however. Donaldson and Kymlicka (2011) emphasise animals' agency in shaping rules for social cooperation, for example, while Palmer (2016) understands agency in terms of wildness, and Špinka and Wemelsfelder (2011) conceptualise it in terms of an animal's competence to deal with novel challenges. Given such different understandings of the concept of agency, Meijer and Bovenkerk call for empirical studies devoted to understanding animal agency 'from the ground up'; their definition of agency as "the capability of a subject to influence the world in a way that expresses her desires and will" (Meijer and Bovenkerk, 2021: 54) is only meant as a working definition for such studies.

What is clear is that agency should be approached as situated and relational: species-specific characteristics matter for how one can act, but so do the circumstances or context in which one's life is embedded. This includes relationships to human and non-human others with whom one shares practices and routines, social roles, and norms as well as relationships to the material environment (Blattner et al., 2020). Relationships do not merely constrain action – although they can also do that – but positively enable various ways of acting. According to the theory of affordances, an animal's possibilities for acting arise in the interplay between the animal's abilities and features of her environment (Gibson, 1979; Hutchby, 2001; Withagen et al., 2012). For example, wooden fences do not afford cats to simply walk from one garden to the next, but cats can usually climb such fences or even use them as platforms to reach higher elevations, thanks to the material design of wooden fences in combination with feline dexterity. An animal's possibilities for acting are also shaped by her social relations.

Depending on the communities in which they are embedded, animals may be able to take up different social roles – for example as a teacher, friend, guardian, or parent to another animal – or even negotiate social norms (Blattner et al., 2020). Empirical studies should thus consider how animals' self-willed actions arise in response to specific circumstances and are made possible by their relations to concrete others as well as material entities (Meijer and Bovenkerk, 2021).

Dairy farming technologies and the agency of cows: a priori analysis

Farmed animals often live in complex environments featuring human and non-human others and various material entities. Dairy cows, for example, live not only among one another but also among farming personnel and among non-artifactual matter like grass and dirt, relatively simple artifacts such as bars and slatted floors, and advanced technologies like feeding machines, roboticised milking machines, and climate control systems. Although all these living and non-living entities could on a relational account be relevant to the cows' agency, the current paper raises distinct perspectives on cow agency by exploring its connection to technologies (including relatively simple ones) used in dairy farming.

Researching how cows' agency relates to dairy farming technologies is significant, firstly, because of the extent to which technological artifacts are present in the daily lives of cows. Cows often stand on artificial flooring, wear sensors around their necks or legs, drink from troughs that refill automatically and encounter machines used in routines like milking and feeding. These are just some examples of cow-technology interactions, and the development of dairy farming technologies is ongoing. Secondly, there are concerns – but also considerable uncertainty – about how technologies affect farmed animals' agency. It has been observed that the material layout of farms serves to control animal behaviour and thus limits the expression of animal agency (Harfeld et al., 2016; Blattner et al., 2020). Material artifacts such as fences and bars keep animals from performing various types of agential behaviours: escaping from the barn, reaching members of the opposite sex, etcetera. Some may therefore assume that farming technologies are mere hindrances to animal agency. This would be an overgeneralisation, however, because it does not follow from the examples considered that all farming technologies have this effect. Besides, even fences and bars may have more complex effects on animal agency than suggested: animals can also use such artifacts to exercise certain kinds of agency, for example by banging them in socially meaningful ways (Cornips and Van den Hengel, 2021). Acknowledging that some technologies hinder some agential behaviours does not exclude that other relations between technology and agency are also possible.

A contrary possibility is that technologies are enablers of animal agency (or expressions thereof). Some technologies enable animals to engage in certain types of behaviour through which they can exercise their agency. Video games can for example be designed that offer animals new ways to play or to interact with humans in potentially positive ways (Driessen et al., 2014; Webber et al., 2020), and some have argued that milking robots enable cows to choose when to be milked (Holloway et al., 2014a, 2014b; Driessen and Heutinck, 2015). Such technologies would perhaps be applied predominantly in contexts where animal agency is already severely constrained: giving pigs video games arguably increases their agency only if they are deprived of other stimulating activities, and robotic milking only grants cows some freedom compared to conventional milking. The technologies concerned would nonetheless give animals some possibilities for agency which they would otherwise lack, which is at least a minor improvement. Moreover, even animals in more favourable circumstances may sometimes be interested in interacting with technologies as a way to exercise agency. Špinka and Wemelsfelder (2011) show that animals are intrinsically motivated to engage in agential behaviours, including problem–solving, exploration and play, and it seems possible to design technologies that support such agential behaviours (Webber et al., 2022). Agency may be more than the ability to perform natural or species-typical behaviours, and although this does not settle the question to what extent animals can have good lives in artificial settings, it does suggest that human-made artifacts can figure in some meaningful expressions of animal agency.

The notion that technologies can both restrict and enable agency can be supported by the theory of affordances (Gibson, 1979; Hutchby, 2001; Withagen et al., 2012). Technologies can be part of the material environment that determines what an animal with a given set of abilities can and cannot do. The same technology can make certain actions impossible while making others possible for the same animal (as bars may simultaneously confine and enable types of meaningful communication among calves), or make different actions possible for different animals, depending on their characteristics (as high wooden fences may afford climbing for cats with normal abilities but not for old cats or short-legged dogs).

According to a third view, one should not assume that agency is fully formed independently of an agent's interactions with technology and remains unchanged through such interactions. Extending Foucault's analysis of how human agency is formed through techniques of disciplinary power, it has been argued that the agency of domesticated animals is shaped similarly and that technologies are implicated in this (Holloway, 2007; Holloway et al., 2014a; Palmer, 2001). Breeding technologies seem to have the potential to shape animal agency over generations: some have for example claimed that animal breeding led to the creation of docile, easy-to-handle animals (Twine, 2010; Turner, 2010). It has also been argued that automated milking systems co-constitute how cows behave and what they experience: how they move through space and regiment their time, how they interact with other cows, etcetera (Holloway, 2007; Holloway et al., 2014a; Driessen and Heutinck, 2015). Whether or not cows come to discipline themselves (or each other) to act in certain ways, their agency is according to these authors 'fluid' and 'becoming' rather than fixed and is formed partly by the milking robot and the wider system around it. On this view, technologies co-shape agency: they do not only change animals' observable behaviours, but also mental states that are relevant to agency (e.g. animals' desires and wants.).

Fourthly, technologies can be approached as mediators of agency. Holloway et al. (2014b) have shown how relations between cows and farmers are mediated by automatic milking systems. But cows also express agency in how they interact with other cows, for example, or with other non-human animals whom they encounter (Blattner et al., 2020). A relatively simple example of how technologies influence such interactions is that metal bars disallow cows to seek each other's proximity, but do enable particular types of meaningful communication among cows (Cornips and Van den Hengel, 2021). A general account of how cows' agency towards other entities is mediated by technology is lacking, however. Blattner et al. (2020) have shown how animals in a multispecies sanctuary show agency in their relations towards various living beings but have not addressed the mediating role of technology. Bear and Holloway (2019) have explored how technology mediates cows' agency, but have focused on milking robots and on resistance or transgression as a paradigmatic expression of agency.

In conclusion, there is a need to improve our understanding of animal agency and how it relates to technology. Non-human animals have an interest in being able to exercise agency, but how technology affects agency deserves further elaboration. Studies

on animal agency and technology have often presupposed a limited conceptualisation of agency (for example as the capacity to 'make a perceptible difference' to the actions of other agents). Moreover, such studies have frequently assumed that technologies either limit, or enable, or co-shape animal agency. What animal agency is and how it relates to technology should arguably be explored from a more open perspective, which could help to recognise differences in how technologies influence animal agency. Ultimately, this could help to develop more informed ethical views about the use of such technologies, or even inform ethical technology design.

Material and methods

General research methodology

Hoping to improve our understanding of animal agency and technology 'from the ground up', the first author conducted multi-species ethnographic fieldwork in the Dutch dairy sector. The general aim of such fieldwork is to develop empirically grounded views about a topic by starting out with an open theoretical perspective, observing and participating in the routines of various (human and other) informants, and iteratively refocusing the research based on one's emerging insights about the topic. Our fieldwork aimed to produce insights on cow agency and technology that would be significant in their own right while inspiring more abstract reflections on animal agency.

Aware of the diverging perspectives on the concepts of animal agency and technology, the first author entered the field only with a 'foreshadowed problem' (Beuving and De Vries, 2014: 17; Hammersley and Atkinson, 2019: 22): the fieldwork would have the relation between cow agency and technology as its topic, but would proceed neither from fixed definitions of agency or technology nor some preset hypothesis about their relation. Accordingly, our literature review on agency and technology served to sensitise the first author to the range of phenomena that connected to our research topic, rather than narrowing down the empirical study beforehand on the basis of theoretical commitments (Beuving and De Vries, 2014; Hammersley and Atkinson, 2019). The point was to approach the research problem from an open theoretical perspective, which allowed exploring the variety of relations between cow agency and dairy farming technologies first and gradually focusing our research efforts based on our emerging insights. Multi-species ethnography allowed taking such a reflexive research strategy and allowed studying cows in their usual surroundings rather than a laboratory setting (Beuving and De Vries, 2014; Hammersley and Atkinson, 2019). Moreover, multi-species ethnographic fieldwork has been presented as a methodology for doing research with animals, with the human researcher trying to understand and represent animals' perspectives on the research topic, and not just on them (Hamilton and Taylor, 2017). This seems ethically appropriate when animals are recognised as agents who have their own perspectives on their lives, notwithstanding the epistemological challenges that trying to understand animal perspectives raises.

Because our ethnographic study was meant to reveal how technologies used in dairy farming affect cow agency and assumed that (re-)enabling animal agency is ethically important, it was an inherently normative project. But ours was not a 'critical' ethnography (Gillespie, 2016a, 2018; Kopnina, 2017): we did not focus on emancipating cows by showing how they are harmed and marginalised in current practices. Without discarding the possibility that themes like power, (systemic) violence, and abuse would become relevant in our research, we decided not to confine our research to 'critical' themes beforehand. This was enabled by our a priori analysis of the different possible relations between technology and animal agency and by our choice to engage with this topic from a non-ideal ethical perspective, that is, by focusing on improving cow agency within the constraints of today's context, without excluding the viewpoint that transforming farming practices more fundamentally would be ethically preferable (Thompson, 2021; Valentini, 2012).

Recruitment and fieldwork

Fieldwork, including the recruitment of dairy farms as fieldwork sites, was performed intermittently from September 2022 until April 2023. Because researchers working on similar topics (Gillespie, 2018; Overstreet, 2018) had reported severe difficulties in getting access to dairy farms and because the resources available for this study were limited, recruitment was in the early phase mainly based on convenience sampling. We concentrated our efforts on farms that had some public function and were easy to approach, typically because they sold foodstuffs locally, or that were affiliated to our universities. As the first author hoped to visit one farm repeatedly later in the project, the location of candidate fieldwork sites was also an important pragmatic constraint. We later switched to recruiting farms mainly on the basis of theoretical sampling (Beuving and De Vries, 2014: 38, 157; Hammersley and Atkinson, 2019: 36; Taylor et al., 2015): by selecting farms that, according to our developing understanding of the field, appeared relevantly different from farms already included in our sample. The farms initially recruited already seemed quite diverse (at least in terms of the technologies they employed), but they were all organic and relatively small farms. Farmers suggested that larger, non-organic farms would be relevantly different and we therefore set out to recruit such farms, sometimes by approaching them directly and sometimes by using a snowball approach. When our recruitment efforts proved to be more successful than anticipated, however, we faced a trade-off between the breadth and the depth of the study (Hammersley and Atkinson, 2019: 33; Small, 2009): visiting more farms would enable drawing comparisons, whereas visiting just a few farms repeatedly would enable us to understand the particularities of individual farms – and cows – more intimately. We struck a balance by paying 1-day visits to several farms and studying one farm more extensively. To triangulate our emerging understanding of the views behind dairy farming technologies (and wider farming assemblages), we had informal talks with farming personnel as well as semi-structured interviews with two farmers, a cow shed designer, and a developer of dairy farming technologies.

The fact that fieldwork took place in autumn, winter, and early spring meant that most observations were made indoors. This was compatible with our research interests, as many technologies used on dairy farms stay in the cow shed. Moreover, fieldwork done on pasture in September and April helped to put the observations made indoors into perspective (e.g. by comparing how cows use space indoors and outdoors) and allowed observing interactions with some technologies used outdoors (e.g. with electric wire fences and hydraulic water pumps that cows operate with their noses). Our study did not include tie stall sheds: the cows we observed were not tethered to fences while they were indoors, but were able to walk around. Farm visits were limited to daytime, except on some farms which started milking in the early morning.

Field observations did not follow strict procedures. The approach to observation was instead adapted flexibly, according to the developing research focus and pragmatic constraints, as is common in ethnographic research (Beuving and De Vries, 2014; Hammersley and Atkinson, 2019). Several strategies were followed, however, to increase the range of relevant phenomena observed. Firstly, simply 'hanging out' (Russell, 2011;

Hammersley and Atkinson, 2019) with cows for extended periods of time increased the chance of witnessing both common and uncommon expressions of agency. Secondly, the first author strived to witness not only daily routines but also special events: he was present when a new rotating cow brush was installed and when two young cows were introduced into the main shed at one farm; watched cows who had recently been introduced to robotic milking; and observed cows when a manure scraping robot was introduced into their shed. Such events, in which new elements were introduced into a network of interacting entities, were expected to motivate uncommon interactions (e.g. cows approaching unfamiliar technologies with curiosity and caution or still lacking the skill to operate them). Uncommon interactions with technology were relevant for our research in their own right and helped to recognise what is required of cows in their everyday interactions with technology (Akrich and Latour, 1992; Latour, 2005). Thirdly, the first author conducted chores among cows during his later visits to one farm, which gave cows more possibilities to exercise agency towards him. This seemed like an ethically appropriate attempt to mitigate the power differences between the researcher and cows and was expected to generate relevant experiences. Fourthly, he charted the interactions around specific actors (cows, technologies, or farmers) regularly or for an extended period of time. At the farm which was visited repeatedly, for example, observations centering on specific technologies (e.g. the milking robot and the manure scraping robot) were alternated with observations of a few individual cows.

The cows followed individually were selected primarily on the basis of theoretical sampling (Beuving and De Vries, 2014: 38, 157; Hammersley and Atkinson, 2019: 36; Taylor et al., 2015): they showed characteristics that enabled us to test and expand upon our developing insights. For example, one cow was selected when she thwarted one-way access gates to arrive in an area where the feeding robot was supplying forage to cows who had recently calved, where she regularly claimed a different spot at the feeding fence by chasing away other cows. Because this cow's cunning in manipulating artifacts, her physical condition, and her social status all seemed relevant to her agency, the first author also observed cows who were different in some of these respects. For example, he followed a cow that according to his own observations and the farmers' testimony seemed to have an even higher social status (who showed less striking interactions with artifacts) and a cow with obvious leg problems (who still proved able to pass one-way access gates in the 'wrong' direction). Some cows who had unordinary relations to technology were also observed recurrently, including a cow who was driven towards the milking robot by the farmer because she would not visit it otherwise, an old cow who spent the rest of her days on the farm but no longer gave milk, and some calves who stayed among the cows in the main shed (and were not deterred in their movements by barriers designed for full-grown cows).

We did not commit to any particular approach to interpreting cows' behaviours and interactions that was available in the literature (e.g. Cornips, 2021; Hulsen, 2008; Rousing and Wemelsfelder, 2006). Judging that these approaches were developed with different purposes in mind, we instead focused on 'tracing associations' (Latour, 2005) within dairy farming assemblages by analysing the interrelations between the actions of cows, technologies, farmers, and other entities. However, our research did assume that an animal's agency cannot be understood properly without presupposing that the animal acts from some will or desire (see the Introduction). We allowed ourselves such explanations insofar as these seemed commonsensical or obvious – for example that cows try to access concentrate feed dispensers because they want such feed and avoid electric fences because they do not want to get shocked. This accords with current views on multi-species ethnographic research: understanding animals' perspectives does not necessitate applying specialised 'objective' methods, but requires spending time with animals, engaging with them empathically, and assuming that their differences with humans are gradual rather than black-and-white (Gillespie, 2016b; Hamilton and Taylor, 2017; Meijer, 2019).

Analysis

Hand-written notes of observations and informal talks with farmers were processed into fieldnotes, which were mainly descriptive at the beginning but gradually came to integrate more theoretical reflections and recordings of interviews were transcribed verbatim (by manually improving an automatic transcription generated by the Amberscript transcription tool). A preliminary analysis was conducted by the first author in Microsoft Excel, after a first round of fieldwork at six farms, and discussed with the second author as well as members of the wider project team (see the project website at https://anthropoceneethics.wordpress.com). These discussions informed the subsequent fieldwork and analyses, which were performed intermittently with farm visits and were carried out in ATLAS.ti 22.

The core of our analyses consisted of identifying themes that emerged as relevant from the fieldnotes and transcripts through open coding, and then structuring these codes by combining them into categories at higher levels of abstraction, which frequently involved renaming and reordering codes or reinterpreting excerpts from the fieldnotes and transcripts. This iterative approach ensured that the theoretical ideas developed were grounded in observations and statements collected in the field, informed further data collection, and formed a coherent whole (Beuving and De Vries, 2014 chapter 7; Hammersley and Atkinson, 2019 chapter 9). The analysis gradually zoomed in on themes that related to cow agency and technology, but also addressed some wider issues, such as scenarios for the life of a cow and ethical issues that arose during the fieldwork. Saturation was reached in the sense that later observations, talks and interviews did not produce new insights about the relations between technology and cow agency, at least not on higher levels of abstraction.

Research ethics and data management

Ethical issues with respect to the fieldwork were anticipated, to an extent, by studying literature on multi-species ethnography and ethics (e.g. Abrell and Gruen, 2020; Hamilton and Taylor, 2017; Van Patter and Blattner, 2020). The fieldwork did not require approval from an animal research ethics committee (as no research interventions would be performed on cows that would cause them suffering or harm equal to or greater than the insertion of a needle; cf. the Dutch *Wet op de dierproeven* article 1b), and these committees are often poorly equipped to assess non-invasive research (Abrell and Gruen, 2020; Hamilton and Taylor, 2017). We did however address the ethics of doing ethnographic research with animals in meetings with our wider project team, which included several animal ethicists and multi-species ethnographers, and in an application to our institute's Social Sciences Ethics Committee. This committee approved our study on 4 July 2022.

Important ethical norms for the fieldwork were, firstly, that the researcher would not assist in procedures that were harmful to cows; he would only contribute to mundane activities such as feeding or scraping dung. Secondly, he would strive not to reinforce power inequalities between himself and cows by positioning himself as the 'subject' engaging with cows as 'objects' in his preferred mode of interaction (e.g. studying them visually from a distance). This involved choosing a spatial position and an attitude that also allowed cows to engage with the researcher on their own terms (e.g. by staying away or alternatively by approaching

and sniffing, licking and prodding the researcher). However, the realities of fieldwork sometimes challenged such norms, raised unforeseen ethical questions, or presented issues that were only with hindsight recognised as morally significant. Was it justifiable for the (vegetarian but non-vegan) researcher to purchase animal products at some farms during the recruitment phase, thus apparently subscribing to animal agriculture from the start? Was helping to pack meat acceptable as a chore and as a way of building rapport? How should one respond when cows exercise agency in ways that are at odds with the farmer's interest, or when a farmer who attempts to drive a cow into a trailer asks you to 'block' a path away from the trailer? To what extent should you try to influence farming personnel in how they treat cows, for example by questioning normalised acts of violence (Gillespie, 2018)? Such questions show that although anticipating situations that may arise during fieldwork and reflecting on the ethical dimensions of such situations is important, multi-species ethnographers also need the ability to make good ethical decisions on the spot (Van Patter and Blattner, 2020). As the first author's involvement in the field progressed, both the moral issues faced and his ability to respond to them developed dynamically. Gaining knowledge of dairy farming and establishing rapport with farmers opened up some opportunities to advocate for cow interests, for example by raising questions about husbandry practices or pointing farmers to the existence of a cow sanctuary in the Netherlands. On the other hand, building and maintaining rapport required avoiding confrontations about husbandry practices and occasionally conducting some chores. The question here is when performing such chores is acceptable (from a non-ideal ethical perspective) as a necessary part of doing fieldwork and at which point one becomes complicit to the practices studied. We hold that performing tasks that do not harm animals can be justified as a means to a study's ethically significant ends, but found that the line between innocuous and harmful actions is thin and sometimes difficult to tread.

The main ethical concerns with respect to farming personnel were related to informed consent and privacy. Farmers were approached with an information package containing information on the study's aims and approach and an informed consent form, which they could study at their convenience and were briefly explained orally (in person or on the telephone). They were usually called or visited again later to address any questions they had about their research and, if they proved willing to participate, to schedule an appointment for a 1-day farm visit. At this visit, the researcher addressed any further questions that might have come up and asked the farmer or other qualified personnel to sign the informed consent form. The researcher would initially take only anonymised written notes of observations and informal talks, but additional informed consent was obtained to make photos and videos during later visits to two farms, with the farmers checking and approving the photos and videos to be used in academic outputs. Written and oral consent were also obtained to make audio recordings of formal interviews and to process these into anonymised transcripts. All data were stored in one of our institute's secure environments, which require two-factor authentication to access, following a Data Management Plan developed in consultation with our institute's Data Management Support service. Personal data were retained no longer than necessary for the purposes of the study, while anonymised data (fieldnotes, photos, and interview transcripts) were archived for at least 10 years after the end of the project.

Results

As the main part of the first author's fieldwork, one cow sanctuary and eight dairy farms were each visited for one full day, one farm was visited twice, and another farm was visited nine times. These farms housed a wide-ranging number of cows, had different farming styles, and had robotised their processes to a different extent (Table 1). As explained in the Material and methods section, our study involved iterating between field work and analysing the findings from our fieldwork by means of progressively developing theoretical concepts and categories. Five main themes emerged from this procedure: technological scripts and programs of action; the role of technology in cow-X relations (including relations to other cows, humans, other animals, technologies, and other material entities); cows' technological skills; technology and embodiment; and emerging ethical issues. The remainder of this paper focuses on the first two themes, but frequently integrates issues relating to embodiment or technological skills.

General technological scripts on dairy farms

Technologies, ranging from mundane artifacts like metal bars to machines operating autonomously, fulfilled various functions on dairy farms. Solid or electric barriers kept cows on the farm's premises, for example, milking machines extracted milk from cows' udders which farmers sold, manure scraping devices cleaned the shed's floors, etcetera. Following Madeleine Akrich and Bruno Latour (Akrich, 1992; Akrich and Latour, 1992; Latour, 1992; Latour, 2005), such technologies can be understood as implementing a number of 'scripts': they were material means to realise certain visions on what should and should not happen between different actors on dairy farms. What such technologies aimed to accomplish can be 'de-scribed', at a general level, by translating the visions that have been 'in-scribed' into their material design back into words. This is relevant for cow agency because the scripts that dairy farming technologies aimed to implement assumed that cows did certain things and sometimes required them (not) to take certain actions, which sometimes motivated taking additional measures to steer cows' actions in desired directions. Without claiming completeness, a number of scripts can be identified which help to understand many of the more particular cow-technology interactions we observed.

Firstly, cows were expected to stay within some designated area: a part of a shed, a plot of pasture, or both. Cows were often divided into groups (for example into groups of lactating cows, cows within a few weeks of giving birth, calves of a similar age, cows meant only for meat production, infirm cows, etcetera) and separated by physical means. Cow sheds usually housed several groups, separated by metal bars and fences or concrete walls, but it was also common to keep some groups in different sheds. Outdoors, groups of cows were confined to a particular area by (electric) wire fences or bodies of water. Such material entities can be understood as implementing a script that can be formulated as: COWS STAY WITHIN DESIGNATED AREAS IN DESIGNATED GROUPS. We made observations outdoors and in sheds housing different groups of cows, but we focused on lactating cows and cows that were housed with them in the same shed, which is where dairy cows spent most of their indoor lives and where most technologies were to be found.

Secondly, milking machines (including conventional milking machines and milking robots) were obviously meant to implement the script COWS GIVE MILK, but more careful analysis allows for refining this script. Milking machines directed most of the milk extracted towards big tanks, from which it was collected by corporations or sold directly to human consumers, but not all milk was meant for human consumption: milk with a high somatic cell count (indicating inflammation) and colostrum (milk from cows who just gave birth, which was fed to young calves because such milk contains a high concentration of antibodies against diseases to which calves are susceptible) was separated automatically.

Table 1
Characteristics of dairy cattle farms visited and number of visits.

		General characteristics		Robotised processes			
Farm ID	No. visits	No. Cows[1]	Farming style	Milking[2]	Removing manure[3]	Providing forage[4]	Pushing forage[5]
A	1	~60	Organic		√		√
B	9	~80	Organic	√	√	√	
C	1	~50	Organic				
D	1	~45	Sanctuary				
E	1	~65	Organic	√	√		
F	1	~30	Biodynamic	√			√
G	2	~140	Conventional		√	√	
H	1	~550	Conventional		√	√	
I	1	~580	Conventional				
J	1	~80	Conventional	√			
K	1	~200	Conventional	√	√	√	√

[1] The numbers in this column indicate the number of milking cows, except for farm D, where no cows were milked and where all female and male bovine animals have been included in the number.
[2] Farms that did not have milking robots had milking parlours, except farm D.
[3] Farms that did not have manure removal robots had scrapers that were automatically pulled along the floor (usually by a chain) at regular intervals.
[4] Farms that did not have robots to distribute forage along the feeding fence used human-operated tractors or shovels.
[5] These robots push forage that is out of cows' reach towards the feeding fence. On farms that did not have such robots, farming personnel used tractors or simple pitchforks to the same end.

Moreover, milking machines were meant to minimise the human labour required and to drain each quarter of a cow's udders properly, thus increasing milk yield and preventing udder infection. The script in which milking machines figured prominently can thus be formulated more appropriately as COWS GIVE MILK (MOSTLY) TO HUMANS AND WITH LIMITED HUMAN LABOUR. As discussed later, implementing this script also required a range of different actors (including but not limited to cows and farmers) to cooperate, according to a particular 'program of action' (Akrich and Latour, 1992; Latour, 1992; Latour, 2005).

Thirdly, cows of course had to eat and drink. What and how much cows ate was managed to a significant extent by humans and technologies, which aimed to implement the script COWS EAT DESIGNATED RATIONS OF FEED AND THEY DRINK ENOUGH. (We focus here on cows eating indoors, but note that farmers also attempted to manage what plants grow on pasture.) Cows usually had access both to forage, consisting of dried or fermented grasses and similar plants, and to concentrate feed. Forage was distributed along feeding fences by farmer-operated or autonomous machines a number of times per day, with different groups of cows receiving a different type of forage, based on what they supposedly needed to stay healthy and productive. Feeding robots often mixed different types of forage in a way that made eating selectively difficult for cows: every bite was meant to have roughly the same composition. Concentrate feed dispensers, on the other hand, identified cows individually (by means of a tag worn on a collar) and provided portions of concentrate feed that were meant to fit their nutritional needs. These needs were inferred from data on how long a cow had been lactating, the amount of milk she produced, the amount of concentrate feed she had been eating, etcetera. Water was not rationed on any farm; troughs that refilled automatically facilitated cows to drink large amounts of water, which was considered especially important for lactating cows who had recently been milked. Calves did not have unlimited access to milk, but were usually provided with one or more buckets of milk with rubber teats to drink from, depending on the size of the group in which they were housed. At one farm, calves were fed by a machine that offered a designated ration of milk based on individual calves' age, thus gradually easing them into a diet consisting of forage, concentrate feed, and water.

Fourthly, to digest large amounts of plants properly and perform the 'metabolic labour' (Beldo, 2017) required to produce milk, cows were expected to ruminate and rest for extended periods of time. Farmers glanced around to ensure that cows were not standing around too much, which would be bad for their claws and would indicate that something was amiss (Hulsen, 2008). Cow sheds contained relatively soft surfaces (cubicles covered with a layer of sand or sawdust, straw pens, and in rare cases patches of sand) that seemed attractive for cows to lay down on, compared to the hard surfaces that made up the rest of the cow shed's flooring. In addition, cubicles contained horizontal bars that required cows to lay down if they moved forward far enough. These material arrangements appeared to implement the script COWS LAY DOWN AND REST FOR EXTENDED PERIODS OF TIME.

Cubicles were also part of a fifth script. Cows urinated and defecated – a lot – and several material entities influenced where these excrements ended up. Feeding fences allowed cows to access forage with their front ends only and thus protected forage from being spoiled by urine or dung. The amount of urine and dung that would end up in cubicles was also limited through material arrangements, because the contamination of cubicles would increase the risk that cows would contract infections and because cleaning cubicles was considered relatively labour-intensive. The width and depth of cubicles ensured that the hindsides of most cows were positioned above a surface that could be cleaned by automated devices, such as slatted metal floors or solid floors with a large opening at one end that led into an underground reservoir. Manure scrapers were pulled along such floors to force dung into the reservoir, robots pushed manure forward to the same effect, or collected dung like a vacuum cleaner and then deposited it into the reservoir. Such devices and the material arrangements they required (e.g. floors with openings and no obstacles which the cleaning device could not pass) implemented the script COWS URINATE AND DEFECATE ON DESIGNATED SURFACES THAT ARE CLEANED WITH LITTLE HUMAN EFFORT.

These scripts are relevant to understanding the agency of cows and its relation to technology. Insofar as agency comprises the ability to make a perceptible difference in how other actors within an assemblage (inter)act (Latour, 2005; Law and Mol, 2008), these scripts clearly refer to the agency of cows. Having a milking machine to implement the script COWS GIVE MILK (MOSTLY) TO HUMANS AND WITH LIMITED HUMAN LABOUR only makes sense for dairy farmers because cows perform the 'metabolic labour' (Beldo, 2017) that is required to produce milk. Moreover, as a part of performing this metabolic labour durably, cows must eat certain types of feed and drink sufficient amounts of water, lay down and rest sufficiently to process this feed properly, and excrete urine and faeces. The scripts implemented by technologies such as feeding

robots, cubicles, slatted floors, and manure scrapers respond to the processes that occur in cows as a necessary part of producing milk – or indeed of living – and try to influence these processes according to certain human demands. However, the scripts identified also presuppose cows' agency in other ways. The script COWS LAY DOWN AND REST FOR EXTENDED PERIODS OF TIME, for example, requires cows to walk over to a cubicle or straw pen and actually lay down, which cows must do carefully to avoid hitting metal bars and injuring themselves. The script COWS EAT DESIGNATED RATIONS OF FEED AND THEY DRINK ENOUGH requires cows to walk towards a feeding fence and take the actions required to obtain and ingest the forage supplied there. The actions required here certainly seem more purposive than performing metabolic labour does, and should in all likelihood be explained with reference to cows' wants and preferences. This is also how farmers appeared to think about cow agency: they sometimes explained cows' eating behaviours by stating that cows considered certain foods tastier than others, for example, and tried to provide rations that cows wanted to eat in good quantities. In sum, dairy farming technologies aim to implement scripts that require cows to perform not only metabolic labour but also to act in ways that by all means seem purposive.

Programs of action, cows' anti-programs, and re-inscription

How technologies depended on cows' purposive actions becomes even more apparent if we consider the specific 'programs of action' (Akrich and Latour, 1992; Latour, 1992; Latour, 2005) that cows and other actors needed to follow to realise these general scripts – and in how cows sometimes counteracted such programs of action. We understand a program of action as a step-by-step procedure that different actors within a particular constellation must take if a technological script is to be realised (Akrich and Latour, 1992; Latour, 1992; Latour, 2005). We focus here on the program of action for conventional milking (i.e. milking in milking parlours, including rotary ones), which is instructive for how cow agency is presupposed in dairy farming more generally. Although there were minor differences among farms with milking parlours, the general procedure which enforced the script COWS GIVE MILK (MOSTLY) TO HUMANS AND WITH LIMITED HUMAN LABOUR was as follows:

(1) The farmer (or farming personnel) drove the cows towards a 'waiting area', a part of the shed that was adjacent to the milking parlour and could be closed off from other parts of the shed.
(2) When all cows had been rounded up, the farmer closed off the waiting area but opened the entrance to the milking parlour.
(3) Cows who could not enter the milking parlour yet stood in the waiting area (or lay in cubicles that are part of the waiting area).
(4) Cows who were near the milking parlour entered it when a spot was available, through an entrance that allowed one cow to enter at a time.
(5) The farmer attached the milking cluster onto the cows' teats.
(6) The milking machine extracted milk from the cows' udders and transported it to a storage tank, and automatically detached when no milk was flowing for a number of seconds.
(7) Cows that were no longer being milked left the milking parlour when an exit fence opened (or when they had been on a rotary milking parlour for a full round).

This step-by-step description covers the basic procedure followed to implement the script COWS GIVE MILK (MOSTLY) TO HUMANS AND WITH LIMITED HUMAN LABOUR when using a milking parlour. Note that this procedure not only requires a cow's metabolism to respond when the milking cluster is attached but also requires her to walk towards the waiting area, move into the milking parlour, and move out of it again. Moreover, this procedure requires cows not to do certain things, such as kicking off the milking cluster with their hind legs or frustrating the farmer's attempt to attach it. This implies that cows can also act or refrain from acting in ways that disrupt the program of action under consideration – they can, in other words, engage in anti-programs (Akrich and Latour, 1992; Latour, 1992).

Such anti-programs were to some extent tolerated. The farmers we observed frequently waited for cows to enter the milking parlour, for example, and only whistled or made brief vocalisations (e.g. "hey!" or "come on!"). Some farmers held onto cows that frequently disrupted the milking process by not entering the milking parlour or by kicking off the milking cluster; these farmers did not get rid of cows that had been uncooperative for a long time. And yet, material means were used to counter certain anti-programs employed by cows. Most milking parlours were equipped with a fence that moved from the far side of the waiting area towards the entrance of the milking parlour at the farmer's control. This fence was either solid or consisted of chains and wires that could be charged with electricity (which most farmers did only rarely, e.g. once per month). Another example is that one rotary milking parlour was equipped with a small weight hanging on a chain; cows that did not leave the milking parlour after one cycle would hit this weight with their backs (without receiving an electric shock). Such artifacts can be understood as attempts to re-inscribe the original program of action by countering cow's anti-programs (Akrich and Latour, 1992; Latour, 1992). This does not mean that all anti-programs were ruled out, however. Several cows managed to avoid or pass through the chain and wire fences that were meant to drive them into the milking parlour. Some cows in the rotary milking parlour with the suspended weight still kept standing for more than one cycle, in which case the farmer would reverse the parlour's turning direction until the cow concerned would be at the exit again, and then, he would chase her out.

This analysis shows, in more detail, how a conventional milking system presupposes cows' agency. This system relies on cow agency in a way that goes beyond cows' ability to perform metabolic labour: at least in a free-stall barn, their role is not comparable to that of a bioreactor in which grass would be converted into milk. Rather, they must be enlisted as active participants: the program of action followed to implement the script COWS GIVE MILK (MOSTLY) TO HUMANS AND WITH LIMITED HUMAN LABOUR requires cows to take certain purposive actions while refraining from others. The technologies used (and the farmers using them) also recognise that cows do not necessarily cooperate with this program of action, but can employ various anti-programs instead. Moreover, such technologies sometimes try to counter cows' anti-programs in ways that appeal to cows' wants and desires. The presupposition behind using fences charged with electricity to drive cows into the milking parlour is that cows want to avoid receiving an electric shock and will thus move into the milking parlour or drive cows in front of them forward when the fence approaches (the possible objection that this would merely be a form of operant conditioning, which would not assume that cows act on wants and desires, is addressed in the Discussion section of this paper). In addition, cows are sometimes lured into the milking parlour with concentrate feed, which appeals to their taste for such feed.

The technologies used on also presupposed that cows have the ability to learn. Fences that were used to drive cows towards the milking parlour usually made a buzzing sound before moving, which sufficed to get most cows moving. This motivated several farmers not to apply electricity to the fence, once the cows had

associated the fence with electric shocks and the buzz with the fence's approach, although they did charge it occasionally because the cows would otherwise learn that they could pass it safely. Farmers relied on cows' ability to learn in other ways, too. Young cows who were not lactating yet would sometimes be included in the milking routine (as an 'internship'), to get used to the technologies before actually getting milked.

Although this analysis focused on technologies involved in conventional milking, other technologies also presuppose that cows are agents who act out of some will or desire and who have the ability to learn. Milking robots, for example, require cows to move into them and to leave when the milking process has stopped. These robots typically offer concentrate feed to motivate cows to visit and move into them and are outfitted with a probe that can deliver an electric shock when a cow lingers in the robot for too long after milking. Manure scraping robots and other moving technologies count on cows to evade them – cows must come to predict the trajectories of such technologies successfully but must also learn not to flee or interrupt their activities excessively (as cows who were just introduced to such technologies frequently did). Finally, some technologies call on cows to operate them purposively. Rotating cow brushes are activated when cows apply pressure to them, for example, and some designs allow cows to swing the brush around to groom hard-to-reach body parts.

We also observed cows deploying anti-programs in relation to other technologies than those involved in conventional milking. For example, some cows did not present at the milking robot, banged concentrate feed dispensers to obtain some extra feed or claimed portions from other cows, escaped enclosures, made feeding robots halt, or managed to pass one-way access fences in the 'wrong' direction. These actions sometimes involved technologies (or design features of technologies) that were actually meant to constrain certain anti-programs; directed cow traffic was for example meant to force cows to visit the milking robot. This shows that dairy farming technologies do not only depend on cows' agency but also are challenged by cows' agential actions in various ways. But the relation between dairy farming technologies and cow agency proved to be even more complex, as explained next: technologies also mediate cows' interactions with other beings in relevant ways.

The technological mediation of cow agency

As we have seen, some technologies used in dairy farms presume that cows act purposively and can be motivated to act by appealing to their wants and desires. Cows are even considered capable of operating and adapting to technologies, and thus of acting purposively towards technologies. However, our fieldwork also identified a range of ways in which technologies co-shape cows' expressions of agency towards other beings. Firstly, technologies mediated interactions among cows. The first author regularly witnessed agonistic interactions that took place around technologies. Cows frequently struggled for access to concentrate feed boxes, for example, and exercised agency by chasing other cows away and claiming their feed or by standing their ground while they were eating. That these interactions occurred could apparently be explained by the fact that concentrate feed dispensers introduced a scarce good into the shed: they provided a desirable feed in limited portions. The material design of concentrate boxes also affected the shape that these interactions took. These boxes had fences on the sides, which meant that cows eating concentrate could only be harassed from behind (which other cows did by rubbing, prodding, or headbutting). Some models were equipped with a hydraulic fence at the back, which would close automatically behind cows who were entitled to some concentrate feed (according to data on a connected computer) and would open automatically after some time. This introduced a time-frame in which cows could not force their way into the concentrate box, but they did still quarrel with other cows near its entrance.

Agonistic interactions also took place around other technologies. For example, milking robots, feeding fences, water troughs, and rotating brushes all created a kind of scarcity that apparently motivated cows to struggle for access. Technologies could also lead to agonistic interactions by other mechanisms. Fences used to drive cows towards the entrance of a milking parlour made cows push and shove to move forward in (or with) the crowd. Another relevant factor here was that cows had to enter these milking parlours through one or two narrow passages, which created a bottleneck at the end of the waiting area. Finally, the material arrangements that made cows share certain spaces appeared to influence their interactions. One cow who was observed frequently on farm B rarely allowed other cows to stand adjacent to her at the feeding fence. While this behaviour was particular to this cow, the material set up did play a role: the shed's size and the feeding fence required cows to line up closely together in the first place.

Technologies also figured in more benign interactions among cows. Cows who were lined up along the feeding fence would often eat with their heads closely together or lick one another. Rotating cow brushes were frequently used by two cows at once, sometimes, even if their design allowed either cow to brush just a small patch of her body. Finally, fresh straw was on some farms provided by a machine that shred a bale of straw and made it hail down into the pen. Cows would often frolic through the descending cloud of straw, running and jumping around collectively. In each of these cases, technology influenced the specific form which social interactions took (Cornips and Van den Hengel, 2021). To be sure, the social interactions among cows were also constrained by artifacts – because they were divided into particular social units by physical barriers, for example, they could usually perform only some of the social roles which Blattner et al. (2020) saw animals engage in at a multi-species sanctuary. However, many technologies appeared to change the shape of social interactions rather than simply limiting it.

Secondly, technologies mediated cows' interactions with humans. On the one hand, sensors and related technologies mediated how farmers acted towards cows. Sensors on milking machines recorded how much milk individual cows produced and measured indicators for udder infection, for example, while wearable sensors tracked how much they ate and moved. The data generated was processed and passed on to the farmer by means of a computer program or app, and influenced farmers' interactions with particular cows (e.g. by seeking veterinary advice or driving a cow to the milking robot). Because data-generating technologies affected when and why farmers were in the cow shed, such technologies also influenced when and how cows engaged with farmers, albeit indirectly. Some other artifacts limited cows' expressions of agency towards humans, including farmers and veterinarians. Cows on whom special physical procedures were performed would first be restrained in a yoke (a feeding fence with a moveable bar that can be locked into position), which prevented them from getting away or resisting the procedures violently. We did not witness cows using technologies as an intermediate in cow-human interactions: to initiate play, to communicate their wants, to resist handling, etcetera.

Thirdly, cows' relations to other (non-human and non-cow) animals were mediated by technology. Cows' ability to initiate interactions with other animals was limited by barriers that kept them within the shed or a particular patch of pasture. Domestic dogs and cats would sometimes walk into the shed but would usually stay on the cleaner side of the feeding fence. Still, cows sometimes initiated interaction by sticking their heads out to and, when these other animals came close enough, nuzzling them. Starlings and

sparrows did enter the enclosed areas where cows resided – using the advantage of flight to avoid manure-covered surfaces – and could often be found near concentrate feed boxes or around water troughs. These birds appeared to have picked the cow shed as their residence because of the goods that such technologies offered. Cows thus had some opportunities to exercise agency in relation to such birds, but we did not observe striking interactions between cows and birds. Cows did exercise agency by chasing flies off their bodies, in particular by sweeping their tails or making shivering movements. Especially in milking parlours, however, this agency was restricted by physical barriers which constrained cows' movements.

Fourthly, some technologies appeared to shape how cows showed agency in engaging with their own bodies. When cows groomed themselves with rotating brushes, they interacted with the technology but at the same time related to their own bodies in a particular, technology-enabled way. Cows also scratched themselves against other material entities, including trees, metal posts, etcetera, but certain rotating brushes allowed cows to swing the brush around, which gives them more flexibility in grooming their own bodies. A grooming cow's body arguably showed a comparable duality here as human hands touching one another (Sartre, 2003): this body was both the subject that acted (by directing the brush) and the object acted upon (by being brushed).

Finally, technologies played a role in the background of cows' interactions with other entities. Huge fans and open cow shed constructions were meant to keep the temperature tolerable for cows during hot periods, although this was not an issue during our period of fieldwork. Artificial lighting allowed farm routines to go on at nighttime and enabled cows, for example, to exercise agency by walking around, grooming, and engaging in social interactions before sunrise.

Discussion

Main insights on cow agency and dairy farming technologies

On an object-oriented conception of agency (Latour, 2005; Law and Mol, 2008), cows can be said to have agency through their metabolic processes. Dairy farming technologies presuppose that cows perform 'metabolic labour' (Beldo, 2017) by producing milk and that this requires cows to eat, drink, ruminate, and defecate. By performing such metabolic labour cows clearly 'make a difference' to other agents: that cows produce milk makes dairy farming feasible for farmers in the first place, and dairy farming technologies often respond to cows' metabolic needs in some way.

Our multi-species ethnographic study has found that technologies used in dairy farming also presuppose a more purposive kind of cow agency. Such technologies aim to implement scripts or visions about what is supposed to happen on dairy farms, which assumes and requires that cows (do not) act in certain ways. Cows are implicated in programs of action that rely on cows to exercise their agency in ways desired by humans and required by technologies, but cows can also exercise agency by employing anti-programs. Some technological countermeasures against such anti-programs simply make certain actions impossible for cows, but others appeal to cows' wants and desires instead: they influence how cows act by offering food rewards or giving them electric shocks. One could say that such technologies do not just 'afford' certain actions, but approach cows as agents who can act purposively and appeal to their wants and desires to 'inhibit' and 'invite' certain actions (Withagen et al., 2012; Kramer and Meijboom, 2022). Cows are also assumed to have the ability to learn, among others, how to operate certain artifacts or respond to moving technologies proportionately.

One might object here that the influence of technologies like electric fences and concentrate feed dispensers on cow behaviour can be explained without assuming that cows are intentional agents who act on wants and desires: such technologies could be said to merely provide stimuli as feedback on certain behaviours, as a means to either reinforce or curtail those behaviours. We cannot address this objection in detail here, but only note that such reductive behaviourist explanations are rejected on methodological and ethical grounds by many animal agency scholars and multi-species ethnographers (see, e.g., Rollin, 2007; Masson and McCarthy, 2016; Hamilton and Taylor, 2017; Meijer and Bovenkerk, 2021). According to such scholars, the influence of stimuli like electric shocks and food rewards on animal behaviour cannot be explained plausibly without referring to animals' wants and desires and their ability to learn. That animals can be conditioned would not exclude that they are agents.

The most striking expressions of animal agency, perhaps, consist in resistance to what humans require of animals. And we did observe cows who would not enter the milking parlour or visit the milking robot, who kicked at the milking cluster, who broke out of their enclosures, who headbutted the feeding robot to make it halt, who spoiled forage by throwing it over the feeding fence onto manure-covered floors, etcetera. But although resistance and dominance are important themes in relation to animal agency (e.g. Carter and Charles, 2013; Bear and Holloway, 2019; Colling, 2020), emphasising these concepts risks oversimplifying our findings. Firstly, as mentioned earlier, farmers frequently tolerated cows' anti-programs, at least to a certain extent. The boundaries of what would be tolerated were fuzzy and subject to 'negotiations' between cows and farmers. For example, calves who swam a ditch to mingle with lactating cows at farm E were not brought back until several hours had passed. The farmers at farm B were experimenting with allowing some calves among lactating cows, but infection risks limited what behaviours they would tolerate from calves. Secondly, cows usually did not resist human plans even when they were in a position to do so. Following Colling (2020), cows can show resistance by escaping from captivity, liberating other animals, responding violently to maltreatment, or defying human will in everyday encounters. But most cows whom we observed followed daily routines without causing farming personnel problems, stayed within barriers that could barely stop a cow who was determined to escape (such as flimsy fences or narrow ditches), and allowed farming personnel to walk among them safely.

This raises the question of why cows often did not resist even though they could. One possible explanation is that these cows were simply content with their lives on the farm. Another possible explanation proceeds from the view (presented in the Introduction) that agency can be shaped by techniques of disciplinary power. Holloway and colleagues (2014a, see also Holloway, 2007) point out that although robotic milking is often presented as giving cows the freedom to decide whether they want to be milked, it actually relies on creating 'cow subjects' whose behaviours fit the system. Holloway and coworkers explain how the farm's architecture nudges cows to present at the milking robot and how the generation of data enables farmers to ensure that cows are milked frequently enough, and we may add that cows learn to associate the robot with a food reward. The point is that cows' cooperation within automatic milking systems is not a given but is secured by the application of such techniques.

If Holloway and colleagues are correct that robotic milking and the associated disciplinary techniques (co–)shape cow agency, the same may be true for other technological systems that involve steering cow behaviour (Williams, 2004). And cow behaviour does seem to be affected durably by other systems and practices. In conventional milking systems, cows are sometimes eased into partic-

ipating in the milking routine by letting them join other cows in the milking parlour before their first lactation (as an 'internship'). Calves typically learn to drink from buckets with rubber teats soon after birth, which may explain why the calves who ended up among lactating cows at farm E did not attempt to drink from real udders, but did follow a farmer carrying a bucket of milk back to the shed. As Holloway and colleagues also recognise, it is difficult to establish unambiguously to what extent cows internalise the behavioural norms which humans and technologies set for them, but it is noteworthy that farmers in our study did assume that cows' behavioural attitudes can be shaped durably. Some farmers believed in adopting a dominant attitude, others said they believed in calmness and positive reinforcement; either way, they assumed one can steer cows' agency towards cooperation or resistance depending on how one treats them.

Directions for ethical reflection

We said in the Introduction that the agency of animals is increasingly recognised as ethically relevant. What, then, are the ethical implications of how cow agency relates to technology? Although this question cannot be answered in detail here, we can offer some pointers for further ethical reflection. It should first of all be recognised that dairy farming technologies have different impacts on cow agency. To be sure, artifacts like metal bars and yokes constrain agency, but technologies like rotating cow brushes also enable agency in certain ways. The idea that dairy farming technologies only limit cows in their agency and that cows are therefore best-off in low-tech environments is thus too simplistic. (And more specifically, the idea that cows have most agency on pasture is too simple: pastures do allow cows more freedom of movement but usually contain few different types of entities to interact with). This opens up possibilities for ethical design (Van de Poel, 2013): cow agency can and arguably should be included among the values for which dairy farming technologies and cow sheds are designed. Our analysis has shown that dairy farming technologies already take cow agency into account in several ways. Dairy farming technologies often require cows to learn to take certain purposive actions, or even to operate artifacts, and steer their behaviour by associating certain actions with food rewards, electric shocks, etcetera. But designing for agency requires more than taking agency into account as something that technologies can appeal to (and have to reckon with) to achieve certain goals: agency has to be treated as a value that deserves to be respected or even promoted through technology design (Van Weeghel et al., 2021; Webber et al., 2022).

What designing for cow agency entails requires further reflection. One aspect may be to resist building intolerance for certain anti-programs into the design of technologies and cow sheds. When we saw several cows halt the feeding robot by headbutting it at farm K, the farmer said that this robot's new model would be charged with electricity to counter such behaviour. We also mentioned earlier that feeding robots mix different kinds of forage in such a way that cows cannot be picky when they eat. Treating agency as a value in technology design raises the question of whether limiting cow agency through such design choices is necessary and justified.

Another option would be to design technologies and farm architectures that are explicitly meant to give cows choices. Simply giving cows options to choose from (for example to lay down in a cubicle or a straw pen or to choosing among different types of rotating cow brushes) may already enable them to exercise agency to some extent. At the same time, offering cows a choice seems ethically significant only if the options provided are sufficiently meaningful to cows. A cow who gets to choose between two types of bland food or two types of uncomfortable bedding, but who is not offered what she would really prefer, may not be able to exercise her agency in a significant way. This raises the question of when agency is meaningful and how meaningful types of agency can be catered for in the design of dairy farming technologies and cow sheds. One possible answer is that having agency is significant insofar as this contributes to or is a necessary constituent of welfare (Van Weeghel et al., 2021; Webber et al., 2022), but it is not obvious that animal agency – any more than human agency – is only meaningful to the extent that it serves welfare. As explained in the Introduction, one could also argue that the agency of both human and non-human animals, insofar as they are agents who have their own perspective on life, deserves our respect and should not be restricted unnecessarily, irrespective of any implications for welfare.

A third aspect of designing for agency is to recognise that technologies do not only limit or open up possibilities for acting, but also can shape how cows interact with other beings, including other cows, humans, and animals of other species. Again, however, the question is when such interactions are meaningful or positive and what this should mean for ethical design. We have suggested that technologies can incite agonistic interactions between cows when they introduce desirable goods in scarce supply, or alternatively figure in cows' social events, which seems relevant to recognise in ethical design. While there can be discussion about which interactions are positive and which are not (for example whether struggles for hierarchy are always undesirable or whether can be meaningful expressions of agency), the general intention should be to avoid designs that have a negative influence on cow-cow relations and maybe even to develop designs that a positive influence. Researchers have also experimented with developing technologies that enable positive animal-human interactions (e.g. Driessen et al., 2014; Webber et al., 2020), and this work can perhaps be extended to promote meaningful cow-human interactions through technology design.

A fourth aspect of designing for agency may be to include cows in the process as 'co-designers'. By presenting a range of prototypes to the animals for whom technologies are being designed, animals can indicate which design features they prefer and whether they are interested in using it at all, show unexpected ways of interacting with a technology, etcetera (e.g. Robinson and Torjussen, 2020; Webber et al., 2020). Using such methods with cows could help to design dairy farming technologies that offer cows options that they value, or even to cater to cows' individual preferences to some extent. This might increase the chance that technologies which are designed for agency actually increase cows' agency in a meaningful way.

At the same time, one can hardly expect that agency will be the main value for which dairy farms and farming technologies are designed. Designing for values requires striking a balance between a plurality of ethical and other values, and designing dairy farming technologies is no exception (Van de Poel, 2013). If designing for agency is to be successful in practice, the economic realities that dairy farmers face need to be taken into account, which may inhibit the inclusion of costly features that do not offer financial benefits. Perhaps, however, ways can be found to make technologies that serve cow agency more attractive financially, for example through subsidies or certifications that enable farmers to sell their products at higher prices.

It may be objected that this is unrealistic and that dairy farming technologies will always give cow agency low priority, compared to financial considerations. Moreover, if designing for agency requires financial incentives in dairy farming to change, one might object, then why not aim to improve cow agency through more systematic reforms, for example by de-intensifying or even abolishing dairy farming? We grant that design may not be the ideal approach to facilitate cow agency: even if financial concerns are

overcome and technology designs are introduced that increase cows' agency on a microlevel, design is unlikely to grant cows more macro-agency. That is, technologies and farm architectures designed for agency may offer cows more choices in their daily lives – such as what to eat, who to associate with, and what to use for scratching themselves – but more fundamental choices about how to live would still be made for them by humans (Donaldson and Kymlicka, 2013). Technology design can hardly enable cows to choose to stay with their mothers after birth, for example, to choose a mate, or to leave the farm and start living elsewhere. But even if the concept of animal agency raises ethical challenges for animal farming as such, looking for ways to give cows more agency in their daily lives can still be ethically significant, given the unlikelihood that animal farming will be reformed systematically on the short to middle long term.

Ethics approval

Approval by an institutional animal ethics committee: Not applicable. The Social Sciences Ethics Committee of Wageningen University approved our study on 4 July 2022.

Data and model availability statement

Upon publication of this paper, anonymised field notes and interview transcripts will be publicly available on the Dutch national centre of expertise and repository for research data (DANS-EASY) database (https://easy.dans.knaw.nl/ui/home).

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) did not use any AI and AI-assisted technologies.

Author ORCIDs

KK: https://orcid.org/0000-0002-7135-6691.
BB: https://orcid.org/0000-0002-3955-2430.

CRediT authorship contribution statement

K. Kramer: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **B. Bovenkerk:** Writing – review & editing, Validation, Supervision, Project administration, Funding acquisition, Conceptualization.

Declaration of interest

None.

Acknowledgements

We would like to thank the cows and farmers who took part in our fieldwork for their participation. We thank all members of our project group for their feedback at different points of study, and Dr. Joost Beuving for his feedback on parts of a manuscript draft.

Financial support statement

This work was supported by the Dutch Research Council (grant number 016.Vidi.185.128)

References

Abrell, E., Gruen, L., 2020. Ethics and Animal Ethnography Working Paper. Retrieved on 8 December 2023 from https://www.wesleyan.edu/animalstudies/WASEvents/FinalEthicsandAnimalEthnographyDraft.
Akrich, M., 1992. The de-scription of technical objects. In: Bijker, W.E., Law, J. (Eds.), Shaping Technology/building Society: Studies in Sociotechnical Change. MIT Press, Cambridge, MA, US, pp. 205–224.
Akrich, M., Latour, B., 1992. A summary of a convenient vocabulary for the semiotics of human and nonhuman assemblies. In: Bijker, W.E., Law, J. (Eds.), Shaping Technology/building Society: Studies in Sociotechnical Change. MIT Press, Cambridge, MA, US.
Bear, C., Holloway, L., 2019. Beyond resistance: Geographies of divergent more-than-human conduct in robotic milking. Geoforum 104, 212–221.
Beldo, L., 2017. Metabolic labor: broiler chickens and the exploitation of vitality. Environmental Humanities 9, 108–128.
Beuving, J., De Vries, G., 2014. Doing qualitative research: the craft of naturalistic inquiry. Amsterdam University Press, Amsterdam, The Netherlands.
Blattner, C., Donaldson, S., Wilcox, R., 2020. Animal agency in community: a political multispecies ethnography of VINE sanctuary. Politics and Animals 6, 1–22.
Bruijnis, M.R.N., Blok, V., Stassen, E.N., Gremmen, H.G.J., 2015. Moral "lock-in" in responsible innovation: the ethical and social aspects of killing day-old chicks and its alternatives. Journal of Agricultural and Environmental Ethics 28, 939–960.
Carter, B., Charles, N., 2013. Animals, agency and resistance. Journal for the Theory of Social Behaviour 43, 322–340.
Colling, S., 2020. Animal resistance in the global capitalist era. Michigan State University Press, East Lansing, MI, US.
Cornips, L., 2021. The animal turn in postcolonial linguistics: the interspecies greeting of the dairy cow. Journal of Postcolonial Linguistics 6, 210–232.
Cornips, L., Van den Hengel, L., 2021. Place-making by cows in an intensive dairy farm: a sociolinguistic approach to nonhuman animal agency. In: Bovenkerk, B., Keulartz, J. (Eds.), Animals in Our midst: the Challenges of Co-Existing with Animals in the Anthropocene. Springer, Cham, Switzerland, pp. 177–200.
Donaldson, S., Kymlicka, W., 2013. A defense of animal citizenship. Part 1: Citizen canine: agency for domesticated animals. Retrieved on 6 May 2024 from https://christianebailey.com/wp-content/uploads/2012/12/CitizenCanine_Agency-for-Domesticated-Animals-Donaldson-and-Kymlicka-2013.pdf.
Donaldson, S., Kymlicka, W., 2011. Zoopolis: a political theory of animal rights. Oxford University Press, Oxford, UK.
Driessen, C., Alfrink, K., Copier, M., Lagerweij, H., Van Peer, I., 2014. What could playing with pigs do to us? game design as multispecies philosophy. Antennae 30, 79–102.
Driessen, C., Heutinck, L.F.M., 2015. Cows desiring to be milked? milking robots and the co-evolution of ethics and technology on Dutch dairy farms. Agriculture and Human Values 32, 3–20.
Gibson, J.J., 1979. The theory of affordances. In: The Ecological Approach to Visual Perception. Houghton Mifflin, Boston, MA, US, pp. 127–137.
Gillespie, K., 2016a. Witnessing animal others: bearing witness, grief, and the political function of emotion. Hypatia 31, 572–588.
Gillespie, K., 2016b. Intimacy, animal emotion and empathy: Multispecies intimacy as slow research practice. In: Moss, P., Donovan, C. (Eds.), Writing Intimacy into Feminist Geography. Routledge, London, UK.
Gillespie, K., 2018. The cow with ear tag #1389. The University of Chicago Press, Chicago, IL, US.
Glasscock, J.S.P., Tenenbaum, S., 2023. Action. In: The Stanford encyclopedia of philosophy (ed. Zalta E.N.). Retrieved on 8 December 2023 from https://plato.stanford.edu/entries/action/.
Hamilton, L., Taylor, N., 2017. Ethnography after humanism: power, politics and method in multi-species research. Palgrave Macmillan, London, UK.
Hammersley, M., Atkinson, P., 2019. Ethnography: principles in practice. Routledge, London, UK.
Harfeld, J.L., Cornou, C., Kornum, A., Gjerris, M., 2016. Seeing the animal: on the ethical implications of de-animalization in intensive animal production systems. Journal of Agricultural and Environmental Ethics 29, 407–423.
Holloway, L., 2007. Subjecting cows to robots: farming technologies and the making of animal subjects. Environment and Planning d: Society and Space 25, 1041–1060.
Holloway, L., Bear, C., Wilkinson, K., 2014a. Re-capturing bovine life: robot-cow relationships, freedom and control in dairy farming. Journal of Rural Studies 33, 131–140.
Holloway, L., Bear, C., Wilkinson, K., 2014b. Robotic milking technologies and renegotiating situated ethical relationships on UK dairy farms. Agriculture and Human Values 31, 185–199.
Hulsen, J., 2008. Cow signals: a practical guide for dairy farm management. Roodbont, Zutphen, The Netherlands.
Hutchby, I., 2001. Technologies, texts and affordances. Sociology 35, 441–456.
Kopnina, H., 2017. Beyond multispecies ethnography: engaging with violence and animal rights in anthropology. Critique of Anthropology 37, 333–357.
Kramer, K., Meijboom, F.L.B., 2022. How do technologies affect how we see and treat animals? extending technological mediation theory to human-animal relations. Ethical Theory and Moral Practice 25, 595–611.

Latour, B., 1992. Where are the missing masses? the sociology of a few mundane artifacts'. In: Bijker, W.E., Law, J. (Eds.), Shaping Technology/building Society: Studies in Sociotechnical Change. MIT Press, Cambridge, MA, US, pp. 225–258.
Latour, B., 2005. Reassembling the social: an introduction to actor-network-theory. Oxford University Press, Oxford, UK.
Law, J., Mol, A., 2008. The actor-enacted: cumbrian sheep in 2001. In: Knappett, C., Malafouris, L. (Eds.), Material Agency: towards a Non-Anthropocentric Approach. Springer, New York, NY, US, pp. 57–77.
Masson, J.M., McCarthy, S., 2016. Unfeeling brutes. In: Bovenkerk, B., Keulartz, J. (Eds.), Animal Ethics in the Age of Humans: Blurring Boundaries in Human-Animal Relationships. Springer, Cham, Switzerland, pp. 103–118.
Meijer, E., 2019. When animals speak: toward an interspecies democracy. New York University Press, New York, NY, US.
Meijer, E., Bovenkerk, B., 2021. Taking animal perspectives into account in animal ethics. In: Bovenkerk, B., Keulartz, J. (Eds.), Animals in Our midst: the Challenges of Co-Existing with Animals in the Anthropocene. Springer, Cham, Switzerland, pp. 49–64.
Overstreet, K. "A well-cared for cow produces more milk": the biotechnics of (dis) assembling cow bodies in Wisconsin dairy worlds. PhD thesis, University of California, Santa Cruz, CA, US.
Palmer, C., 2001. "Taming the wild profusion of existing things"? a study of Foucault, power, and human/animal relationships. Environmental Ethics 23, 339–358.
Palmer, C., 2016. Climate change, ethics, and the wildness of wild animals. In: Bovenkerk, B., Keulartz, J. (Eds.), In Animal Ethics in the Age of Humans: Blurring Boundaries in Human-Animal Relationships. Springer, Cham, Switzerland, pp. 131–150.
Robinson, C., Torjussen, A., 2020. Canine co-design: investigating buttons as an input modality for dogs. In: Proceedings of the 2020 ACM Designing Interactive Systems Conference, 6—10 July 2020, Eindhoven, The Netherlands, 1673-1685. https://dl.acm.org/doi/10.1145/3357236.3395462.
Rollin, B., 2007. Animal mind: science, philosophy, and ethics. The Journal of Ethics 11, 253–274.
Rousing, T., Wemelsfelder, F., 2006. Qualitative assessment of social behaviour of dairy cows housed in loose housing system. Applied Animal Behaviour Science 101, 40–53.
Russell, B.H., 2011. Research methods in anthropology: qualitative and quantitative approaches. AltaMira Press, Lanham, MD, US.
Sartre, J.-P. (2003). Being and nothingness (Trans. Barnes, H.E.; 2nd ed.). Routledge, London, UK.
Sayes, E., 2014. Actor-network theory and methodology: just what does it mean to say that nonhumans have agency? Social Studies of Science 44, 134–149.
Sebo, J., 2017. Agency and moral status. Journal of Moral Philosophy 14, 1–22.
Small, M.L., 2009. 'How many cases do I need?': on science and the logic of case selection in field-based research. Ethnography 10, 5–38.
Špinka, M., Wemelsfelder, F., 2011. Environmental challenge and animal agency. In Animal welfare. CABI International, Wallingford, UK.
Steward, H., 2009. Animal Agency. Inquiry 52, 217–231.
Taylor, S.J., Bogdan, R., DeVault, M., 2015. Introduction to qualitative research methods: a guidebook and resource. John Wiley & Sons, Hoboken, NJ, US.
Thomas, N., 2016. Animal ethics and the autonomous animal self. Palgrave Macmillan, London, UK.
Thompson, P.B., 2021. The vanishing ethics of husbandry. In: Bovenkerk, B., Keulartz, J. (Eds.), Animals in Our midst: the Challenges of Co-Existing with Animals in the Anthropocene. Springer, Cham, Switzerland, pp. 203–221.
Turner, J., 2010. Animal breeding, welfare and society. Routledge, London, UK.
Twine, R., 2010. Animals as biotechnology: ethics, sustainability and critical animal studies. Routledge, London, UK.
Valentini, L., 2012. Ideal vs. non-ideal theory: a conceptual map. Philosophy Compass 7, 654–664.
Van de Poel, I., 2013. Translating values into design requirements. In: Michelfelder, D.P., McCarthy, N., Goldberg, D.E. (Eds.), Philosophy and Engineering: Reflections on Practice, Principles and Process. Springer, Dordrecht, The Netherlands, pp. 253–266.
Van Patter, L.E., Blattner, C., 2020. Advancing ethical principles for non-invasive, respectful research with nonhuman animal participants. Society & Animals 28, 171–190.
Van Weeghel, H.J.E., Bos, A.P., Jansen, M.H., Ursinus, W.W., Groot Koerkamp, P.W.G., 2021. Good animal welfare by design: an approach to incorporate animal capacities in engineering design. Agricultural Systems 191, 103154.
Webber, S., Cobb, M.L., Coe, J., 2022. Welfare through competence: a framework for animal-centric technology design. Frontiers in Veterinary Science. 9, 885973.
Webber, S., Carter, M., Smith, W., Vetere, F., 2020. Co-designing with orangutans: enhancing the design of enrichment for animals. Proceedings of the 2020 ACM Designing Interactive Systems Conference, 6—10 July 2020, Eindhoven, The Netherlands, pp. 1713–1725. https://dl.acm.org/doi/10.1145/3357236.3395559.
Williams, A., 2004. Disciplining animals: sentience, production, and critique. International Journal of Sociology and Social Policy 24, 45–57.
Withagen, R., De Poel, H.J., Araújo, D., Pepping, G.-J., 2012. Affordances can invite behavior: reconsidering the relationship between affordances and agency. New Ideas in Psychology 30, 250–258.