J. Dairy Sci. 107:5754–5778
https://doi.org/10.3168/jds.2024-24155

A Living Lab approach to understanding dairy farmers' technology and data needs to improve herd health: Focus groups from 6 European countries

C. Doidge,[1]* L. M. Ånestad,[2] A. Burrell,[3] J. Frössling,[4,5] L. Palczynski,[6] B. Pardon,[7] A. Veldhuis,[8] J. Bokma,[7] L. P. Carmo,[2] P. Hopp,[2] M. Guelbenzu-Gonzalo,[3] N. V. Meunier,[3] A. Ordell,[4] I. Santman-Berends,[8] G. van Schaik,[8,9] and J. Kaler[1]

[1]School of Veterinary Medicine and Science, University of Nottingham, Sutton Bonington LE12 5RD, United Kingdom
[2]Norwegian Veterinary Institute, 1431 Ås, Norway
[3]Animal Health Ireland, Carrick-on-Shannon, Co. Leitrim N41 WN27, Ireland
[4]Department of Epidemiology, Surveillance and Risk Assessment, Swedish Veterinary Agency (SVA), 751 89 Uppsala, Sweden
[5]Department of Applied Animal Science and Welfare, Swedish University of Agricultural Sciences (SLU), 532 23 Skara, Sweden
[6]Innovation for Agriculture, Stoneleigh Park, Warwickshire CV8 2LZ, United Kingdom
[7]Department of Internal Medicine, Reproduction, and Population Medicine, Faculty of Veterinary Medicine, Ghent University, 9820 Merelbeke, Belgium
[8]Royal GD, 7400 AA Deventer, the Netherlands
[9]Department of Population Health Sciences, Faculty of Veterinary Medicine, Utrecht University, 3584 CL Utrecht, the Netherlands

ABSTRACT

For successful development and adoption of technology on dairy farms, farmers need to be included in the innovation process. However, the design of agricultural technologies usually takes a top-down approach with little involvement of end-users at the early stages. Living Labs offer a methodology that involve end-users throughout the development process and emphasize the importance of understanding users' needs. Currently, exploration of dairy farmers' technology needs has been limited to specific types of technology (e.g., smartphone apps) and adult cattle. The aim of this study was to use a Living Lab approach to identify dairy farmers' data and technology needs to improve herd health and inform innovation development. We conducted 18 focus groups with a total of 80 dairy farmers from Belgium, Ireland, the Netherlands, Norway, Sweden, and the United Kingdom. Data were analyzed using Template Analysis, and 6 themes were generated representing the fundamental needs of autonomy, comfort, competence, community and relatedness, purpose, and security. Farmers favored technologies that provided them with convenience, facilitated their knowledge and understanding of problems on farm, and allowed them to be self-reliant. Issues with data sharing and accessibility and usability of software were barriers to technology use. Furthermore, farmers were facing problems around recruitment and management of labor and needed ways to reduce stress. Controlling aspects of the barn environment, such as air quality, hygiene, and stocking density, were particular concerns in relation to youngstock management. Overall, the findings suggest that developers of farm technologies may want to include farmers in the design process to ensure a positive user experience and improve accessibility. The needs identified in this study can be used as a framework when designing farm technologies to strengthen need satisfaction and reduce any potential harm toward needs.
Key words: precision livestock technology, decision support tools, user-centered design, dairy farmers, responsible innovation

INTRODUCTION

Farmers are being increasingly encouraged to adopt technologies by government and the media to improve the economic, environmental, and social sustainability of dairy farms (Lovarelli et al., 2020; Barrett and Rose, 2022). To ensure sustainability of the dairy industry, it is necessary to improve efficiency and reduce milk production costs on farms (Britt et al., 2018), which may be achieved through adoption of technologies (Kelly et al., 2020; Parikoglou et al., 2022). Technology is an umbrella term that includes higher-tech and lower-tech technologies, as well as new ideas or mindsets (Barrett and Rose, 2022). Some examples of technologies used on dairy farms include automatic milking systems, automatic feeders, activity sensors, and estrus detection systems (Costa et al., 2021). Most technologies are data-driven and use algorithms or changes in data signals to detect

Received September 4, 2023.
Accepted February 18, 2024.
*Corresponding author: charlotte.doidge@nottingham.ac.uk

The list of standard abbreviations for JDS is available at adsa.org/jds-abbreviations-24. Nonstandard abbreviations are available in the Notes.

events (Occhiuto et al., 2022), which are usually aimed at aiding the management of adult dairy cows (Kleen and Guatteo, 2023). In Europe, dairy farmers are more likely to adopt technologies than other livestock farmers (Groher et al., 2020), and farms with larger herd sizes tend to adopt more technologies (Abeni et al., 2019). However, a large proportion of farmers still do not adopt technologies (Gabriel and Gandorfer, 2023; Palma-Molina et al., 2023). Furthermore, data-capture technologies (e.g., activity and rumination sensors) and technologies that are not related to milking practices (e.g., automatic calf feeders) have particularly low adoption on farms (Groher et al., 2020; Palma-Molina et al., 2023).

One reason for the lack of adoption of some technologies is that the design of agricultural technologies usually takes a top-down approach with little involvement of end-users at the early stages of development (Rose and Chilvers, 2018). The actors (e.g., scientists, designers, and engineers) involved in designing agricultural technologies tend to design them based on their own values and normative assumptions, which can result in uneven adoption of innovations by farmers (Bronson, 2019). Designers tend to focus on the benefits that technologies can bring to farms. However, technologies can also cause harm, including displacement of the agricultural workforce and marginalization of certain (usually smaller) farms (Gardezi et al., 2022). These harms are often not presented in media or policy sources (Lajoie-O'Malley et al., 2020; Barrett and Rose, 2022; Mohr and Höhler, 2023).

This lack of engagement with end-users has led to a call for a Responsible Innovation approach to develop farm technologies (Bronson, 2019, Fielke et al., 2022), including in the dairy industry (Eastwood et al., 2019). A Responsible Innovation approach acknowledges that innovators should be responsive to the social and ethical challenges of research and innovation through an interactive process with stakeholders (Fielke et al., 2022). Key dimensions of Responsible Innovation are the anticipation of potential consequences, responsiveness to societal needs, the inclusion of relevant stakeholders throughout the development process, and being reflexive about motivations and assumptions (Rose and Chilvers, 2018; Eastwood et al., 2019). A Responsible Innovation framework has previously been used to assess to the development of dairy technologies in New Zealand (Eastwood et al., 2019). The authors identified a lack of participatory or user-centered design approaches in previous technology development projects and recommended using these approaches to implement Responsible Innovation of dairy technologies.

Living Labs offer a methodology for developing innovations while achieving Responsible Innovation goals (Van Geenhuizen, 2019; Gardezi et al., 2022). Living Labs have been defined as "a user-centric innovation milieu built on every-day practice and research, with an approach that facilitates user influence in open and distributed innovation processes engaging all relevant partners in real-life contexts, aiming to create sustainable values" (Bergvall-Kåreborn et al., 2009a, p. 3). It is a co-creative approach, which involves stakeholders at all stages of development. The innovation is developed in iterative stages by incorporating co-produced knowledge from multiple stakeholders through multiple methods (Almirall et al., 2012). There are different types of Living Labs, of which FormIT is one of the most developed (Ståhlbröst and Holst, 2012). FormIT Living Labs have 3 stages (concept, prototype, and innovate), which each have 3 phases (explore, design, and evaluate). This paper focuses on the concept stage, which aims to understand users' needs to develop a concept for an innovation. The concept stage of the Living Lab is the most important for innovation development as this is the stage where users can make the greatest impact because they can set the focus of the design (Ståhlbröst and Holst, 2012). Therefore, the foundation of Living Labs is to understand users' needs in the concept stage before developing an innovation (Bergvall-Kåreborn et al., 2009b; Bergvall-Kåreborn and Ståhlbröst, 2009).

Needs relate to overall goals, motivations, and desires, and tend to be broader and less influenced by trends compared with technical requirements (Patnaik and Becker, 1999). For example, a technical requirement could be to add password protection to a device, whereas the corresponding need would be for security. The Living Lab approach to collecting information on users' needs is influenced by 3 theoretical streams: Soft Systems Thinking, which recognizes the value of plural points of view (Checkland, 2000); Needfinding, which values looking for needs rather than solutions (Patnaik and Becker, 1999); and Appreciative Inquiry, which gives emphasis to positive idea generation over negative problem identification (Armstrong et al., 2020). The theoretical basis of Living Labs is therefore to generate needs through creating rich narratives with the intended users to identify opportunities for concept development (Bergvall-Kåreborn et al., 2009b). This calls for the use of qualitative approaches to explore users' experiences, motivations, and future goals. In this paper, the 3 theoretical streams of Living Labs were used as a lens for designing the qualitative data collection method, for example, by shaping the questions included in the discussion guide.

It can, however, be challenging for users to articulate their needs through direct questioning. Instead, researchers can identify users' needs from the dialog the users produce regarding their experiences, goals, and motiva-

tions (Bergvall-Kåreborn et al., 2009b). To aid identification of users' needs, Desmet and Fokkinga (2020) have produced a typology of fundamental needs, which aims to be used as a repertoire for human-centered design. It includes 13 fundamental needs and 52 subneeds. Some examples of the fundamental needs include comfort (i.e., having a simple, easy life), competence (i.e., exercising skills and knowledge), and purpose (i.e., having a life with meaning). To determine users' needs in this paper, the needs typology was used as a coding template for analyzing the qualitative data. Overall, users' needs can be generated by using the theoretical foundations of Living Labs to collect data on users' experiences, motivations, and goals, and then applying the data to a fundamental need typology (Bergvall-Kåreborn et al., 2009b).

Many studies have investigated factors that affect adoption of technologies and adoption rates on dairy farms (Hennessy and Heanue, 2012; McDonald et al., 2016; Abeni et al., 2019; Groher et al., 2020; Silvi et al., 2021; Bianchi et al., 2022). Fewer have investigated farmers' experiences of using technology (Hartung et al., 2017). These studies do not usually aim to understand dairy farmers' technology needs and tend to focus on the implications of technology on human-animal interaction and work practices (Schewe and Stuart, 2015; Butler and Holloway, 2016; Tse et al., 2018; Lundström and Lindblom, 2021). One study did investigate farmers' needs for a smartphone app, which focused on a later stage of tool development where the initial concept was already established (Kenny and Regan, 2021). There is potential to involve farmers during earlier stages of development so that they also have input into the initial generation of concepts for tools and technologies.

Despite the availability of several precision livestock technologies to monitor dairy calves (Costa et al., 2021), previous studies on dairy farmers' experiences of technologies appear to only include technologies for adult dairy cows (e.g., automated milking systems) (Schewe and Stuart, 2015; Lundström and Lindblom, 2021). Research suggests that calves tend to have a marginal status on dairy farms due to their lower perceived value (Enticott et al., 2022, Palczynski et al., 2022). The establishment of technical and support structures is required for more appropriate calf care (Palczynski et al., 2022). Thus, farmers may have different needs in relation to youngstock management.

Using a Living Lab methodology, we wanted to gain a broad perspective on farmers' needs around farm technologies and data so that we could develop technological concepts that could fulfill these needs. Therefore, the aim of this study was to understand dairy farmers' needs for data use, technology use, and disease management. We also aimed to include perspectives of technologies for both adult cows and youngstock to achieve a more holistic understanding of farmers' needs.

METHODS

Study Context

This study was conducted as part of the DECIDE project (https://decideproject.eu/), which aimed to develop data-driven support tools to aid with disease control and management in cattle, pigs, poultry, and salmon (van Schaik et al., 2023). The tool development process used the FormIT Living Lab methodology (Bergvall-Kåreborn and Ståhlbröst, 2009). The FormIT Living Lab had 3 stages: concept, prototype, and innovate. These stages each had 3 phases: explore, design, and evaluate (Figure 1). This study represents part of the explore phase of the concept stage, which aimed to explore and understand users' needs.

The study was carried out in 6 European countries: Belgium, Ireland, the Netherlands, Norway, Sweden, and the United Kingdom. The focus groups conducted in Belgium were with farmers from the Flanders region, which is the Flemish-speaking part of the country. Table 1 shows that herd sizes in Norway are typically much smaller than the other countries, which is due to the topography of the land. Herd sizes in the United Kingdom tend to be larger than the other countries.

In Norway, tiestall housing is common (Hansen et al., 2022). All cows in Sweden, and tiestalled cows in Norway, are required by law to have access to outdoors areas during the summer months (van den Pol-van Dasselaar et al., 2020; Karlsson et al., 2023). The winter housing period depends on how north the farm is located. Pasture-based dairy production is dominant in Ireland and the United Kingdom (March et al., 2014; Kelly et al., 2020). However, some farms in the United Kingdom house cows 24 h/day (March et al., 2014). In Belgium and the Netherlands, the situation is more variable, with an estimated 30% to 95% and 65% to 85% of cows having access to grazing, respectively (van den Pol-van Dasselaar et al., 2020). Cubicle housing is common in the Netherlands (EFSA Panel on AHAW et al., 2023).

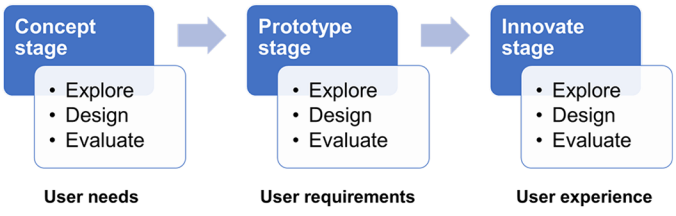

Figure 1. FormIT Living Lab stages.

Table 1. Average dairy herd sizes in the 6 European countries where focus groups were conducted; average herd size is measured as the number of dairy cows

Country	Dairy farms (n)	Average herd size	Data collection year	Reference
Belgium (Flanders)	4,991	69	2020	BCZ (2022)
Ireland	15,973	103	2022	O'Brien (2022)
Netherlands	14,046	113	2022	CHSS (2022)
Norway	6,655	31	2022	Norwegian Agricultural Agency (2022); TINE (2022)
Sweden	2,895	106	2022	Swedish Board of Agriculture (2022)
United Kingdom	11,900	160	2018 (number of farms) 2021 (herd size)	Uberoi (2021); AHDB (2022)

Study Design

We used focus groups as the data collection method for this study because we wanted to understand a wide range of perspectives and experiences with technologies and farm management (Braun and Clarke, 2013). Focus groups allow the participants to interact with each other by sharing and comparing their views and experiences, which can reveal more than individual interviews (Morgan, 1997). We conducted the research within a critical realist paradigm. This acknowledges that people's perceptions of reality are socially constructed, but reality exists independently of human activity (Braun and Clarke, 2021a). In other words, the focus groups provide us with the farmers' perceptions of their reality, and biological, social, and material structures will help to shape these perspectives.

Ethics Approval

The study was approved by the ETH Zurich Ethics Committee (application: EK 2021-N-224). Participants provided written, informed consent by completing a form.

Researcher Characteristics and Reflexivity

Author CD was involved in the study conceptualization, project management, conducting focus groups in the United Kingdom, analyzing the data, and writing the draft of the paper. She is female, has a PhD in veterinary epidemiology, and is a research fellow. She has an understanding of livestock farming from her PhD work and is experienced in qualitative research. She is British and does not have experience with farming in other countries. Therefore, it was important to have discussions with other authors who have experience with dairy farming in other European countries when developing the study and analyzing the data.

Author JK was involved in the study conceptualization, project management, supervision, and reviewing and editing the paper. She is a senior researcher at a British university and is a qualified veterinarian with a PhD in veterinary epidemiology. She has research experience with farmers in the United Kingdom and is experienced in qualitative research.

The researcher characteristics of other authors are presented in the Appendix.

Sampling Approach

The aim of our sampling approach was to obtain a diverse sample of participants to capture a range of views, and therefore we did not enforce an eligibility criterion other than working on a dairy farm. Table 2 shows the approaches to recruit participants to focus groups in the 6 countries. Most countries used a convenience sampling approach, which means recruiting based on accessibility and availability to the researcher. In Ireland, snowball sampling was also used, where new participants were recruited by previous participants. In Norway, a stratified random sampling approach was used, where farmers were contacted based on region and herd size. There were differences in the way that farmers were compensated for their time, and this was dependent on the normal compensation standards of each institution in each country.

We used a pragmatic approach and the concept of information power to guide our sample size (Malterud et al., 2016). Information power is an approach to determining sample size which is more theoretically coherent with thematic analyses than the more commonly used data saturation concept (Braun and Clarke, 2021b). Based on our study aim, data collection method, analysis method, previous experiences, and the diversity of the sample, we anticipated that we would need 2 to 4 focus groups per country. For example, we decided that we needed to have more than one focus group for each country to ensure we captured a diversity of experiences from each country. However, we also needed to consider that the analysis would not be able to reach sufficient depth if the sample was too large. When assessing the transcripts, we judged that the focus groups provided rich information because the farmers appeared to feel comfortable discussing both positive and negative experiences of data and technology use, perhaps because technology use is not an accepted

Table 2. Recruitment approaches for the dairy farmer focus groups in the 6 European countries for a study on farmers' needs for technologies to improve herd health performed in 2022

Country	Recruitment approach
Belgium	Convenience sampling. Participants were recruited by flyers, researcher networks, calls, and mailing lists. Farmers were reimbursed with a calf blanket. The researchers had no prior relationship with the participants.
Ireland	Convenience and snowball sampling. Participants were recruited through professional networks within Animal Health Ireland and then asked to refer their peers. The researchers involved in this study had no prior relationship with participants.
Netherlands	Convenience sampling. Participants were recruited through researcher networks, although the researchers had no prior relationship with participants themselves. The participants received a €50 gift voucher as compensation for the time they spent in the focus groups.
Norway	Stratified random sampling, taking into consideration herd size and Norway's regions. Participants were initially contacted by email and then by telephone. The researchers had no prior relationship with the participants.
Sweden	Convenience sampling. Participants were recruited through researcher networks. A total of 18 cattle farmers were contacted by telephone, and 6 alternative dates and time points for participation were suggested. Only one farmer declined. The participants were offered 700 Sk (US$65) compensation for the time they spent in the focus groups.
United Kingdom	Convenience sampling. Participants were recruited online through advertisements on social media, researcher networks, and mailing lists. Farmers were reimbursed with a £40 (US$50) Amazon voucher for their time, apart from the first focus group. The researchers had no prior relationship with the participants.

norm on dairy farms (Doidge et al., 2023b). Our final sample included 18 focus groups with 80 farmers (Table 3). We believed that this sample had sufficient information power to answer the research question.

Data Collection

The focus groups were conducted online using Microsoft Teams and lasted approximately 90 min. A topic guide was used to guide the discussion on the subjects of data and technology use and disease management in youngstock. Because we wanted to collect information on farmers' needs using a Living Lab approach, the guide was informed by the theoretical streams of NeedFinding and Appreciative Inquiry (Patnaik and Becker, 1999). Therefore, farmers were also asked about their goals for the future of their farm and positive aspects of what currently works well on their farm (Bergvall-Kåreborn and Ståhlbröst, 2009). The discussion guide is available in the Appendix. The focus groups were conducted in Flemish, Dutch, Norwegian, Swedish, or English language. Information about the dates and authors involved in focus group data collection is presented in Table 4.

All focus groups were audio-recorded, and most were also video-recorded. The recordings were transcribed verbatim. Because the researcher conducting the analysis (CD) could only understand the English language, focus groups that were conducted in Flemish, Dutch, Norwegian, and Swedish were translated into English by a translation company. All the translations were reviewed by a second translator. The focus group transcripts were read by CD, and any unclear wording was checked by the authors who conducted the focus groups.

Table 3. Number of focus groups and participants for each country

Country	Focus group	Participants (n)	Herd size range (cows)
Belgium	1	5	56–170
	2	4	
Ireland	1	5	74–216
	2	5	
	3	4	
Netherlands	1	6	40–125
	2	3	
Norway	1	5	20–96
	2	2	
	3	6	
	4	2	
Sweden	1	4	95–470
	2	5	
	3	5	
United Kingdom	1	5	50–1,000
	2	5	
	3	3	
	4	6	

Data Analysis

Template analysis was chosen to analyze the focus group transcripts because it is a method that can comfortably handle larger qualitative samples and permits the use of priori a themes (Brooks et al., 2015). This allowed us to apply the design-centered needs typology to the data from the focus groups. The coding process was supported by the use of NVivo (NVivo qualitative data analysis software version 12, QSR International Pty Ltd.). First, CD familiarized herself with the transcripts by reading them. Next, preliminary coding was conducted using an initial coding template, which is available in the Appendix. This included coding to priori top-level themes and second-level themes, which were derived from the needs and subneeds of the design-centered needs typology (Appendix Table A1; Desmet and Fokkinga, 2020). Narrower codes were also developed, which represented a third level. A coding template was developed, and during a further round of coding, the template was modified. For example, where information from the focus groups did not adequately fit into existing codes, new codes and

Table 4. Information about focus group data collection in 6 European countries in a study on farmers' needs for technologies to improve herd health performed in 2022

Country	Moderators and assistant	Focus groups date
Belgium	J. Bokma, B. Pardon	Aug. 2022–Sep. 2022
Ireland	A. Burrell, N. Meunier, M. Guelbenzu-Gonzalo	Aug. 2022
Netherlands	A. Veldhuis, I. Santman-Berends	Sep. 2022
Norway	L. M. Ånestad, P. Hopp	Sep. 2022
Sweden	J. Frössling, A. Ordell	Mar. 2022
United Kindgom	C. Doidge, L. Palczynski	Dec. 2021–Jun. 2022

subthemes were developed and included in the template. The a priori themes were removed from the template if they appeared redundant. The themes of community and relatedness were merged as codes overlapped. The transcripts were coded with the new version of the coding template, which was deemed to adequately reflect the information in the focus group data. The final template included 6 top-level themes and 19 second-level themes. The template was discussed with the authors who conducted the focus groups in each country. The farmers' quotes in the results section are represented by an identifier that provided information on respondent number, focus group number, and country. For example, respondent (**RES**) 1 in focus group (**FG**) 1 in Belgium would be represented as RES1, FG1, Belgium.

RESULTS

The final template with the 6 themes generated from the analysis is presented in Figure 2. The themes represented the psychological needs of autonomy, comfort, competence, community and relatedness, purpose, and security.

Autonomy: Acting in Their Own Interests

This theme reflects farmers' psychological need to be in control of their actions and being able to make choices that are not determined by others. It includes the subthemes of "data ownership," "ability to make decisions," and "self-reliance."

Data Ownership. First, farmers wanted to have the ability to control how their data were used by others. Farmers mentioned that they were reluctant to share data because they did not know who would be using the data. They were particularly concerned that data could be used to the detriment of farmers. This was most common in the Irish and UK focus groups:

> *It's not entirely clear who has access to this information and who should have it. There's a bit of a question mark, maybe over who does actually look at this information… and there could be someone analyzing it from afar that maybe shouldn't be.* (RES2, FG2, Ireland)

In contrast, a farmer from Ireland mentioned that he felt comfortable sharing data because he knew he was the data owner:

> *I think one thing that I feel is important and we're very fortunate in Ireland versus the rest of the world when it comes to farmer data, the data is owned by the farmer. I think that's key. We don't want to get into a position where this data gets owned by some sort of military company or something like that.* (RES1, FG1, Ireland)

The following quote demonstrated how some farmers thought that sharing their data should be beneficial for farmers, for example, by generating an income:

> *This data is quite valuable and you are sharing it with companies that they can make improvements to the business from your data and I think, I don't know maybe as farmers instead of somebody else holding onto our data maybe there is a place for farmers to make a bit of profit by sharing results and things.* (RES4, FG1, UK)

In summary, there were conflicting opinions on how comfortable farmers felt about sharing their data. However, there was a mutual desire to be in control of their data.

Ability to Make Decisions. Farmers appreciated technologies that could help them make informed decisions. In general, farmers felt more empowered to make decisions when backed up by evidence. For example, this farmer from Belgium wanted to increase their use of technologies to support their decision-making:

> *I am also a proponent to start using more and more technology or digitization, to be able to extract certain conclusions from that data, as a support for making decisions in a company.* (RES3, FG2, Belgium)

1. **Autonomy – acting in their own interests**
   - 1.1. Data ownership
   - 1.2. Ability to make decisions
   - 1.3. Self-reliance
     - 1.3.1. Not relying on staff
     - 1.3.2. Not relying on technologies
     - 1.3.3. Maintaining control as herd sizes increase
     - 1.3.4. Workload management
2. **Comfort – having an easy, simple life**
   - 2.1. Convenience
     - 2.1.1. Accessibility of information
     - 2.1.2. Easily identify cattle that need attention
     - 2.1.3. Easily record information
     - 2.1.4. Making farm practices more efficient
     - 2.1.5. Integrating different sources
     - 2.1.6. Practicality of technology
     - 2.1.7. Technologies that are intuitive to use
     - 2.1.8. Work flexibly
   - 2.2. Overview and structure
     - 2.2.1. Data overview
     - 2.2.2. People management
     - 2.2.3. Presenting useful outputs
   - 2.3. Peace of mind
     - 2.3.1. Trusting technologies
     - 2.3.2. Reducing stress
   - 2.4. Simplicity
3. **Competence – exercising skills**
   - 3.1. Challenge
   - 3.2. Environmental control
     - 3.2.1. Housing ventilation & air quality
     - 3.2.2. Outdoor is best
     - 3.2.3. Reducing environmental contamination
     - 3.2.4. Housing structure
     - 3.2.5. Stocking density
     - 3.2.6. Dealing with weather & seasonal changes
   - 3.3. Knowledge & understanding
     - 3.3.1. Value of tacit knowledge
     - 3.3.2. Technology produces new knowledge
     - 3.3.3. Technology provides knowledge of illness sooner
     - 3.3.4. Information about unknown issues
   - 3.4. Skill progression
4. **Community & relatedness – having personal connections & social structures**
   - 4.1. Emotional support
   - 4.2. Social harmony
     - 4.2.1. Communicating with other farmers
     - 4.2.2. Communicating with staff
     - 4.2.3. Working with vets
     - 4.2.4. Being in harmony with the public
   - 4.3. To nurture and care for cattle
5. **Purpose – having life with meaning**
   - 5.1. Life goals & direction
   - 5.2. Meaningful activity
6. **Security – feeling safe & minimizing risks**
   - 6.1. Conservation
   - 6.2. Financial security
   - 6.3. Social security

Figure 2. Final template of themes that represent dairy farmers' technology needs.

Similarly, in the following quote, an Irish farmer discussed how technologies help farmers to make a decision:

> *They're all tools to help you in the running of your business every day and to deal with the health from the point of view of cows with an antibiotics, in-drug milk retention, in-drug meals retention. These are all things that are a big aid to a farmer when he's making decisions on a daily basis* (RES3, FG1, Ireland)

It was also important to farmers that they could make some decisions without needing to defer to other people, such as their veterinarian. Guidelines acted as a way to facilitate decision-making on farms:

> *I'm also not so familiar with the exact different diseases in calves… If you could get some sort of template… Some sort of guideline for when you are alone facing a group that has diarrhea for example. That it guides you in a direction on what may have caused it.* (RES3, FG3, Sweden)

Overall, most farmers had positive experiences with technologies aiding their decision-making or believed that adopting technologies could help with their decision-making in the future, especially when they have to make decisions alone.

Self-Reliance. The subtheme of self-reliance reflects farmers' need to depend on their own abilities and resources rather than relying on others. First, farmers felt that they could not always rely on the staff on their farms. One of the reasons for this was because staff may be less skilled in noticing problems on the farm:

> *This is particularly true in our case because we also milk with different milkers. One milker, milks five or six times a week, but also several students milk once or twice a week. They do not see changes in the cows and then it is a very useful tool.* (RES6, FG1, the Netherlands)

Although some of the farmers did not want to rely on staff to manage their farm, they realized that they would not be able to manage the workload on their own. Being able to manage workload was important because it had impacts on animal health:

> *There is the staff issue as well. An employee costs money and at the same time you cannot manage everything by yourself.* (RES2, FG1, Sweden)

Many of the farmers mentioned that they had increased their herd size or were planning on increasing the size in the future, which meant that workload was likely to increase. Technologies were seen to assist farmers with larger numbers of cattle and stay self-reliant:

> *Sensor technology, I think is gradually becoming indispensable. Herds are getting bigger so it's a tool that can assist you very well.* (RES6, FG1, the Netherlands)

Although many farmers thought that technologies could be useful on farms, they did not want to wholly rely on technologies to make decisions on the farm. Farmers mentioned a need for humans to be present for the smooth running of farms:

> *You have to be present, and you need to remain focused. To not relax, thinking that technology will solve it all. This will always be a potential danger.* (RES2, FG3, Norway)

In summary, farmers did not want to rely on staff, but they also had experienced increases in workload they could not manage alone. They thought that technologies could reduce workload but also did not want to fully rely on technologies.

Comfort: Having an Easy, Simple Life

This theme reflects farmers' psychological need for having an easy life, rather than experiencing stress or difficulties. It includes the subthemes of "convenience," "overview and structure," "peace of mind," and "simplicity."

Convenience. The subneed of convenience involves making tasks or activities easy to carry out by reducing the effort or time required to do so. The first aspect of convenience relates to how accessible the data are. First, farmers would like to access information from wherever they are. They did not want to be constrained to a certain place (e.g., computer office) to look at their data:

> *Now, there's apps for all these. These are on my phone. I could be traveling, I could be at a meeting somewhere and I can go back and look at it.* (RES1, FG1, Ireland)

Farmers also mentioned that some information can be difficult to access because of complicated login systems. The following quote shows that having to input a username and password can act as a barrier to using apps:

> *I also think the livestock controller is a bit unwieldy when it comes to logging into it. I end up using it less because you need to get the password sent by SMS. When I am inside the barn, you need to send an SMS and get a code to log in. Then, I end up not doing it, and you just sit there*. (RES3, FG1, Norway)

Farmers valued having accessible information that can be easily shared with others who request the information such as vets or supermarkets. This farmer in the United Kingdom describes how they use their software to provide a supermarket with information:

> *It does mean that when [supermarket] ask me how many lame cows do you have or how many cases of lameness did you have I could really just jump into that and I can get the number very quickly.* (RES1, FG1, UK)

The second aspect of convenience was related to ease of recording data. Many of the farmers struggled with recording data accurately. For example, some farmers found it difficult to manually enter data into computer software:

> *Since my son is gone, I have put nothing like that up in the computer. I write everything in the book. I might actually pay someone to do it because, just the thought of even writing things in the computer, I'm so slow and it would take me months to do it.* (RES1, FG3, Ireland)

Others found it difficult to record information in paper-based records. Furthermore, the following quote shows that paper-based records could easily get lost and were seen as less practical:

> *They [staff] must write it [weights] down and it is not always done, and you cannot track it over time when it is just written on some paper somewhere. It would be nice with some clever way to keep track of the calves' growth.* (RES1, FG2, Sweden)

Technologies that automatically record information, such as digital weigh scales, were seen as an option to improve data recording on farms. They reduced the need for farmers to write information down themselves:

> *So by investing in a new weigh crush we can then track individual animal performance a lot better, it's got Bluetooth connectivity so it's just beaming straight to my phone that I'm speaking to you on now, so nobody has to worry about writing anything down and getting the wrong numbers* (RES5, FG2, UK)

A third aspect of convenience was ways to make farm practices more efficient. Many of the farmers mentioned that they lack time to perform youngstock management practices. In particular, management and care of sick animals took up a lot of farmers' time. Thus, farmers acknowledged a need to reduce the time required for everyday tasks:

Time is the biggest enemy yes, because in itself, providing drink to calves is not a big job. However, if you have calves with diarrhea, then you have to run 4, 5 times to your calf pens. (RES1, FG2, Belgium)

Many of the farmers mentioned that technologies can provide a convenient way of identifying problems with cattle. This meant that farmers did not have to spend so much time looking over their cattl,e and instead focused their attention on checking cattle that have warning signals:

I find that very important and yes, in our farm the cows all have a collar on, with which the heat detection and the activity is measured, but we can also easily pick out cows that are less active. (RES3, FG2, the Netherlands)

Farmers mentioned that data recording could become more efficient if software and data from different sources could be integrated together. For example, some farmers noted that other people, such as vets, were recording data about their farms. In some cases, the farmer did not have access to the data and then must record the data themselves. The following farmer gives the example that they would like veterinarian records to be integrated with their farm system to avoid the duplication of medicine record data:

When I take a bottle or a package of something out of the vets, I don't understand how data can't automatically show up on my end somewhere on some database that it doesn't have to do away with these prescriptions because I think they're just a total nightmare. (RES5, FG2, Ireland)

Some of the farmers suggested that the software that they used took a long time to learn to use and adjust to. They preferred to have technologies that were more intuitive to use to improve efficiency on their farms:

Any management system or technology that you have to switch to always takes a lot of energy and time, so that was unpleasant. (RES3, FG2, the Netherlands)

I feel the challenge is that the more that comes, the longer we must spend to familiarize ourselves with things to be able to analyze and use the new tool. (RES1, FG4, Norway)

The final aspect of convenience was that some technologies did not appear to be practical to use. One example given by a few farmers was calving alert systems that ended up causing injuries to cattle, resulting in extra cow care work:

I struggled to put it on the tail. If it's too loose, it falls off, and if it's too tight, it might affect the tail circulation. I had a case of a too-tight tail leading to an infection. We didn't amputate, but we had to do many rounds of penicillin. Technically, it worked well, but to put it on the tail was very difficult. (RES1, FG2, Norway)

Another example was that computer software often needed internet access, but some areas where cattle were kept did not have this. In summary, farmers expressed the need for several aspects of convenience including accessible information, easy identification of cattle, easy data recording, increased efficiency of farm practices, and intuitive and practical technologies.

Overview and Structure. This subtheme covers the need to format the large amount of information produced on farms in a clear way. Farmers were collecting many different types of data. Therefore, they valued tools that could store information in one place in an organized way:

Like you no longer have a phone, you're walking round with like, if you look back 20 years ago, your mobile phone does more than your computer, doesn't it? I can look at where the cows are going tonight, what the grass is growing, the budgets, the animal health records, whether she's bulling or not, the weights, suppliers, invoices, all from a phone. (RES3, FG3, UK)

Some farmers mentioned that they would forget historical information about their animals. Even if they wrote information down in paper-based records, farmers may not use this information at a later stage because it was not easily accessible. Therefore, farmers also valued having tools that allowed them to look back at individual animals' historical data so that they can improve their decision-making:

Now with the app then, what I find is brilliant is, in particular, you can look up your animal details. If it's a calf, you can look up to see is she 30 d old or 40 d old? Especially if you're thinking about selling, you don't have to be trying to work out, "Sugar, she was born on the 3rd of February, it's the 3rd of March. How many days is she"? It gives you too straight away once you click on the animal. (RES2, FG3, Ireland)

As farmers were collecting vast amounts of information, there was a need to reduce this information into specific

outputs. They found technologies such as computer programs useful if they could sort this information into clear outputs that could be used to make decisions. The following quote shows how the Belgian farmer uses graphs produced by computer software to decide when a cow is in heat:

> *The computer says how much chance there is of a rut, and then you can look at the graphs through the program. If there is only a very small peak, we do nothing. But if you see several peaks one after the other, you can be sure that the cow is in heat*. (RES4, FG1, Belgium)

However, some farmers also mentioned that some technologies did not produce useful outputs. For example, some software generated too many outputs or did not go into the required level of detail.

People employed on farms also create a lot of data. Farmers mentioned a need to have structured routines for staff, especially if they employ large numbers, so that this data can be used appropriately:

> *If you've got 10 members of staff, it can be problematic trying to keep everything all in a central place so that everybody knows what's going on.* (RES5, FG2, UK)

Furthermore, they would like to use this data as a way to get an overview of the work that staff have done. This Swedish farmer describes how they use an app to follow and manage their employees' routines:

> *Then you go in and follow your instructions and do them, and you are almost clocked by when you start your routine. I can go in and see that it was started at eight in the morning and it was finished at nine, and then they can start a new work-task.* (RES2, FG3, Sweden)

This sub*theme* therefore shows how farmers would like to be provided with an overview of their data, presented as useful outputs. They would also like an overview to help with their people management.

Peace of Mind. This subtheme focuses on the different levels of trust farmers have with the technologies they use. Some farmers trusted the technologies that they used. They felt that they could rely on the technology to perform the required task:

> *Here anyway, we have a detection system around the neck and the milking robots, and we can actually trust it blindly*. (RES4, FG1, Belgium)

A few farmers mentioned that technologies can make data collection more objective and reduce mistakes in data recording. Therefore, they thought that electronically recorded data were more reliable than paper-based recorded data:

> *I think it's just that if you connect data electronically, you expect it to be more credible like EID [electronic identification] on calves and weighing them… it's not very subjective*. (RES3, FG3, UK)

However, others expressed having bad experiences with technologies that did not work as expected. For example, some farmers had issues with the sensitivity or specificity of technologies that give them false alerts or inaccurately measured temperatures. These farmers were less likely to trust the outputs of the technology. This is exemplified by the following quote, in which the farmer described how they would be reluctant to use collars on youngstock because of their experience with collars providing too many warnings for their cows:

> *I think you get a lot of warnings maybe, of cows, to look at cows [from collars]. A lot of time you couldn't find anything wrong with them, that you just wouldn't want to be too sensitive to it, and I'd say that's maybe the danger with using them in younger stock at some stage in the future, that you could be running around checking animals left, right, and center.* (RES2, FG2, Ireland)

In summary, some farmers have had positive experiences of technologies and therefore find them trustworthy. In contrast, other farmers have had negative experiences, which resulted in a lack of trust in technology. This can be a barrier to technology adoption.

Simplicity This subtheme focuses on the user experience of technologies. Many of the farmers wanted technologies that were simple and easy to use. It was suggested that the simplicity of entering information into a system had a substantial impact on whether a technology was used or not:

> *I find user friendliness the most important regarding the program you use. If you are unhappy with the system, it's not used, and none of the goals is fulfilled.* (RES1, FG2, Norway)

> *The most important thing is that the app is very simple, in that case, that it is quick to enter that the calf has had diarrhea*. (RES1, FG3, Sweden)

The user interface was an important aspect of the usability of software. A few farmers mentioned software that

they enjoyed using because it were easy to navigate and access different sections:

> *I found with [software] it was very much like using one of my children's toys, everything was bright colors, so it made it easier to navigate*. (RES1, FG1, UK)

Therefore, this subtheme shows that user-friendliness is important for the adoption and continued use of technologies on farms.

Competence: Exercising Skills and Feeling Capable

This theme focuses on farmers' psychological need for competence, which reflects their ability to exercise skills, rather than feeling incompetent. It includes the subthemes of "challenge," "environmental control," "knowledge and understanding," and "skill progression."

Challenge. The subtheme of challenge reflects farmers' need to avoid farming without self-awareness, sometimes called "farm blindness" (Mee, 2020). Farmers suggested that it can become easy to normalize issues on the farm such as mortality and morbidity rates:

> *Sure, you cannot get any better than zero dead calves, for example, or zero diarrhea, or zero pneumonia, but you can still easily think like this: "This is the way it is on my farm, and it's pretty normal." But then it may not be at all common or normal to have 10% diarrhea or 5% dead calves or whatever you are at.* (RES4, FG3, Sweden)

Therefore, farmers suggested ways to become more self-aware of their farming performance. This was by bringing a veterinarian or farm advisor onto the farm to challenge current performance and suggest changes to their practices:

> *It's a new pair of eyes that sees the animals. You might also discover some things you did not notice before, like if their backbone is a little weaker, for example. It's easy to become blinded inside your own barn sometimes. So, therefore, bringing in somebody from the outside who says what's on their mind is valuable.* (RES5, FG3, Norway)

Another way was to take part in benchmarking where farmers could measure their performance against other similar farmers. Thus, farmers felt that they needed to be challenged by veterinarians, advisors, or other farmers to improve their farm.

Environmental Control. The subneed of environmental control was important for farmers, as the majority of them thought that the environment was a key cause of disease in their cattle. However, they often felt they had very little control over the environment. This subneed was particularly relevant for the management of youngstock.

Many of the farmers appeared to have problems with the air quality of their youngstock housing. Some had tried to address the air quality by attempting to improve ventilation, for example by adding mechanical ventilation or changing the barn structure. However, this did not always solve the problems with air quality. Therefore, some farmers suggested technologies to provide surveillance of the youngstock environment so that they could make management changes based on the environmental outputs:

> *We have recently built a new barn for the calves, that was in 2016, and that calf department we can ventilate mechanically, but that is not quite perfect yet, so to speak. It is often, or too humid, or too drafty yes, it is difficult to control and therefore we sometimes have a calf with pneumonia*. (RES3, FG2, the Netherlands)

Many of the farmers had increased their herd size but had not adapted their youngstock housing to account for this change. This led to high stocking densities in barns, which farmers believed contributed toward increased incidences of disease. Therefore, many of the farmers' future goals for their farm were to build housing to reduce stocking density and account for their herd size increasing in the future:

> *The problem is a bit that we have too few calf pens, too little vacancy causing the animals to come into the pens too quickly. That's a problem that we still have to work on a bit… we do notice that because of the abundance in youngstock, that we have a bit more problems then.* (RES3, FG2, Belgium)

Stocking density could also cause hygiene issues on the farms. Farmers were aware that bacteria and viruses could be present in their youngstock housing and that they needed to ensure good hygiene. However, many farmers mentioned that their youngstock housing was always in use and they did not usually have a time where it was empty. Farmers believed this led to the buildup of disease in their housing because they did not have the capacity to thoroughly disinfect surfaces:

> *With calves in particular, like cleaning their sheds out regularly and disinfecting them and trying not to let it build up. It's difficult if you don't have enough storage room for calves.* (RES1, FG3, Ireland)

Farmers also thought that changes in the weather were a major cause of illness in their youngstock which they did not have control over:

> *Respiratory [problems] probably is per change of weather. A lot of the time if the weather turns from maybe swapping about mild weather to cold weather, or drafts in houses* (RES2, FG1, Ireland)

Respiratory and gastrointestinal diseases were more commonly developed in certain seasons. The following quotes show that the most challenging season can be different depending on the farming context and country:

> *We do spring and autumn calving and we get it worse off in the spring calving. So, the weather has been quite weird at the moment. It's gone from really hot, and it will go like freezing cold rain and wind.* (RES2, FG3, UK)

> *Usually in the autumn, or before Christmas there is often also a bad period.* (RES6, FG1, the Netherlands)

It appeared that several farmers believed youngstock performed better when they were kept outside rather than being in barns. These farmers said that they experienced less calf mortality and morbidity. To move to outdoor rearing, farmers have had to adapt their practices, such as housing calves in igloos or hutches. However, some farmers suggested that they could not move to an outdoor system. For example, the temperature of Norwegian winters meant it was not feasible to keep youngstock outdoors:

> *Well, we have some calves outside and some inside. I see a difference between when, for example, something is going on outside; it goes over more smoothly. That climate is different, and that does have its influence.* (RES4, FG1, Belgium)

> *Some have chosen to move the calves outside, but I live in an area where winters tend to get cold, so I don't see this as an option.* (RES2, FG1, Norway)

In summary, many farmers felt a lack of control over their environment for youngstock and wished to have tools that could improve this control. They found it difficult to deal with variable weather conditions and ventilation quality and experienced challenges in relation to stocking density and hygiene measures.

Knowledge and Understanding. Farmers often mentioned using the tacit knowledge they have gained through experience to identify illness in their youngstock. They thought it was important to build and use this experiential knowledge. This appeared especially important in Norwegian and Swedish focus groups, but also came up in most focus groups in the other countries:

> *Yes, you can see this if the next generation or the next person learns from another person. Especially considering the mating and things like that. It's about seeing the signs and seeing their behavior. You don't learn this through observing and pressing the keys of a computer.* (RES1, FG4, Norway)

For example, in the following quote, a Swedish farmer mentions the importance of "having an eye for animals" (*djuröga* in Swedish). This phrase depicts the ability to see and understand how the animals feel and what they need (Doidge et al., 2023a):

> *You can see the disease the day before it is on its way, and it is very important to tackle it. It's about having an eye for animals to learn to see the problem. To be able to catch the problem the day before.* (RES5, FG2, Sweden)

Sometimes farmers mentioned that they encountered unknown issues on their farms which could take a long time to identify the cause. One example was the use of diagnostic tests to identify the causative agent of disease, where it could take weeks to get a result. Therefore, farmers suggested that they would like to have a tool that can find problems on their farm and give farmers knowledge of these problems so that they can act as soon as possible:

> *If you had pneumonia or something developing in calves, there would be some way of helping you to identify that you had a problem even if it was a matter of taking a blood test, or a mucous test, or something to identify what the exact problem is.* (RES1, FG1, Ireland)

Therefore, although farmers valued their tacit knowledge, they also valued technologies that provided them with knowledge that they would otherwise not have:

> *Apart from the cows' activity, it [heat detector] also measures the rumination effect or the rumination intervals. We, farmers, and humans would never discover these things. We cannot maintain an overview.* (RES2, FG3, Norway)

An example of a technology that provided farmers with new knowledge was a colostrum refractometer to test the quality of colostrum. Using the refractometer allowed farmers to understand their colostrum quality based on

a numerical threshold. Farmers used this information to make changes to their management practices to improve colostrum quality and manage the potential consequences of low-quality colostrum if needed:

> *Probably what we find here is the refractometer, just in terms of the colostrum management. God, we've learned so much about colostrum management from using that*. (RES3, FG1, Ireland)

Similarly, many of the farmers mentioned that they would like to have knowledge of sick animals before it is possible to identify the sickness through their own tacit knowledge. A few farmers recollected positive experiences with technologies they used that were able to reveal signs of illness before it was visible to the human eye:

> *Before you see it [illness] yourself, you usually already know, because of that collar and then we just go there, quickly measuring temperatures, quarters, just passing by to see if nothing is wrong.* (RES3, FG2, the Netherlands)

> *There's been three occasions where you've had an animal that outwardly appears fine and we've had the vets out to look at them because it's showing that they're not eating it's diagnosed DAs [displaced abomasum] two or three days before you would even see it on the cow* (RES1, FG1, UK)

Overall, farmers valued their tacit knowledge of understanding when an animal was sick. However, they also valued how technologies could provide them with new knowledge or identify previously unknown issues so that their understanding is enhanced.

Skill Progression. This subtheme focuses on how farmers strive to continuously learn new skills to improve their farm performance. Some examples given by farmers include attending educational courses, watching videos, and asking their veterinarian or advisor. The following quote shows how a Norwegian farmer employed new practices because they attended some educational courses on calf management:

> *During my time as a farmer, I have attended three calf courses. I have learned quite a lot from these. … I attended the last calf course six years ago. After this, I implemented several measures, such as opening the door to improve the air circulation, as well as forming smaller groups and such. I feel these courses have been quite valuable for me.* (RES2, FG1, Norway)

Technologies could help farmers to follow their skill progression. It appeared that farmers enjoyed learning and improving their skills:

> *It's satisfying to see that you are improving. I find this as a motivator. Logging into the cow controller [Norwegian dairy herd recording system] to see that measures have been implemented. It works very well!* (RES3, FG1, Norway)

Technologies could be improved by providing more support and training on how to use them. This would allow more farmers to develop skills in using software and technology:

> *As everyone says, they're [software company] actually getting better in supporting it. They're now doing online videos on YouTube and that to help farmers, will say go through how to put in things.* (RES4, FG3, Ireland)

In summary, this subtheme shows that farmers were motivated to improve their skills and monitor the resulting improvements through technologies. To do so, farmers required training and support facilities.

Community and Relatedness: Having Personal Connections and Social Structures

This theme reflects farmers' psychological need to feel part of social groups and having warm relationships with people and animals they care about. It includes the subthemes of "emotional support," "social harmony," and "to nurture and care."

Emotional Support. Many of the farmers suggested that caring for cows and youngstock can be a stressful experience. Sick animals put farmers under a lot of emotional strain because of the increased physical workload of caring, as well as the mental impacts of seeing animals in pain or distress:

> *It's just soul destroying when something like that happens. It just affects your every thought and it just drains you of energy. It has huge impact on you mentally and physically when something like that happens. The better you can keep at preventing anything happening is just colossal.* (RES1, FG3, Ireland)

The following quote shows how some farmers perceived that the farmers' and animals' wellbeing are connected:

> *If an animal is sick, the farmer is sick too.* (RES4, FG1, the Netherlands)

Farmers indicated that they needed to focus on preventing diseases to avoid these stressful situations. For example, one farmer in the United Kingdom (RES2, FG4) had a goal of "keeping stress to a minimum for people and animals" which he aimed to do by using technologies and data to "highlight stress points." Thus, this subtheme highlights a need for emotional support for farmers, especially during disease outbreaks.

Social Harmony. This subtheme represents how farmers would like to communicate with others to create a shared understanding of their farm and relate to others. For example, some farmers mentioned that it was important to talk to other farmers as it represented an opportunity to learn from other people who have had similar experiences. This provides feelings of relatedness. Farmers in different countries also mentioned that they enjoyed participating in the focus groups because of this:

> *I think the important thing is to get farmers to share their stories, because if you look at farmers, they love going to the discussion groups, they maybe love picking up the paper and reading maybe a testimonial on a farmer that had X, Y, and Z of a problem, and how did he remedy it.* (RES3, FG1, Ireland)

Farmers also suggested that there was a need for communication between farm staff. Some farmers mentioned that they had some communication issues on their farm where staff do not carry out their required tasks:

> *Now we have some communication issues sometimes. If we are maybe two or three people who take turns feeding the calves, then you need to get everyone to write down when a calf does not eat, for example.* (RES3, FG3, Sweden)

A few farmers used apps to communicate with their staff. This appeared to work well, as it allowed staff to know what tasks each person has done and therefore work together in harmony:

> *We just had an app for all the staff who were on the farm, so that jobs being done. We were able to click in, or someone could be told to do something and so then everyone knows that that's done by that person or whatever.* (RES1, FG3, Ireland)

Some of the farmers worked closely with their veterinarian. For example, some had regular discussions or veterinary visits:

> *I'll be quick to make a phone call when I see that it really is necessary, or I first discuss with the vet like, "Look, is it necessary, yes or no"? If it is necessary, she'll stop by, but I'll be quick to call, even if it is just for a telephone talk and to ask advice.* (RES3, FG2, Belgium)

However, a few farmers did not talk to their veterinarian very often. Instead, they only used the veterinarian when there was a health problem on their farm:

> *I do use data, and I do discuss this also with my feed advisor, not with the veterinarian. The vet is for sick cows... I think the vet is too expensive for that.* (RES4, FG1, the Netherlands)

A few farmers noted that technologies could reduce tensions between farmers and members of the public. One example given by farmers in Norway was a technology that provides virtual fencing, so they no longer have to rely on physical fencing and gates to keep livestock enclosed. This resolved the issue where members of the public would leave gates open, which allowed cattle to escape. Some farmers also suggested that they considered consumers' expectations when changing their practices or building new infrastructure on their farm:

> *I think it's [virtual fencing] the future, especially for our general public. Many private fences go out toward the public, and very few know how to do fencing today. Usually, the animals are the ones to go through them*. (RES2, FG2, Norway)

Overall, this subtheme highlights that farmers wanted to be in social harmony with their workers, the public, and sometimes their veterinarian. They also liked to have feelings of relatedness by communicating with other farmers. Communication technologies helped farmers to solve practical issues on the farm.

To Nurture and Care. This subtheme focuses on farmers' relationships with their cows and youngstock. Many of the farmers appeared to enjoy working with cattle and felt a personal connection to their animals. They had an altruistic motivation to care for their cows. This included ensuring cattle had the correct nourishment and were clean and healthy. Some farmers suggested that using data-capturing technologies and inspecting their data helped them to feel closer to their animals. For example, the farmer in the following quote mentioned that data "protects" their animals:

> *What I find most with my data is that it really helps protect your cows and your herd really. ...The best part about being a dairy farmer to me is the cows and the cows are basically everything to me and I will do whatever to make sure that they are the number one really.* (RES2, FG3, UK)

Simultaneously, farmers were also motivated to care for their cows through self-interest as this improved their productivity:

> *If you want to raise calves well, they have to have colostrum very quickly, and they have to be clean. You have to give them love and then you get the most beautiful results.* (RES4, FG1, the Netherlands)

Therefore, being able to nurture and care for cows was important for farmers, both for altruistic and self-interested reasons. Technologies and data can help farmers in their caring of their animals.

Purpose: Having a Life With Meaning

This theme focuses on the psychological need of Purpose, which reflects having direction and meaning in life. It includes the subthemes "life goals and direction," and "meaningful activity."

Life Goals and Direction. Many of the farmers had ambitious goals where they would like to improve their farm. Some examples include reducing mortality or morbidity, improving breeding, and improving colostrum quality. There was a suggestion that some tools could be more future-oriented by allowing farmers to submit their goals:

> *The Cow-control [dairy herd recording system that provides analysis reports] is based on history all the time. You should enter your goals, and then you can see how you are doing. You only get the conclusion.* (RES2, FG2, Sweden)

Farmers can use data to provide direction on how to improve the farm and allow progress to be mapped:

> *You can link up from a year to another, or you can compare. We like to do stats, not big stats, but we can just say, "Look, we only had whatever X% mortality compared to the previous year," or whatever. I think it's nice to track, especially when you're trying to improve your business and calf health or cow health. It's really good to make better decisions.* (RES3, FG3, Ireland)

Some farmers mentioned that it was important to highlight what was working well on the farm, as this provides a positive motivation. Often, data outputs focused on negative aspects and problems:

> *I think looking at it from positivity, if you add it in there really that it's actually to confirm that some of the changes you've made work. Most of what you got in there are negatives. Actually, some of the data used is to confirm that you've done the right thing rather than being a negative.* (RES2, FG4, UK)

This subtheme therefore shows that farmers would like technologies that provide a more goal-oriented approach, which also highlight positive situations on the farm.

Meaningful Activity. Many farmers thought that data collection can be a meaningless activity with no benefit to them. Data were often collected but not used for management decisions. There was a need to turn data into meaningful information with actionable insights:

> *I feel that half of the data we collect ourselves is useful. The rest of it I need to utilize when I insert it into KSL [Kvalitetssystem I Landbruket (a centralized database for quality assessment of agricultural data)]. I feel that a lot of the data registered here is completely meaningless, considering its value and the actual management.* (RES5, FG1, Norway)

> *There is no point in collecting a lot of data if you don't know what to do with it, without any action plan.* (RES2, FG2, Sweden)

Some farmers also struggled to collect data. The farmers needed some kind of motivation to collect data and make decisions. For example, the following farmer was motivated by preventing diseases in their animals:

> *Well, if you have a lot of sick animals, it gets tricky.…Well, you don't want that so if you have that motivation, you'll be better able to work preventively.* (RES4, FG1, the Netherlands)

Therefore, this subtheme highlights that some farmers were not motivated to collect or use their data. To become motivated, they need a way to produce meaningful information from the data.

Security: Feeling Safe and Minimizing Risks

This theme reflects farmers' psychological need to feel safe from harm and minimize uncertainties. It includes the subthemes of "conservation," "financial security," and "social stability."

Conservation. The farmers mentioned 2 aspects of conservation. First, a few farmers talked about performing practices to help with the environmental sustainability of their farm. Some examples include conducting wildlife reports, reducing fertilizer use, learning about regeneration farming, and joining environmental schemes. A few

farmers mentioned how collecting data on environmental aspects could help them to understand how they can become more sustainable:

> *We got a wildlife report done as well this year. That's the other thing that—just to see what species of wildlife were on the farm and just plants and species and a couple of things that maybe we could do to improve basically.* (RES1, FG3, Ireland)

Second, some of the farmers were concerned about antibiotic resistance and therefore aimed to conserve the use of antibiotics. Farmers suggested that it was important to keep accurate data on antibiotic use and animal health to reduce their antibiotic use. Furthermore, some farmers mentioned that they would like their data to be analyzed faster, as they thought this could conserve antibiotic use:

> *We've been using selective dry cow therapy for 10 years. Therefore, I think that we find the usage of antibiotics quite important.* (RES1, FG2, Belgium)

Environmental and antibiotic sustainability were there important for some farmers. Collecting and using data on these issues could help farmers to understand areas where they could improve their sustainability.

Financial Security. The farmers made many financial considerations around technology and management of their cattle. There was a general need to keep animal management practices at low costs, as farmers often have low economic margins:

> *That will probably remain a goal, right, to keep costs as low as possible in all areas.* (RES4, FG2, Belgium)

Farmers also considered the financial impact of disease as illness has long-term consequences on the productivity of cattle. Thus, there was a need to reduce the long-term costs of disease outbreaks:

> *Yes, we find that any effect that a calf seems to get from any type of a disease, it'll have a huge knock-on effect throughout their life. We find that they don't survive in herds long enough to actually start paying back for the cost of actually getting them to that point.* (RES4, FG3, Ireland)

Finally, farmers also needed to consider the costs of investing in technologies. Some farmers suggested that it can be difficult to see the return in investment as this usually is not calculated. This was especially true for youngstock as productivity losses or gains as a result of youngstock management practices may only be apparent when they become adult cattle:

> *It [disease prevention] remains a cost item and you always see it, but you don't see the yield. Yes, you can see them, but you can't calculate them on paper.* (RES6, FG1, the Netherlands)

Overall, financial security was important for farmers because of their low economic margins. Thus, they needed to consider the long-term impact of diseases and the value of technologies.

Social Stability. The subtheme of social stability relates to the predictability, reliability, and cohesion of society. One social aspect of dairy farming which was not reliable was employment on farms. Some farmers mentioned that it can be difficult to find people to work on their farm. This was particularly the case for farmers from Ireland, Sweden, and the United Kingdom. Data-driven technologies, such as early warning systems, were seen as a way of alleviating some of the labor issues:

> *I presume we want to try and find ways of identifying and eliminating them [diseases] at farm level, because labor is becoming a major issue or has become a major issue on Irish farms, so we need to be in a position that we can avoid these problems.* (RES1, FG1, Ireland)

Sometimes farmers and service providers did not work cohesively together because of different ways of working or understanding. The following quote shows a conflict between the farmer and artificial insemination service provider. The service provider preferred a certain metric, but the farmer thought that this metric did not suit his farming system, so they changed service providers. Thus, farmers want to work with people who have cohesive values, and this can affect which technologies they choose to adopt and use:

> *The farm owner has spent her life breeding these animals in these families and then we're starting to move toward what [genetics company] wanted, they wanted the smaller grazing type animals, yes that's great for the right system but for my system that isn't what we want, that's not the cow we wanted.* (RES1, FG1, UK)

In summary, the 2 issues affecting farmers' social stability were the availability of labor, which was a driver for technology adoption, and having conflicting values with service providers, which was a barrier for technology adoption.

DISCUSSION

To the authors' knowledge, this is the first study to use a Living Lab methodology to generate dairy farmers' needs of animal health technologies on farms. The study was novel, as we included (1) farmers' perspectives of youngstock technologies, (2) perspectives of farmers from 6 European countries, and (3) farmers' perspectives before the development of technologies. The findings illustrate that farmers expressed a desire for tools that fulfill the psychological needs of autonomy, competence, comfort, community and relatedness, purpose, and security. Farmers liked to use technologies to help them manage workload and labor, and to provide direction for their decision-making. Issues with data sharing and accessibility, and usability of software were barriers to technology use. For youngstock, there was scope for technologies to improve farmers' control of their farm environment. The study also highlighted that Living Lab methodologies may be useful for achieving Responsible Innovation. These aspects are discussed further in the following sections.

Having Direction

We show that setting goals and mapping progress against these goals is important for farmers, which represents the psychological need for purpose. Goal setting is a key part of multiple behavior change theories such as Control Theory and Goal-Setting Theory (Webb et al., 2010) and is also a type of behavior change technique (Marques et al., 2023). People use goals to undergo self-regulation to reduce discrepancies between actual behavior and target behavior. For goals to be influential, they need to be specific and of the appropriate difficulty (Locke et al., 1981). Farmers may currently lack the opportunity to set formal goals for their farms (Derks et al., 2012), and veterinarians are often not aware of farmers' goals (Shortall et al., 2016; Sumner et al., 2018). The use of software which allows farmers to set goals may increase veterinarians' awareness of farmers' goals and allow them to provide tailored advice to achieve those goals.

Another way in which technologies provided farmers with direction was by identifying areas that need attention on the farm. Farmers felt that technologies could help them to make more informed decisions, which may facilitate the prioritization of tasks for management and care of youngstock and other cattle. Similarly, helping with on-farm decision-making has been shown to be a key reason for adoption of smartphone apps by dairy farmers in Australia (Schulz et al., 2022). To aid decision-making, technologies need to provide farmers with necessary outputs. However, our study suggests that there is scope to improve outputs to make them more relevant to farmers' needs. Similarly, a study of German farmers indicated that existing farm management information systems do not provide solutions to farmers' needs (Schulze Schwering et al., 2022). During the technology development process, researchers should work with farmers to ensure that the outputs produced are useful and relevant to their decision-making activities.

Managing Labor Issues

We also show that farmers expressed a desire to have tools and technologies that allow them to be less reliant on other people, which represents the need for autonomy. Increases in herd sizes mean that farmers can no longer rely on family labor alone, yet the availability of rural local labor in Europe has eroded over recent years (Rye and Scott, 2018). This has led to uncertainty in the availability of a workforce on farms and a lack of social stability. Therefore, the need for autonomy is linked to the need for security.

In particular, there is a need for a more sustainable workload on dairy farms. Calf care is the second most labor intensive task on dairy farms after milking (Hogan et al., 2022). Farmers in our study suggested that technologies can help with this by enabling greater flexibility in working hours, making some management practices and decisions more efficient, and monitoring the impacts of their decisions. Farms that have adopted technology have been shown to be more labor efficient (Hogan et al., 2023b). However, previous research also suggests that technologies such as automatic feeding systems may require greater labor input (Gleeson et al., 2008). Therefore, the time-saving abilities of technologies should not be assumed and need to be investigated further to provide farmers with this evidence.

Farmers in our study indicated that better work organization required methods to facilitate communication with, and management of, their staff. Indeed, a study investigating time use on Irish dairy farms suggested that farmers with effective work organization have shorter working weeks due to the structure and standardization of the working days (Hogan et al., 2023a). Technologies can play an important role in creating routines, delegation, and standardization of tasks on farms (Doidge et al., 2023a). Thus, incorporating methods of communication and collaboration between staff members into technologies may satisfy the subneeds of social harmony and overview and structure. Some examples of achieving social harmony in farm technologies is the inclusion of chatroom-style messaging to provide extra clarification and color-coding to help prevent language barriers (Doidge et al., 2023a).

Environment Is Key for Youngstock

Our results suggest that the environment was a key concern in relation to youngstock management. At present, many farmers felt that they had little control over air quality, the amount of wind in the stable, and temperature changes. This had an impact on their perceived capabilities to control disease and thus harmed the psychological need for competence. The presence of drafts in pens is a risk factor for respiratory diseases in calves (Lundborg et al., 2005). Furthermore, environmental factors such as weather can be a source of stress for farmers (Brennan et al., 2022). Consequently, many farmers' goals for the future of their farm were related to improving housing. Similarly, a survey of cattle farmers in the United Kingdom showed that housing, stocking density, and facilities were the top areas for desired improvement (Baxter-Smith and Simpson, 2020).

The farmers' concerns around the control of the environment tended to focus on their youngstock rather than adult cattle. This may be because of the marginal status of calves, where investing in the housing of the milking herd is usually prioritized over that of youngstock (Palczynski et al., 2021). Therefore, we were able to identify a specific need for this age group, which highlights the importance of including farmers' perspectives of youngstock technologies in the analysis.

Although technologies are available to help improve and monitor the youngstock housing environment, they are not routinely adopted on farms. For example, the majority of surveyed UK dairy farmers did not measure the environmental temperature of calf housing or use mechanical ventilation (Mahendran et al., 2022). Designing the optimal youngstock housing is complicated because farmers need to consider several factors including size and capacity of the barn, natural ventilation, group sizes, resting surfaces, and feed and water access (Nordlund and Halbach, 2019). There is scope for the development of technologies to aid farmers with decision-making around changes to their youngstock environment.

User Experience

The identified psychological need of comfort highlights the importance of understanding and improving user experience when developing farming innovations. User experience is the way users interact with and experience a product or service. This includes the aesthetic experience, emotional experience, and usability (Hassenzahl and Tractinsky, 2006). The farmers in our study stressed the need for simplicity when navigating apps or computer programs. Similarly, Michels et al. (2019) show that perceived ease of use was associated with the intention to use smartphone apps for herd management, suggesting that app interfaces need to be as simple as possible. Ease of use can be investigated through usability testing such as task completion or think aloud studies (Maramba et al., 2019). This would help to resolve current barriers to using technologies, such as issues with accessibility and practicality in the field.

The emotional experience when interacting with technologies should also be investigated. Although technologies can improve farmers' quality of life by allowing greater work flexibility (Kenny and Regan, 2021), alerts that provide knowledge of problems on the farm could be a source of stress, which may harm the subneed of emotional support. Instead, technologies can be developed to elicit positive and reduce negative emotional states by providing empathetic and positive messages (Howick et al., 2018). Peoples' actions are connected to their values, desires, and needs. Therefore, there is a relationship between fulfillment of psychological needs such as security, autonomy, and competence, and positive affect (Hassenzahl et al., 2010). One example in this study was that farmers enjoyed communicating with other farmers, as it provides a relatedness experience. Farmers are likely to have a positive emotional experience with a technology if they feel it fulfills their needs.

Data Sharing and Accessibility

Our findings show that farmers had concerns about the ownership of their data, which can act as a barrier to sharing and using data. Issues with data sharing, such as a lack of transparency around what farm data are used for, lack of benefits, and potential negative consequences, have been identified in previous studies (Jakku et al., 2019; Kenny and Regan, 2021; Brown et al., 2022). Our work builds on this by highlighting that the perceived lack of data ownership harms the psychological need for autonomy. Farmers' willingness to share data depends on the type of data being shared, what is done with the shared data, and with whom the data are being shared (Zhang et al., 2021; Brown et al., 2022). Thus, clear messaging is needed about how farmers' data will be used and whom when designing technologies that use or produce data.

Implications for Innovation Design

Our study was part of the explore phase of the concept stage of a Living Lab, which aimed to explore and understand users' needs. This method provided a way of achieving the Responsible Innovation goals of anticipation, inclusion, reflexivity, and responsiveness. We suggest that innovators can be more responsive to dairy farmers' needs by considering the fundamental psychological needs of autonomy, comfort, competence, community and relatedness, purpose, and security when

developing tools and technologies. Desmet and Fokkinga (2020) recommend that innovators should consider how their tool can (1) strengthen current needs, (2) introduce new needs, and (3) reduce harmed needs. For example, a data management tool may help farmers to achieve some aspects of comfort by providing overview and structure of their data. However, the tool may not have a simple interface, and thus the simplicity could be strengthened through redesigning the interface. An example of introducing new needs into a tool could be incorporating a chat box into the data management tool to introduce the need for social harmony.

Considering harmed needs and how to reduce them is connected with the anticipation dimension of the Responsible Innovation framework because developers have to anticipate the potential negative consequences of their technology (Rose and Chilvers, 2018). An example of a harmed need is that some technologies do not provide farmers with clear messages around the ownership of their data and how they are used, which can have a negative impact on the need for autonomy. This harmed need can be reduced through being transparent about data use and sharing. Thus, we can consider the needs to increase the positive impact and reduce the negative impact of technologies.

By including farmers in the initial stages of technology development, we can design tools that fit with farmers' motivations and values, rather than using researchers' own assumptions and motivations. The researchers involved in the DECIDE project have already started reflecting on the results of the focus groups. For example, they have decided to not progress with one of their initial ideas for a calf rearing tool in Ireland due to farmers' need for autonomy and the concerns they raised about sharing sensitive data. Instead, they concluded that leveraging existing data sources and current information flow in the national Irish Cattle Breeding Federation database (Ballincollig, Ireland; https://www.icbf.com/) and dashboards, which farmers currently have access to, are familiar with, and find acceptable, has the potential for further development with end-users' input.

The next stage of tool development would be to get researchers or developers of the technology to reflect on farmers' needs. To sensitize their tool or technology to the needs of farmers, developers can use a needs empathy map that includes the 6 fundamental psychological needs identified in our study. A needs empathy map is a template that includes a persona (i.e., an archetypical user), questions about how the person thinks and feels, and a section on the relevance of the psychological needs to the persona (Krueger, 2022). Using personas allows tools to be designed to match the needs of heterogeneous groups (Pollmann et al., 2022). Thus, the next steps could be to develop personas of typical users of the intended tool so that needs can be mapped for different types of farmers. This would ensure that technologies are designed with the intended users and their corresponding needs in mind.

We recommend that researchers who are aiming to develop innovations responsibly could work with farmers to understand their needs by using a Living Lab approach. In particular, we suggest that information is collected on farmers' experiences, values, and desires before innovation development by including questions about farmers' future goals and what is currently working well on the farm. We also recommend that the design-centered needs typology is a useful tool for identifying user needs from the information that has been gathered. The needs typology provided a shared language for researchers (Huang and Desmet, 2023), which meant that researchers developed a common understanding of what farmers' needs were. This is important for communication and collaboration between interdisciplinary teams.

Study Reflections

The focus groups were held online, which may restrict farmers who are less knowledgeable about technologies from taking part in the study, thereby affecting our study sample. Each focus group had between 2 and 6 participants, which may be a smaller group size than usual. However, we felt that the smaller group sizes allowed the participants to provide rich descriptions of their experiences and opinions while still being able to have group interaction where they shared and compared with others (Morgan, 1997, 2016).

Our study aimed to inform the development of tools for farmers, and many of the authors are involved in the development of these tools. Therefore, this study adopted a pro-innovation perspective, where we believed technologies could provide solutions to problems on the farms. Many problems on farms are highly complex social, political, and ethical issues (Doidge et al., 2023a), and the notion that these can be solved by technological innovations may be too simplistic (Guthman and Butler, 2023). However, farmers do sometimes use technologies to alleviate complex problems. For example, in our previous study, which employed a more critical perspective of technologies, we showed that farmers in Sweden used technologies as a contingency for when they lack skilled farm workers or to aid communication where language barriers exist between workers (Doidge et al., 2023a). Thus, these technologies helped farmers to achieve the needs of social stability (security) and social harmony (community and relatedness). We do not suggest that technologies will solve all of the needs mentioned in this study. Instead, we suggest that these needs are kept in mind when attempting to develop technologies for dairy farms.

This study aimed to understand farmers' needs for technologies. Therefore, we did not specifically investigate factors that influence farmers' decision-making for adoption of technologies. Several studies have shown that farmers' decision-making is influenced by the individual farm context, such as the husbandry system (Groher et al., 2020) and herd size (Gargiulo et al., 2018), as well as farmer characteristics such as age (Drewry et al., 2019) and lack of knowledge (Martínez-García et al., 2015).

CONCLUSIONS

We analyzed data from focus groups from 6 countries to understand dairy farmers' needs for farm technologies for adult cows and youngstock. Farmers expressed needs of autonomy, comfort, competence, community and relatedness, purpose, and security. Issues around data sharing and the accessibility of information need to be considered during technology development. Help with social problems such as workload, labor efficiency, and communication were key areas where technologies could facilitate need fulfillment. Ability to control the environment was a particularly important issue in relation to youngstock. Furthermore, farmers would like technologies that provide them with direction such as goal setting and identifying areas that need attention. We suggest that our Living Lab approach helps to achieve Responsible Innovation goals by including farmers at the beginning of the innovation process, and allowing researchers to be responsive to farmers' needs, anticipate potential harmed needs, and begin to be reflexive about their own assumptions.

NOTES

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement no. 101000494 (DECIDE). We thank Alice E. O. Smith (University of Nottingham, Nottingham, United Kingdom), Tanja Knific (University of Ljubljana, Ljubljana, Slovenia), Wouter van Mol (Ghent University, Merelbeke, Belgium), Jeroen Vermijlen (Rubovet, Ploegsteert, Belgium), Dirk Audenaert (Boerenbond, Leuven, Belgium), and Barbara Beci (Ghent University) for their help with conducting the focus groups. We also thank the farmers who took part in the study. The study was approved by the ETH Zurich Ethics Committee (application: EK 2021-N-224). The authors have not stated any conflicts of interest.

Nonstandard abbreviations used: FG = focus group; RES = respondent.

REFERENCES

Abeni, F., F. Petrera, and A. Galli. 2019. A Survey of Italian Dairy farmers' propensity for precision livestock farming tools. Animals (Basel) 9:202. https://doi.org/10.3390/ani9050202.

AHDB (Agriculture and Horticulture Development Board). 2022. Average size of dairy herd by country. Accessed Jul. 24, 2023. https://ahdb.org.uk/dairy/uk-and-eu-cow-numbers.

Almirall, E., M. Lee, and J. Wareham. 2012. Mapping living labs in the landscape of innovation methodologies. Technol. Innov. Manag. Rev. 2:12–18. https://doi.org/10.22215/timreview/603.

Armstrong, A. J., C. M. Holmes, and D. Henning. 2020. A changing world, again. How Appreciative Inquiry can guide our growth. Soc. Sci. Humanit. Open 2:100038. https://doi.org/10.1016/j.ssaho.2020.100038.

Barrett, H., and D. C. Rose. 2022. Perceptions of the fourth agricultural revolution: What's in, what's out, and what consequences are anticipated? Sociol. Ruralis 62:162–189. https://doi.org/10.1111/soru.12324.

Baxter-Smith, K., and R. Simpson. 2020. Insights into UK farmers' attitudes towards cattle youngstock rearing and disease. Livestock (Lond.) 25:274–281. https://doi.org/10.12968/live.2020.25.6.274.

BCZ (Belgische Confederatie van de Zuivelindustrie). 2022. Jaarverslag 2022. Accessed Jul. 24, 2023. https://www.bcz-cbl.be/nl/feiten-en-cijfers.

Bergvall-Kåreborn, B., C. I. Eriksson, A. Ståhlbröst, and J. Svensson. 2009a. A milieu for innovation: defining living labs. in Proc. ISPIM Innovation Symposium: 06/12/2009–09/12/2009.

Bergvall-Kåreborn, B., M. Hoist, and A. Stahlbrost. 2009b. Concept design with a living lab approach. Pages 1–10 in Proc. 42nd Hawaii International Conference on System Sciences. IEEE.

Bergvall-Kåreborn, B., and A. Ståhlbröst. 2009. Living Lab: An open and citizen-centric approach for innovation. International Journal of Innovation and Regional Development 1:356–370.

Bianchi, M. C., L. Bava, A. Sandrucci, F. M. Tangorra, A. Tamburini, G. Gislon, and M. Zucali. 2022. Diffusion of precision livestock farming technologies in dairy cattle farms. Animal 16:100650. https://doi.org/10.1016/j.animal.2022.100650.

Braun, V., and V. Clarke. 2013. Successful Qualitative Research: A Practical Guide for Beginners. Sage, London, United Kingdom.

Braun, V., and V. Clarke. 2021a. Conceptually locating reflexive thematic analysis. Pages 157–189 in Thematic Analysis: A Practical Guide. A. Maher, ed. SAGE Publications Ltd., London, United Kingdom.

Braun, V., and V. Clarke. 2021b. To saturate or not to saturate? Questioning data saturation as a useful concept for thematic analysis and sample-size rationales. Qual. Res. Sport Exerc. Health 13:201–216. https://doi.org/10.1080/2159676X.2019.1704846.

Brennan, M., T. Hennessy, D. Meredith, and E. Dillon. 2022. Weather, workload and money: determining and evaluating sources of stress for farmers in Ireland. J. Agromedicine 27:132–142. https://doi.org/10.1080/1059924X.2021.1988020.

Britt, J. H., R. A. Cushman, C. D. Dechow, H. Dobson, P. Humblot, M. F. Hutjens, G. A. Jones, P. S. Ruegg, I. M. Sheldon, and J. S. Stevenson. 2018. Invited review: Learning from the future—A vision for dairy farms and cows in 2067. J. Dairy Sci. 101:3722–3741. https://doi.org/10.3168/jds.2017-14025.

Bronson, K. 2019. Looking through a responsible innovation lens at uneven engagements with digital farming. NJAS Wagening. J. Life Sci. 90–91:100294. https://doi.org/10.1016/j.njas.2019.03.001.

Brooks, J., S. McCluskey, E. Turley, and N. King. 2015. The utility of template analysis in qualitative psychology research. Qual. Res. Psychol. 12:202–222. https://doi.org/10.1080/14780887.2014.955224.

Brown, C., Á. Regan, and S. van der Burg. 2022. Farming futures: Perspectives of Irish agricultural stakeholders on data sharing and data governance. Agric. Human Values 40:565–580. https://doi.org/10.1007/s10460-022-10357-8.

Butler, D., and L. Holloway. 2016. Technology and Restructuring the Social Field of Dairy Farming: Hybrid Capitals, 'Stockmanship' and Automatic Milking Systems. Sociol. Ruralis 56:513–530. https://doi.org/10.1111/soru.12103.

CHSS (Cattle Health Surveillance System). 2022. Animal health monitoring 2022. Accessed Jul. 24, 2023. https://www.gddiergezondheid.nl/nl/Diergezondheid/Monitoring.

Checkland, P. 2000. Soft systems methodology: A thirty year retrospective. Syst. Res. Behav. Sci. 17(S1):S11–S58. https://doi.org/10.1002/1099-1743(200011)17:1+<::AID-SRES374>3.0.CO;2-O.

Costa, J. H. C., M. C. Cantor, and H. W. Neave. 2021. Symposium review: Precision technologies for dairy calves and management applications. J. Dairy Sci. 104:1203–1219. https://doi.org/10.3168/jds.2019-17885.

Derks, M., L. M. van de Ven, T. van Werven, W. D. Kremer, and H. Hogeveen. 2012. The perception of veterinary herd health management by Dutch dairy farmers and its current status in the Netherlands: A survey. Prev. Vet. Med. 104:207–215. https://doi.org/10.1016/j.prevetmed.2011.12.019.

Desmet, P., and S. Fokkinga. 2020. Beyond Maslow's pyramid: Introducing a typology of thirteen fundamental needs for human-centered design. Multimodal Technol. Interact. 4:38. https://doi.org/10.3390/mti4030038.

Doidge, C., J. Frössling, F. C. Dórea, A. Ordell, G. Vidal, and J. Kaler. 2023a. Social and ethical implications of data and technology use on farms: A qualitative study of Swedish dairy and pig farmers. Front. Vet. Sci. 10:1171107. https://doi.org/10.3389/fvets.2023.1171107.

Doidge, C., L. Palczynski, X. Zhou, A. Bearth, G. van Schaik, and J. Kaler. 2023b. Exploring the data divide through a social practice lens: A qualitative study of UK cattle farmers. Prev. Vet. Med. 220:106030. https://doi.org/10.1016/j.prevetmed.2023.106030.

Drewry, J. L., J. M. Shutske, D. Trechter, B. D. Luck, and L. Pitman. 2019. Assessment of digital technology adoption and access barriers among crop, dairy and livestock producers in Wisconsin. Comput. Electron. Agric. 165:104960. https://doi.org/10.1016/j.compag.2019.104960.

Eastwood, C., L. Klerkx, M. Ayre, and B. Dela Rue. 2019. Managing socio-ethical challenges in the development of smart farming: from a fragmented to a comprehensive approach for responsible research and innovation. J. Agric. Environ. Ethics 32:741–768. https://doi.org/10.1007/s10806-017-9704-5.

EFSA Panel on AHAW (Animal Health and Animal Welfare); S. S. Nielsen, J. Alvarez, D. J. Bicout, P. Calistri, E. Canali, J. A. Drewe, B. Garin-Bastuji, J. L. Gonzales Rojas, C. Gortázar Schmidt, M. Herskin, V. Michel, M. A. Miranda Chueca, B. Padalino, H. C. Roberts, H. Spoolder, K. Stahl, A. Velarde, A. Viltrop, A. De Boyer des Roches, M. B. Jensen, J. Mee, M. Green, H.-H. Thulke, E. Bailly-Caumette, D. Candiani, E. Lima, Y. Van der Stede, and C. Winckler. 2023. Welfare of dairy cows. EFSA J. 21:e07993. https://doi.org/10.2903/j.efsa.2023.7993.

Enticott, G., K. O'Mahony, O. Shortall, and L.-A. Sutherland. 2022. 'Natural born carers'? Reconstituting gender identity in the labour of calf care. J. Rural Stud. 95:362–372. https://doi.org/10.1016/j.jrurstud.2022.09.034.

Fielke, S., K. Bronson, M. Carolan, C. Eastwood, V. Higgins, E. Jakku, L. Klerkx, R. Nettle, Á. Regan, D. C. Rose, L. C. Townsend, and S. A. Wolf. 2022. A call to expand disciplinary boundaries so that social scientific imagination and practice are central to quests for 'responsible' digital agri-food innovation. Sociol. Ruralis 62:151–161. https://doi.org/10.1111/soru.12376.

Gabriel, A., and M. Gandorfer. 2023. Adoption of digital technologies in agriculture—An inventory in a European small-scale farming region. Precis. Agric. 24:68–91. https://doi.org/10.1007/s11119-022-09931-1.

Gardezi, M., D. T. Adereti, R. Stock, and A. Ogunyiola. 2022. In pursuit of responsible innovation for precision agriculture technologies. J. Responsib. Innov. 9:224–247. https://doi.org/10.1080/23299460.2022.2071668.

Gargiulo, J. I., C. R. Eastwood, S. C. Garcia, and N. A. Lyons. 2018. Dairy farmers with larger herd sizes adopt more precision dairy technologies. J. Dairy Sci. 101:5466–5473. https://doi.org/10.3168/jds.2017-13324.

Gleeson, D., B. O'Brien, and K. O'Donovan. 2008. The labour input associated with calf care on Irish dairy farms. Livest. Sci. 116:82–89. https://doi.org/10.1016/j.livsci.2007.08.019.

Groher, T., K. Heitkämper, and C. Umstätter. 2020. Digital technology adoption in livestock production with a special focus on ruminant farming. Animal 14:2404–2413. https://doi.org/10.1017/S1751731120001391.

Guthman, J., and M. Butler. 2023. Fixing food with a limited menu: On (digital) solutionism in the agri-food tech sector. Agric. Human Values 40:835–848. https://doi.org/10.1007/s10460-023-10416-8.

Hansen, B. G., M. N. Jenssen, and I. M. Larsson. 2022. Loose housing-nothing to lose? Exploring the on-farm profitability, risk and agricultural policy consequences associated with a tie-stall ban on dairy farms. Agric. Food Sci. 31:123–135. https://doi.org/10.23986/afsci.113911.

Hartung, J., T. Banhazi, E. Vranken, and M. Guarino. 2017. European farmers' experiences with precision livestock farming systems. Anim. Front. 7:38–44. https://doi.org/10.2527/af.2017.0107.

Hassenzahl, M., S. Diefenbach, and A. Göritz. 2010. Needs, affect, and interactive products—Facets of user experience. Interact. Comput. 22:353–362. https://doi.org/10.1016/j.intcom.2010.04.002.

Hassenzahl, M., and N. Tractinsky. 2006. User experience—A research agenda. Behav. Inf. Technol. 25:91–97. https://doi.org/10.1080/01449290500330331.

Hennessy, T., and K. Heanue. 2012. Quantifying the effect of discussion group membership on technology adoption and farm profit on dairy farms. J. Agric. Educ. Ext. 18:41–54. https://doi.org/10.1080/1389224X.2012.638784.

Hogan, C., J. Kinsella, M. Beecher, and B. O'Brien. 2023a. The impact of work organisation on the work life of people on pasture-based dairy farms. Animal 17:100686. https://doi.org/10.1016/j.animal.2022.100686.

Hogan, C., J. Kinsella, B. O'Brien, M. Gorman, and M. Beecher. 2022. An examination of labor time-use on spring-calving dairy farms in Ireland. J. Dairy Sci. 105:5836–5848. https://doi.org/10.3168/jds.2022-21935.

Hogan, C., B. O'Brien, J. Kinsella, and M. Beecher. 2023b. Longitudinal measures of labour time-use on pasture-based dairy farms, incorporating the impact of specific facilities and technologies. Animal 17:100747. https://doi.org/10.1016/j.animal.2023.100747.

Howick, J., A. Moscrop, A. Mebius, T. R. Fanshawe, G. Lewith, F. L. Bishop, P. Mistiaen, N. W. Roberts, E. Dieninytė, X.-Y. Hu, P. Aveyard, and I. J. Onakpoya. 2018. Effects of empathic and positive communication in healthcare consultations: A systematic review and meta-analysis. J. R. Soc. Med. 111:240–252. https://doi.org/10.1177/0141076818769477.

Huang, S., and P. Desmet. 2023. Needs matter: A detailed typology of thirteen fundamental needs for human-centered design. In Proc. Creativity, Innovation and Entrepreneurship. AHFE International Conference. AHFE Open Access.

Jakku, E., B. Taylor, A. Fleming, C. Mason, S. Fielke, C. Sounness, and P. Thorburn. 2019. "If they don't tell us what they do with it, why would we trust them?" Trust, transparency and benefit-sharing in Smart Farming. NJAS Wagening. J. Life Sci. 90–91:100285. https://doi.org/10.1016/j.njas.2018.11.002.

Karlsson, J. O., H. Robling, C. Cederberg, R. Spörndly, M. Lindberg, C. Martiin, E. Ardfors, and P. Tidåker. 2023. What can we learn from the past? Tracking sustainability indicators for the Swedish dairy sector over 30 years. Agric. Syst. 212:103779. https://doi.org/10.1016/j.agsy.2023.103779.

Kelly, P., L. Shalloo, M. Wallace, and P. Dillon. 2020. The Irish dairy industry— Recent history and strategy, current state and future challenges. Int. J. Dairy Technol. 73:309–323. https://doi.org/10.1111/1471-0307.12682.

Kenny, U., and Á. Regan. 2021. Co-designing a smartphone app for and with farmers: Empathising with end-users' values and needs. J. Rural Stud. 82:148–160. https://doi.org/10.1016/j.jrurstud.2020.12.009.

Kleen, J. L., and R. Guatteo. 2023. Precision livestock farming: What does it contain and what are the perspectives? Animals (Basel) 13:779. https://doi.org/10.3390/ani13050779.

Krueger, A. E. 2022. Two methods for experience design based on the needs empathy map: Persona with needs and needs persona. Mensch und Computer 2022—Workshopband. https://doi.org/10.18420/muc2022-mci-ws07-425.

Lajoie-O'Malley, A., K. Bronson, S. van der Burg, and L. Klerkx. 2020. The future(s) of digital agriculture and sustainable food systems: An analysis of high-level policy documents. Ecosyst. Serv. 45:101183. https://doi.org/10.1016/j.ecoser.2020.101183.

Locke, E. A., K. N. Shaw, L. M. Saari, and G. P. Latham. 1981. Goal setting and task performance: 1969–1980. Psychol. Bull. 90:125–152. https://doi.org/10.1037/0033-2909.90.1.125.

Lovarelli, D., J. Bacenetti, and M. Guarino. 2020. A review on dairy cattle farming: Is precision livestock farming the compromise for an environmental, economic and social sustainable production? J. Clean. Prod. 262:121409. https://doi.org/10.1016/j.jclepro.2020.121409.

Lundborg, G. K., E. Svensson, and P. Oltenacu. 2005. Herd-level risk factors for infectious diseases in Swedish dairy calves aged 0–90 days. Prev. Vet. Med. 68:123–143. https://doi.org/10.1016/j.prevetmed.2004.11.014.

Lundström, C., and J. Lindblom. 2021. Care in dairy farming with automatic milking systems, identified using an Activity Theory lens. J. Rural Stud. 87:386–403. https://doi.org/10.1016/j.jrurstud.2021.09.006.

Mahendran, S. A., D. C. Wathes, R. E. Booth, and N. Blackie. 2022. A survey of calf management practices and farmer perceptions of calf housing in UK dairy herds. J. Dairy Sci. 105:409–423. https://doi.org/10.3168/jds.2021-20638.

Malterud, K., V. D. Siersma, and A. D. Guassora. 2016. Sample size in qualitative interview studies: Guided by information power. Qual. Health Res. 26:1753–1760. https://doi.org/10.1177/1049732315617444.

Maramba, I., A. Chatterjee, and C. Newman. 2019. Methods of usability testing in the development of eHealth applications: A scoping review. Int. J. Med. Inform. 126:95–104. https://doi.org/10.1016/j.ijmedinf.2019.03.018.

March, M. D., M. Haskell, M. Chagunda, F. Langford, and D. Roberts. 2014. Current trends in British dairy management regimens. J. Dairy Sci. 97:7985–7994. https://doi.org/10.3168/jds.2014-8265.

Marques, M. M., A. J. Wright, E. Corker, M. Johnston, R. West, J. Hastings, L. Zhang, and S. Michie. 2023. The Behaviour Change Technique Ontology: Transforming the Behaviour Change Technique Taxonomy v1. Wellcome Open Res. 8:308. https://doi.org/10.12688/wellcomeopenres.19363.1.

Martínez-García, C. G., S. J. Ugoretz, C. M. Arriaga-Jordán, and M. A. Wattiaux. 2015. Farm, household, and farmer characteristics associated with changes in management practices and technology adoption among dairy smallholders. Trop. Anim. Health Prod. 47:311–316. https://doi.org/10.1007/s11250-014-0720-4.

McDonald, R., K. Heanue, K. Pierce, and B. Horan. 2016. Factors influencing new entrant dairy farmer's decision-making process around technology adoption. J. Agric. Educ. Ext. 22:163–177. https://doi.org/10.1080/1389224X.2015.1026364.

Mee, J. F. 2020. Denormalizing poor dairy youngstock management: Dealing with "farm-blindness". J. Anim. Sci. 98(Suppl. 1):S140–S149. https://doi.org/10.1093/jas/skaa137.

Michels, M., V. Bonke, and O. Musshoff. 2019. Understanding the adoption of smartphone apps in dairy herd management. J. Dairy Sci. 102:9422–9434. https://doi.org/10.3168/jds.2019-16489.

Mohr, S., and J. Höhler. 2023. Media coverage of digitalization in agriculture—An analysis of media content. Technol. Forecast. Soc. Change 187:122238. https://doi.org/10.1016/j.techfore.2022.122238.

Morgan, D. 2016. Are We Too Limited on Group Size? What About 2 or 3 Person "Mini-Groups"? Accessed Jul. 5, 2022. https://researchmethodscommunity.sagepub.com/blog/are-we-too-limited-on-group-size-what-about-2-or-3-person-mini-groups.

Morgan, D. L. 1997. The uses of focus groups. Pages 18–30 in Focus Groups as Qualitative Research. SAGE Publications, Inc., London, United Kingdom.

Nordlund, K. V., and C. E. Halbach. 2019. Calf barn design to optimize health and ease of management. Vet. Clin. North Am. Food Anim. Pract. 35:29–45. https://doi.org/10.1016/j.cvfa.2018.10.002.

Norwegian Agricultural Agency. 2022. Register of production subsidies per 1st October 2022. Accessed Jul. 24, 2023. https://www.ssb.no/en/jord-skog-jakt-og-fiskeri/jordbruk/statistikk/gardsbruk-jordbruksareal-og-husdyr.

O'Brien, B. 2022. Average dairy and suckler herd sizes for 2022 revealed. Accessed Feb. 23, 2023. https://www.agriland.ie/farming-news/average-dairy-and-suckler-herd-sizes-for-2022-revealed/.

O'Brien, B. 2022. Average dairy and suckler herd sizes for 2022 revealed.

Occhiuto, F., J. A. Vázquez-Diosdado, C. Carslake, and J. Kaler. 2022. Personality and predictability in farmed calves using movement and space-use behaviours quantified by ultra-wideband sensors. R. Soc. Open Sci. 9:212019. https://doi.org/10.1098/rsos.212019.

Palczynski, L. J., E. C. Bleach, M. L. Brennan, and P. A. Robinson. 2021. Stakeholder perceptions of disease management for dairy calves: "It's just little things that make such a big difference". Animals (Basel) 11:2829. https://doi.org/10.3390/ani11102829.

Palczynski, L. J., E. C. Bleach, M. L. Brennan, and P. A. Robinson. 2022. Youngstock management as "The key for everything"? Perceived value of calves and the role of calf performance monitoring and advice on dairy farms. Front. Anim. Sci. 3:835317. https://doi.org/10.3389/fanim.2022.835317.

Palma-Molina, P., T. Hennessy, A. H. O'Connor, S. Onakuse, N. O'Leary, B. Moran, and L. Shalloo. 2023. Factors associated with intensity of technology adoption and with the adoption of 4 clusters of precision livestock farming technologies in Irish pasture-based dairy systems. J. Dairy Sci. 106:2498–2509. https://doi.org/10.3168/jds.2021-21503.

Parikoglou, I., G. Emvalomatis, and F. Thorne. 2022. Precision livestock agriculture and productive efficiency: The case of milk recording in Ireland. Agric. Econ. 53(S1):109–120. https://doi.org/10.1111/agec.12729.

Patnaik, D., and R. Becker. 1999. Needfinding: The why and how of uncovering people's needs. Des. Manage. J. 10:37–43. https://doi.org/10.1111/j.1948-7169.1999.tb00250.x (Former Series).

Pollmann, K., D. Janssen, N. Fronemann, M. Velić, P. Bouillé, B. Foucault, and N. Bégoc Bécam. 2022. Identifying and addressing needs of heterogeneous user groups—A case study from the banking sector. Multimodal Technol. and Interact. 6:103. https://doi.org/10.3390/mti6120103.

Rose, D. C., and J. Chilvers. 2018. Agriculture 4.0: Broadening responsible innovation in an era of smart farming. Front. Sustain. Food Syst. 2:87. https://doi.org/10.3389/fsufs.2018.00087.

Rye, J. F., and S. Scott. 2018. International labour migration and food production in rural Europe: A review of the evidence. Sociol. Ruralis 58:928–952. https://doi.org/10.1111/soru.12208.

Schewe, R. L., and D. Stuart. 2015. Diversity in agricultural technology adoption: How are automatic milking systems used and to what end? Agric. Human Values 32:199–213. https://doi.org/10.1007/s10460-014-9542-2.

Schulz, P., J. Prior, L. Kahn, and G. Hinch. 2022. Exploring the role of smartphone apps for livestock farmers: Data management, extension and informed decision making. J. Agric. Educ. Ext. 28:93–114. https://doi.org/10.1080/1389224X.2021.1910524.

Schulze Schwering, D., L. Bergmann, and W. Isabel Sonntag. 2022. How to encourage farmers to digitize? A study on user typologies and motivations of farm management information systems. Comput. Electron. Agric. 199:107133. https://doi.org/10.1016/j.compag.2022.107133.

Shortall, O., A. Ruston, M. Green, M. Brennan, W. Wapenaar, and J. Kaler. 2016. Broken biosecurity? Veterinarians' framing of biosecurity on dairy farms in England. Prev. Vet. Med. 132:20–31. https://doi.org/10.1016/j.prevetmed.2016.06.001.

Silvi, R., L. G. R. Pereira, C. A. V. Paiva, T. R. Tomich, V. A. Teixeira, J. P. Sacramento, R. E. Ferreira, S. G. Coelho, F. S. Machado, M. M. Campos, and J. R. R. Dórea. 2021. Adoption of precision technologies by Brazilian dairy farms: The farmer's perception. Animals (Basel) 11:3488. https://doi.org/10.3390/ani11123488.

Ståhlbröst, A. and M. Holst. 2012. The Living Lab Methodology Handbook.

Sumner, C. L., M. A. von Keyserlingk, and D. M. Weary. 2018. Perspectives of farmers and veterinarians concerning dairy cattle welfare. Anim. Front. 8:8–13. https://doi.org/10.1093/af/vfx006.

Swedish Board of Agriculture. 2022. Farm Animals in June 2022. Statistic Report JO0103. Official Statistics of Sweden. Vol. 2023.
TINE. 2022. Statistikksamling for ku- og geitekontrollen for 2022. Accessed Jul. 24, 2023. https://medlem.tine.no/fag-og-forskning/statistikksamling-for-ku-og-geitekontrollen-for-2022.
Tse, C., H. W. Barkema, T. J. DeVries, J. Rushen, E. Vasseur, and E. A. Pajor. 2018. Producer experience with transitioning to automatic milking: Cow training, challenges, and effect on quality of life. J. Dairy Sci. 101:9599–9607. https://doi.org/10.3168/jds.2018-14662.
Uberoi, E. 2021. UK dairy industry statistics. Vol. 2023. House of Commons Library, London, United Kingdom.
van den Pol-van Dasselaar, A., D. Hennessy, and J. Isselstein. 2020. Grazing of dairy cows in Europe—An in-depth analysis based on the perception of grassland experts. Sustainability (Basel) 12:1098. https://doi.org/10.3390/su12031098.
Van Geenhuizen, M. 2019. Applying an RRI filter in key learning on urban living labs' performance. Sustainability (Basel) 11:3833. https://doi.org/10.3390/su11143833.
van Schaik, G., M. Hostens, C. Faverjon, D. B. Jensen, A. R. Kristensen, P. Ezanno, J. Frössling, F. Dórea, B.-B. Jensen, L. P. Carmo, W. Steeneveld, J. Rushton, W. Gilbert, A. Bearth, M. Siegrist, J. Kaler, J. Ripperger, J. Siehler, S. de Wit, B. Garcia-Morante, J. Segalés, B. Pardon, J. Bokma, and M. Nielen. 2023. The DECIDE project: From surveillance data to decision-support for farmers and veterinarians. Open Res. Eur. 3:82. https://doi.org/10.12688/openreseurope.15988.1.
Webb, T. L., F. F. Sniehotta, and S. Michie. 2010. Using theories of behaviour change to inform interventions for addictive behaviours. Addiction 105:1879–1892. https://doi.org/10.1111/j.1360-0443.2010.03028.x.
Zhang, A., R. Heath, K. McRobert, R. Llewellyn, J. Sanderson, L. Wiseman, and R. Rainbow. 2021. Who will benefit from big data? Farmers' perspective on willingness to share farm data. J. Rural Stud. 88:346–353. https://doi.org/10.1016/j.jrurstud.2021.08.006.

APPENDIX

Researcher Characteristics and Reflexivity

Lise Marie Ånestad (DVM) is a cattle health expert at the Norwegian Veterinary Institute (Ås, Norway). She is a female researcher with experience in cattle health surveillance and clinical experience from working as a cattle practitioner. At present, she is also working on a PhD where she is researching bacterial respiratory pathogens in Norwegian dairy and beef calves.

Alison Burrell (C.Psychol) is a chartered health psychologist with a doctoral-level practitioner qualification in health psychology from the British Psychological Society (Leicester, United Kingdom). At the time of the study, she was employed at Animal Health Ireland (Carrick-on-Shannon, Ireland) as a health psychologist, is female and has experience in conducting qualitative research in human and animal health settings.

Jenny Frössling (DVM, PhD) is a senior epidemiologist at the Swedish Veterinary Institute (Uppsala, Sweden) and associate professor affiliated to the Swedish University of Agricultural Sciences (Skara, Sweden). She is a female researcher with expertise in veterinary epidemiology and animal health surveillance. She has been educated in social science research methodology for use in veterinary epidemiologic research and has been involved in previous focus group studies in Sweden.

Laura Palczynski (PhD) is a livestock project manager at Innovation for Agriculture (Stoneleigh Park, United Kingdom), an independent knowledge exchange organization in the UK. Her interests are in animal welfare, calf rearing and knowledge exchange. She has previous experience in conducting semi-structured interviews and focus groups.

Bart Pardon is male and is a professor in large animal internal medicine from Belgium. He has a PhD in Veterinary Medicine, is a diplomate of the European College for Bovine Health Management (Ghent University, Merelbeke, Belgium), and is a veterinarian (Ghent University).

Jade Bokma is female, has a PhD in veterinary sciences, and is a research fellow at Ghent University (Belgium). She is Dutch, but obtained her master's degree in veterinary medicine (specialization ruminants) at Ghent University (Belgium). Therefore, she has understanding of the Belgian livestock farming system.

Luís Pedro Carmo (DVM, MSc, PhD, Dip.ECVPH) is, at the time of writing, a senior researcher at the Norwegian Veterinary Institute. He is a male researcher with experience in epidemiology, animal health and surveillance. He has also conducted inter- and transdisciplinary research and has an interest in integrated approaches to health.

Petter Hopp (DVM, PhD) is a senior epidemiologist at the Norwegian Veterinary Institute. He is a male researcher with experience in animal health epidemiology with a focus on surveillance.

Maria Guelbenzu-Gonzalo is a veterinarian with a PhD in bovine viral diarrhea control by Queens University, Belfast (Belfast, Ireland). At the time of the study she was employed at Animal Health Ireland as the program manager for the bovine viral diarrhea and infectious bovine rhinotracheitis programs. She is female and has extensive experience in dealing with industry stakeholders and participating in research projects.

Natascha Meunier is a veterinarian with a PhD in epidemiology and is a diplomate of the European College of Veterinary Public Health. At the time of the study, she was employed as a program manager at Animal Health Ireland. She is female and has experience with qualitative research in animal health settings.

Anna Ordell (DVM) is a female veterinarian and PhD-student at the Swedish Veterinary Institute. She has experience from veterinary practice and farm advisory service with focus on calf health and disease management in dairy farms.

Inge Santman (MSc, PhD) is a senior scientist and head of the epidemiology department at Royal GD (Deventer,

the Netherlands). She is a female researcher with wide experience in epidemiological research in cattle, mostly focused on epidemiology, monitoring and surveillance, and preventive animal health.

Gerdien van Schaik (MSc, PhD) is the coordinator of the DECIDE project and is a professor at Utrecht University (Utrecht, the Netherlands) and a senior researcher at Royal GD. She is a female researcher with experience in epidemiology, animal health economics and surveillance.

Discussion Guide

Imagining an ideal future (20 min; asterisks indicate the most important prompts to ask during the focus groups)

Take a moment to think about your ideal future farm and how technology can play a role in cattle health and welfare. Set your imagination free—don't worry about what is possible or not possible in the real world. Using Mentimeter, please write down some end-goals you would like to achieve on your farm, with a particular focus on cattle health and welfare. Please go back to menti.com and type in the code at the top of the screen.

- Please share some of your goals for your future farm.
- Why do you think this goal is important to you?
- How do you think technology and data could help you to achieve your goals?

Technology use (15 min)

Technology could be anything from a farm management software, an automatic milking system, or a thermometer, for example.

- Thinking about your day-to-day practices on-farm, do you use any technologies to help you? If so, please describe
  - How does it affect the decisions you make?
  - Do any technologies help with identifying or controlling diseases?*
  - *Note: If farmers do not use any technologies on their farm, please use the following question:* If not, can you think of any technologies that help you in your everyday life outside of farming?
- Are there available technologies that you think work well on your farm? Why do they work well?
  - *Note: If farmers cannot think of any technologies, probe about farm management software, automatic calf feeders, weighing scales and automatic milking systems (if dairy).*
  - What technologies wouldn't work well on your farm?
  - How do they fit, or not fit, with your farm routine?

Data use (15 min)

We are interested in your views on any types of data collected on your farm—it doesn't have to be related to cattle diseases. The data collect could be related to cattle movements, medicine use, or finances, for example. Data refers to any information you record—it doesn't have to be using software.

- What is your experience of collecting and using data on your farm?
  - What types of data do you collect on your farm?
  - *Probe on: collecting data related to cattle management and disease*, the environment, production.*
  - How do you collect this data? Do you collect any data without the use of technology?
  - How do you utilize the data you collect?*
  - Who do you share the data with?
  - How do they utilize your data?
- Some of the factors that you might value about the data you collect are currently presented on the screen. Which of these values are the most important to you? Please go back onto menti.com and rank them in the order of what is most important to you.
  - *Note: The moderator's assistant should present the ranking slide.*
  - Why is [value] most important to you?
  - Is there anything that you value about data that is missing from this list?

Identifying and experiencing respiratory diseases and scours (15 min)

We would like you to focus on respiratory disease and scours as these are 2 really significant health problems on beef/dairy farms.

- What is your experience of these health problems in your cattle?
  - How often does it occur?
  - Does it happen at a particular time or place?
  - How do you think respiratory diseases/scours impact on (welfare, productivity, time, economic costs), if at all?
- How do you usually identify these health problems in your cattle?
  - At what stage do you first tend to notice any problems?
  - Any tools/technology that could help you?*
  - Does this identification usually happen at a certain time or place?
  - Why do you think these methods work well for you?

    - What role does your vet have in disease identification?
- How has the ways you identify and control these health problems in your cattle changed, if at all?
    - What made you change your practices?*
    - Why do you think your current practice is better?
    - If there have not been any changes: Why do you think your practices have stayed the same?
    - *Note: There is no restriction to timeframe for this question (e.g., farmers can talk about changes that happened last year or 20 years ago)*

Wrap up (5 min)

- What are you taking away from today's discussion?
- Are there any final thoughts that anyone would like to share, before we close today's session?

Coding template

Table A1. Initial coding template of needs (From Desmet and Fokkinga, 2020)

Top-level code	Second-level codes
Autonomy (being the cause of your actions)	Freedom of decision; individuality; creative expression; self-reliance
Beauty (place of elegance, coherence, and harmony)	Unity and order; elegance and finesse; artistic experiences; natural beauty
Comfort (having an easy, simple life)	Peace of mind; convenience; simplicity; overview and structure
Community (being part of a social group)	Social harmony; affiliation and group identity; rooting (tradition, culture); conformity
Competence (exercising skills)	Knowledge and understanding; challenge; environmental control; skill progression
Fitness (strong, healthy, and full of energy)	Nourishment; health; energy and strength; hygiene
Impact (actions/ideas have impact on world)	Influence; contribution; to build something; legacy
Morality (acting in line with values)	Have guiding principles; acting virtuously; a just society; fulfilling duties
Purpose (making life meaningful and valuable)	Life goals and direction; meaningful activity; personal growth; spirituality
Recognition (appreciation for what you do)	Appreciation; respect; status and prestige; popularity
Relatedness (having warm, mutual relationships)	Love and intimacy; camaraderie; to nurture and care; emotional support
Security (feeling safe from harm and threats)	Physical safety; financial security; social stability; conservation
Stimulation (feeling mentally and physically stimulated)	Novelty; variation; play; bodily pleasure