Bridging HRI Theory and Practice
Design Guidelines for Robot Communication in Dairy Farming

Cila, Nazli; González, Irene González; Jacobs, Jan; Rozendaal, Marco

DOI
10.1145/3610977.3634991

Publication date
2024

Document Version
Final published version

Published in
HRI 2024 - Proceedings of the 2024 ACM/IEEE International Conference on Human-Robot Interaction

Bridging HRI Theory and Practice: Design Guidelines for Robot Communication in Dairy Farming

Nazli Cila[†]
Human-Centered Design
Delft University of Technology
Delft, The Netherlands
n.cila@tudelft.nl

Irene González González
Human-Centered Design
Delft University of Technology
Delft, The Netherlands
irene310g@gmail.com

Jan Jacobs
Lely
Maassluis,
The Netherlands
jjacobs@lely.com

Marco Rozendaal
Human-Centered Design
Delft University of Technology
Delft, The Netherlands
m.c.rozendaal@tudelft.nl

ABSTRACT

Using HRI theory to inform robot development is an important, but difficult, endeavor. This paper explores the relationship between HRI theory and HRI practice through a design project on the development of design guidelines for human-robot communication together with a dairy farming robot manufacturer. The design guidelines, a type of intermediate-level knowledge, were intended to enrich the specialized knowledge of the company on farming context with relevant academic knowledge. In this process, we identified that HRI theories were used as a frame, a tool, best practices, and a reference; while the HRI practice provided a context, a reference, and validation for the theories. Our intended contribution is to propose a means to facilitate exchanges both ways between HRI theory and practice and add to the emerging repertoire of designerly ways of producing knowledge in HRI.

CCS CONCEPTS

• Human-centered computing • Interaction design • Interaction design theory, concepts and paradigms

KEYWORDS

Design guidelines, Intermediate-level knowledge, Research-practice gap, Dairy farming, Robot development

ACM Reference format:

Nazli Cila, Irene González González, Jan Jacobs and Marco Rozendaal. 2024. Bridging HRI Theory and Practice: Design Guidelines for Robot Communication in Dairy Farming. In *Proceedings of ACM/IEEE International Conference on Human-Robot Interaction (HRI '24).* March 11-14, 2024, Boulder, CO, USA. ACM, New York, NY, USA. 10 pages. https://doi.org/10.1145/3610977.3634991

HRI'24, March 11-14, 2024, Boulder, CO, USA.

ACM ISBN 979-8-4007-0322-5/24/03.
https://doi.org/10.1145/3610977.3634991

1 INTRODUCTION

Picture a dairy farm. In an open and airy barn, some cows patiently await milking, while others rest in stalls or enjoy silage from feed troughs. A diligent farmer tends to the milking process, and another oversees feeding plans, both ensuring the health and wellbeing of their livestock. They also clean the cow pen, maintain equipment, and keep financial and administrative records of the farm, ensuring that the farm's operations are as efficient as possible.

Amidst growing global food market competition, modern farms handle larger animal herds with reduced staff [58]. The depicted mechanical, administrative, and managerial duties of farmers demand significant time and physical effort, prompting the recent introduction of new actors. In many farms (most of them in Northwestern Europe, while some in North America, Australia, and New Zealand), cows are milked by a milking robot (Figure 1a), while their manure is swept by another robot circulating in cow pens (Figure 1b). Autonomous feeding robots precisely deliver nutrients to different animal groups (Figure 1c) and push feeds back toward the pen to minimize waste and labor (Figure 1d). These robotic entities not only streamline farm operations but also gather real-time data, contributing to enhanced productivity, quality, profitability, sustainability, and the overall well-being of the herd.

To work with such robotic companions, farmers must acquire new knowledge and cultivate managerial skills [12; 60; 83]. Implementation of robots in farms is complex, given the intricate interplay of a robot's social, cyber, and physical dimensions [69]. This complexity introduces potential challenges in daily farm operations, exemplified by instances such as the stress-inducing nature of handling robot alarms [55] and the mental strain associated with managing substantial amounts of farm data [58]. Similarly, the unpredictable movements of manure sweeping robots triggered stress responses in cows [25]. Collaborating with farming robots poses new interaction design challenges regarding trust (ensuring the robot poses no harm to individuals, animals, or equipment and performs accurately and predictably) and intelligibility into the capabilities, limitations, status, intentions, and messages of a robot.

Human-robot collaboration is a burgeoning research field propelled by the integration of robots into diverse contexts for working together with people. Researchers study the factors distinguishing successful human-robot collaborations, constructing frameworks that delineate key interaction qualities (e.g., [6, 14]). These works often emphasize high-level behavioral principles intended for generalization across various contexts and robot types. Therefore, the research insights are not likely to be applied immediately in the real-world situations [87]. Moreover, as highlighted by Matarić [59], Human-Robot Interaction (HRI) research is not consistently driven by practical utility. While academic HRI research may offer conceptual insights into predictability that could help designing the behavior of a robot in a way that cows would understand what it will do next for example, translating these insights into actual robot behavior demands additional effort. The scarcity of research on HRI in the farming context [84] exacerbates this translational challenge.

Figure 1: a) Lely Astronaut, the milking robot; b) Lely Collector, the manure cleaning robot; c) Lely Vector, the feeding robot; d) Lely Juno, the automatic feed pusher (courtesy of Lely)

On the other hand, farming robots are being developed and deployed by companies whose purpose is to ensure these robots operate in the real-world seamlessly [1]. They possess expertise in technology, their robots, and the tasks at hand. However, their view on the farm context and farmers' lived experiences may occasionally lack comprehensiveness. This limitation parallels findings in collaborative robots within the manufacturing domain. Moniz and Krings [61] revealed that companies developing such robots often prioritized the technical and safety aspects, neglecting the social dimensions of human-robot interaction. Similarly, Kopp et al. [49] argued that the companies focused only on technical aspects lacked a clear picture of what determines employees' trust in a robot—a critical aspect of successful implementation.

In summary, a gap appears to exist between the high-level abstract knowledge produced by HRI research and the specific, situated interaction design knowledge utilized by robotics companies. In this paper, we offer a means to bridge this gap in the form of "intermediate-level knowledge" [42]. Our approach involved participatory research at a multinational dairy farming robot manufacturer, resulting in *design guidelines*—an instantiation of intermediate-level knowledge [54]—to enhance the company's specialized knowledge of farming robots and farm context with pertinent academic insights. These guidelines, framed as "code of conduct for human-robot communication", aimed at assisting developers to design communication behaviors for dairy farming robots that are clear, pleasant, and consistent across all robots of the company.

These design guidelines represent a fusion of the dairy farming context's necessities, the values of the company, and relevant theoretical knowledge pertaining to the best practices of human-robot collaboration. This paper outlines the reciprocal exchange between HRI theories and a specific robot development practice, elucidating how this interaction shaped the creation of the guidelines. Our first intended knowledge contribution to the HRI research community lies in presenting a theoretical framework that unravels the intertwined nature of HRI practice and theory. Second, we intend to expand the HRI design epistemology by providing a tangible means for generating intermediate-level knowledge, contributing to the evolving array of designerly approaches for knowledge production in HRI (e.g., [56, 57]).

In the remainder of this paper, we will first review the gap between HRI research and practice, and then contextualize our work within the framework of intermediate-level knowledge. The paper will then expound on the development process of the code of conduct, illustrating how HRI theory and practice converged in this iterative process. Finally, we will conclude by discussing the potential impact of the code and the implications of the design process for broadening the HRI epistemology.

2 BRIDGING HRI THEORY AND PRACTICE

On one facet of HRI work lie the theoretical underpinnings. A *theory* describes how something works by showing its elements in relationship to one another [32]. It often attempts to provide a simple, high-level view while providing detail about the underlying complexity [90]. In the realm of HRI, theories contribute to a foundational understanding about people as they interact with robots, how specific design choices affect interactions with robots, and how novel mechanisms or computational tools can be used to improve interactions [45]. Trafton et al. [81] categorize two pertinent types of theories for HRI: Design theories, which provide some reason to believe that one robot or robot component functions differently than another, and psychological theories, which delve into how human cognition and behavior change under diverse interactions.

On the opposing side of the HRI spectrum lies the realm of robot development *practice*—the professional activities dedicated to conceiving, designing, manufacturing, and testing robots. Roboticists engage in diverse stages of development, from creating software to constructing hardware and troubleshooting the final product. Interaction designers and UX designers anticipate and explore user needs, experiences, behaviors, and cognitive abilities, leveraging these insights to craft robotic artefacts that are useful, usable, and user-friendly. Their design considerations span the robots' operating system, interface, form, configuration, sound, and movement.

Ideally, HRI researchers influence the practice by sharing theories and frameworks, while practitioners provide real-world cases that would inspire new phenomena to study. Gray et al. [38] describe this dynamic relationship through the trickle-down (i.e., the adaptation of theory in practice) and bubble-up effects (i.e., abstracting the knowledge and methods of practice into refined theory and defined methods). In HRI, research to date has been primarily confined to labs, often examining a single human interacting with a single robot [45], without making a real connection with real user populations and environments [59]. Furthermore, research is far removed from the intense attention to detail, reliability, and robustness that characterize deployment of robots in the real-world. These situations pose problems for trickling-down of HRI research into the robot development practice. On the other hand, robot development is also concerned with reliability, cost, and sales, while most of the time working under strict confidentiality requirements of companies or context (e.g., military). It is not always possible to share the internal processes, findings, and procedures with a wider audience. Furthermore, the real world is complex and messy with uncontrolled variables, which sometimes contradicts the neatness and robustness that is required for eliciting theories. These issues pose a problem for bubbling-up of the knowledge from practice to theories in HRI.

Taken altogether, we argue that there exists a need to fortify the connection between HRI research and practice—an issue commonly referred to as the "gap problem". Similar gaps are prevalent in psychology, nursing, human resources, library sciences, management, education, social work, and more (e.g., [7], [13], [20], [68]). Human-Computer Interaction (HCI), a closely related field to HRI, has also been pointing to this gap: It has been repeatedly shown that the theoretical insights from research had been rarely adopted in design practice even though the practitioners acknowledged its value [10; 16; 67]. Fallman and Stolterman [29] attribute this gap to three factors: *relevance* (addressing problems and themes that are important to professionals), *applicability* (being able to utilize results in the form of new knowledge and methods), and *accessibility* of research findings (presenting research in an understandable way).

In addition to these, issues related to the terminology and practicality of research papers [16, 17, 34, 36, 67, 71], failure to adequately address the lived complexity of design practices [36, 76], difficulties in accessing academic resources [3, 17], dissimilar incentive structures [17] and communication means of the two fields (e.g., journals and conferences for academia; and blogs, trade publications, and social media for practice) [38], and different cultures and skill sets of researchers and practitioners [16, 63] were also identified as barriers hindering the use of academic research in practice.

We argue that the same barriers apply to HRI. To our knowledge, this research-practice gap has not been explicitly addressed in HRI, yet it appears as an ancillary insight in some studies. For instance, Kim et al. [48] revealed that the HRI research on the use of robots for supporting autism spectrum disorders had gotten little attention from the clinicians even though it generated excitement within the robotics community. Although the focus of this work was on the gap between two separate disciplines, the insights are still important to show how complicated it is for HRI research to get adopted in the real-world. Regarding applicability, Krämer et al. [50] discussed the difficulty of using theories from human-human communication to design human-robot communication. This time the difficulty lies in these theories being extremely complex. For example, a basic communication prerequisite such as common ground takes years to implement into robots even in primitive forms. Thus, even though the developers would like to derive implementations from theory, they end up falling back on their personal experience [50].

There are multiple strategies suggested for bridging the research-practice gap. Going back to HCI, Colusso et al. [16] recommended to leverage visual representations of theories as examples, writing actionable design guidelines and prescriptive recommendations, redesigning scholarly search of resources with design-oriented search filters, integrating resources into existing tools. Some others recommended to present research papers in different formats [37, 67], doing design work along with practitioners to learn their practice [36], build a library of theoretical constructs that are understood by both researchers and practitioners (e.g., the concept of "affordance") [4], and insert an intermediary discipline between research and practice which translates research findings into the language of practice, while at the same time converting the concerns of practice into issues that researchers can address [63].

2.1 Intermediate-level knowledge

In addition to these concrete action points, HCI scholars also made a considerable effort to generate different types of knowledge that have relevance for practice and are apart from theories. This "intermediate-level knowledge" is more abstracted than particular instances (i.e., highly situated, specific and contextual knowledge related to an artefact or situation) yet does not aspire to the generality of a theory [42]. Examples are strong concepts [42], design patterns [8], annotated portfolios [18, 33], assets [16], experiential qualities [53], design concepts [72], heuristics [24], research objects [64], bridging concepts [19], and tutorials [22]; which all respect both the varied nature of design practice and the means of adequately representing this knowledge with potential uptake for future scholarship and practice [37].

The adoption of intermediate-level knowledge forms in HRI is at a nascent state. Lupetti et al. [56] provided an extensive overview on how they are currently employed in HRI. A few examples include "design patterns" created for describing the interaction of a robot with a child within a particular context [46] and "heuristics" such as continuous actions and boundary signaling to improve the robots' social acceptability [41].

2.2 Design guidelines and the present work

This paper centers on "design guidelines", a set of principles ensuring consistency and best practices in the design of an artefact [54]. We chose this format to support the dairy farming robotics company, as the company lacked a comprehensive guide addressing key interaction design challenges specific to the farm context.

In HRI research, there are various examples of design guidelines for issues such as accessibility [66], usability of interfaces for robot teleoperation [2], addressing ethical and legal issues related to robots [52], assisting older adults [5] and engaging them as co-designers [65]. These studies are highly valuable for providing an overview of the complexity of such challenges and principles for addressing them, yet they come from an academic tradition and their uptake in the practice is not clear. In HCI, for example, there is a rich history of providing guidelines to improve user experience, however, it has been shown that the practitioners often faced challenges in selecting, prioritizing, or translating them in their work [16, 89].

Investigating how practitioners used Google+AI guidelines, Yildirim et al. [89] found that teams and organizations had a strong desire to develop their own resources or adapt existing ones for their specific application domains. Similarly, in robotics, Kapeller et al. [47] advised to establish "domain-specific recommendations" for guiding the design of wearable robots. Considering the need for context-dependent recommendations, we made two pivotal design decisions: (1) working closely with the company where the guidelines would be used and (2) framing the guidelines under a familiar "style" for the company—a code of conduct.

A code of conduct is a set of rules outlining principles and values to be respected by the members of an organization, which every member commits to [31]. Most companies have similar documents, where the recommended or discouraged behaviors are defined. Guidelines can take various forms from manifestos to white papers [56]. In this project, we chose the code of conduct to be an appropriate form extending the values of the company also to include how their robots should behave to represent the company in the best possible way.

Such a document would need to bring together the scientific knowledge about best practices of human-robot interaction design, knowledge of the dynamic farming context, and knowledge of the company culture. In other words, there are two types of practice that the code needs to focus on: (1) *Farming practice* refers to the context that the robots operate in, including the farm environment; people, animals, and their needs; and the tasks and responsibilities related to dairy farming. It is important to study this practice as the code is specifically intended for designing robots that would add value to this context. (2) *Robot development practice* is a "professional practice", namely what practitioners do, what they experience, and the context where this takes place [35]. This practice is important to study as the code is intended to support the employees of a particular company in a way that would fit their values, responsibilities, and workflow.

During the development of the code, we continuously shifted back and forth between HRI theories and the knowledge from these two practices. Our aim was to identify how the company would like to be represented through the way their robots communicated and guide the implementation through the recommendations grounded strongly in HRI theory.

3 CREATING A CODE OF CONDUCT

3.1 The context and the problem

This project was conducted with Lely at their Netherlands headquarters between September 2021 and February 2022. Renowned for its dynamic and innovative approach, Lely specializes in developing and globally distributing robotic solutions for dairy farming, holding a prominent position in the industry.

Prior to project initiation, multiple briefing meetings with various company employees highlighted areas for improvement. While Lely maintained a strong visual identity in its robots, the robots' communication with farmers lacked consistency. For instance, the feed-pusher used an orange light to indicate that it is in-motion, the feed distributor used white and red lights, and the manure cleaner did not use lights at all. Each robot was introduced to the market at a different time and had unique goals, features, capabilities, and limitations. Considering that the farmers generally bought multiple robots together to run different errands, the discrepant communication behaviors of the robots increased the learning curve. Although the company provided maintenance support (which increased the costs) and farmers became familiar with the robots through daily interaction, certain behaviors remained unpredictable, such as robot movement directions or unexpected beeping.

In short, there were several interaction problems caused by the inconsistent and/or unclear communication behaviors of robots. Our observations and briefing meetings identified three primary reasons: Firstly, while some developers were part of a fixed team, others joined projects briefly based on their expertise (e.g., data analysts or experts in ML/AI). The frequent rotation of individuals through projects made it challenging to maintain a shared perspective. Secondly, within the large and dynamic company, employees often lacked the time to explore the work in other departments. Although efforts were made to provide an overview of different projects through presentations and internal documents, the situation was not ideal. Lastly, only a minority of robot developers worked adjacent to farmers and in farming context. Members of UX, sales, and services teams had frequent visits to farms where clients used the robots; yet the feedback gathered often failed to reach the robot development team, situated in traditional office spaces at a distance from the context.

Lely acknowledged these challenges and has been actively addressing them. The company established a growing UX team dedicated to creating consistent, effective, and pleasant robot communication across all designs. We collaborated with this team to develop guidelines supporting their efforts.

3.2 The design process

The project team comprised two HRI/HCI researchers from an academic background and two interaction designers from Lely. One of the designers was the lead of the UX section and worked at Lely for 10 years. The other designer led this project and was hired by Lely for the project duration. She coordinated activities to make the tacit values of the employees explicit, identify issues to support the company with, and shape the code document. Immersed in the company, she also shared her daily routine with the employees for weeks, fostering valuable formal and informal conversations about their work practices, responsibilities, challenges, and values.

We adhered to a user-centered design process, employing a combination of investigative methods (interviews and observations) and generative methods (co-creation workshops) to develop a comprehensive understanding of the context. Throughout the project, diverse stakeholders were engaged, ensuring representation of technical, business, and human dimensions. In total, 55 employees from different departments, six external roboticists, and four farmers were interviewed, aimed at gaining a deeper insight into Lely's work practices and the farming context.

In addition to interviews, we visited a robotized dairy farm six times during the project to observe the robots in action and their collaboration with farmers. We also conducted two workshops at the company to determine the guidelines required. The first workshop involved nine employees representing HR, product management, marketing, software development, UX, and technical support. Its aim was to reflect on company values and discuss their transferability to robots. We compiled a set of 20 values derived from foundational company policy documents—Employee code of conduct, Brand book, Employee Handbook, Future Farm Vision, Red Rules. Through guided discussions, participants identified the following values for Lely robots to represent: *Accuracy, Reliability, Efficiency, Clarity,* and *Friendliness.* In the second workshop, nine engineers discussed potential ways to implement these values within their existing workflows.

Taken together, the insights from the two workshops helped to outline what the "code" in a robot communication code of conduct document should be about. They also underlined the need to have guidelines in place as it was continuously mentioned how open, broad, and context-dependent these values were. As in line with the objective of this project, the participants pointed to a need to understand how they could be translated into robot features and improved interactions. Additional design requirements also emerged through the interviews, including accommodating all Lely products while being flexible to embrace new additions, providing a desirable vision for improved interactions, guiding robot developers to account for all factors influencing the user and animal experience, fitting the development process, and being a clear and engaging document that people would enjoy reading.

Based on these requirements, we explored ways to convey the code effectively and pleasantly to developers, striking a balance between abstraction and actionability. We investigated storytelling techniques and evolved the design through tests until an effective and engaging style emerged. A notable success was crafting value descriptions from the perspective of a Lely robot. This not only introduced each value in a manner tailored to the company, but also enhanced the document's readability. Adopting the viewpoint of a robot proved to be a novel approach for the company, allowing them to perceive their familiar context with a fresh perspective, as supported by research (e.g., [23, 26]). Another narrative style employed involved presenting examples of values in a format akin to fables or religious parables. Each story was given a catchy title for easy recollection and reference, accompanied by a (often humorous) illustration, and concluded with an overview of takeaway lessons.

The final version of the code could be seen as a supplementary material to this paper. It is a document with 13 stories for representing the five values intended for supporting developers to design human-robot communication for the dairy farming context (Figure 2). The code was evaluated by 27 Lely employees, assessing its benefits, fit to developers' workflow, usability, and integration within the company. At the moment of writing this paper, the code is actively used at Lely as part of the requirements in new projects and to document functional requirements that ensure portfolio-wide consistency. The company also created a new function, robot interaction designer, provided by the increased awareness that the document fostered.

Figure 2: An example page from the Lely Code of Conduct for Human-Robot Communication

4 HRI THEORY AND PRACTICE INTERTWINED

While undertaking the activities described above, we went through a dynamic interplay of theoretical and practice-based explorations, emblematic of experimental design projects [19]. We drew knowledge from dairy farming context and work practices of Lely, as well as upon many strands of HRI and HCI research. We kept a meticulous record of the design process and the underlying rationale behind each design research activity and design decision, allowing for a detailed examination of the interplay of theory and practice. In this section, we will describe how exchanges back and forth between HRI theory and practice were facilitated and how each was used in the process.

4.1 The use of knowledge from HRI theories

HRI theories played multiple roles during the different stages of the project and the design outcome:

4.1.1. HRI theory as a "frame": There is a limited number of, but highly valuable studies on how the introduction of robots has fundamentally changed dairy farmers' working day and relations with animals. For example, it has been reported that investing in a milking robot improved their quality of life and provided them a more flexible working day [39, 78, 70], increased animal welfare through a more stable treatment of the cows [39], increased the possibility for succession or to grow without additional labor [28, 39, 78], reduced the heavy physical workload [78]. On the other hand, the milking robots also changed the composition of farm work [11, 86], replaced the physical contact and visual inspection of each individual cow [27, 55, 78], and raised a range of concerns about privacy, ethics, and democratic governance of farming data [9, 43]. These works provided us with a frame about the complex socio-technical networks of dairy farming robots and starting points to study the dynamics and challenges of this context.

4.1.2. HRI theory as a "tool": HRI literature played a pivotal role in designing the user research activities. It provided critical topics and points of interest to craft appropriate interview questions for different stakeholders. These questions eventually led to anecdotes that grounded our knowledge to actual practice, and therefore, resonated with the audience when incorporated into the code. Among many others, examples included interviewing the farmers about what it meant to be a "good farmer" after the introduction of robotic assistants (inspired by [27]), interviewing the engineers about the ways they ensured a common ground between the robots and the farmers and have robots signal their perceptual and cognitive capabilities to onlookers (inspired by [80]) or how they decided whether an interaction should take place through a digital or physical channel (inspired by [62]).

Similarly, HRI theories were also used as a tool to craft the observation protocol, i.e., which problematic points are anticipated by the literature, e.g., intent recognition [44] or mitigating breakdowns [51]; and some workshop activities, e.g., some of the most commonly addressed human-robot communication issues—needing assistance, informing the user about its status, giving an overview about decisions—were used in scenarios for participants to enact and identify the desirable communication behaviors for Lely robots.

4.1.3. HRI theory as "best practices": After identifying which values to focus on, we collected implications and recommendations from relevant studies to create actionable guidelines. For example, the "International chef" story describing one facet of reliability guides the developers to "Make the capabilities and limitations of the robots transparent when needed", which is based on the work of [30], [73], and [80]. The guideline "Identify when the robot may need help from a user and make sure it can reach them" is based on the work of [51], [75], [82], among others.

4.1.4. Theory as "reference" for design decisions: Beyond HRI theory, we also consulted theories from other disciplines to establish the basis for some design decisions and situate the document within a lineage of style. For example, we shaped the narrative and the tone of voice of the document following the advice on how to write actionable and relevant design implications from academic studies (e.g., [37], [72]); and what makes "good" guidelines (e.g., [79]).

4.2 The use of knowledge from HRI practice

The guidelines were directed towards the concrete issues in the robot development practice for dairy farming. These practices played a role in the design process and the design outcome in the following ways:

4.2.1. HRI practice as "context": Robots are increasingly placed in complex social contexts characterized by multiple people, roles, tasks, goals, and dependencies [45]. Dairy farms are one of such contexts with its own unique qualities that set it apart from others. For example, the observations and interviews revealed that the robotized farms often owned two or more robots for different tasks. Therefore, we considered that the values such as "efficiency" should be addressed in the context of larger robot ecologies rather than optimizing one robot. The efficiency would also be determined by the synchronization of different robots for task accomplishment and sharing resources. Similarly, the issues related to animals—about their proper care, wellbeing, interactions with the farmer and the robots—were the key qualities in this context. This adds an additional layer to unpack regarding the "friendliness" of robots for example. In short, to design efficient or friendly robot communication behaviors, there are many dairy farm-specific factors to be acknowledged. This practice was used for making the stories very specific in the code.

Furthermore, the interviews and workshops conducted with the employees helped us to understand the company culture, values, and processes. These insights from the professional practice provided a context to be able to integrate the code seamlessly into the existing workflow.

4.2.2. HRI practice as "reference" for research activities: The fieldwork also inspired new directions of research that we needed to seek and consider in the guidelines. For instance, we observed that both farmers and robot developers (often inadvertently) referred to the manure sweeping robot as "dumb" because of its primary task, even though the robot had one of the most sophisticated technologies. Such observations led to consulting HRI theories on robot personalities and when/how to design them (e.g., [88]) and discussing it during the interviews with developers. Similar loops from the interviews to HRI literature, and back to the interviews were also made in relation to the concept of perceived trust (after learning that the farmers switched off the safety sensor of the robot kitchen since they thought they could predict the robots' movement) or about cow psychology (after learning that the cows rather often kicked the milking robots), among others.

4.2.3. HRI practice as "validation of theory": The dairy farming practice also acted as a context for validating the generalizability of HRI theories. Through the interviews with farmers and developers about the urgent interaction problems and guiding them through speculations about alternative scenarios, we assessed whether, for example, context-independent theories on intelligibility [80], trust [82], or soliciting help [75] also applied to the dairy farm environment as they were intended, e.g., would positive politeness be more effective strategy for a feed pusher robot to ask for help when it is stuck? (inspired from [75]). These surely were more anecdotal and speculative validations, yet they helped to ground the guidelines in HRI theory while making them applicable to the farm context through concrete examples.

5 DISCUSSION AND CONCLUSION

Design research contributes new knowledge through both the intricate qualities of end products and the rich nature of the processes involved [33]. We consider that our design outcome—design guidelines presented as a code of conduct for human-robot communication—and the process leading to this code are inherently rooted in theory and practice simultaneously, without reduction to either. Our collaborative project addressed key issues and areas of interest for both communities, making the results accessible to both. The generated guidelines aim to carve out a knowledge space informing future human-robot communication development, where the interaction between theory and practice mutually constitutes contextual boundaries.

Throughout the design process, knowledge from HRI/HCI theory *framed* the sociotechnical complexity of the robotized dairy farming context indicating the points of attention, served as a *tool* for crafting interview questions, observation points, and generative activities in the workshops. It also *guided design decisions*, such as the tone of voice and the document's actionability. In the final design outcome, the theory also manifested itself in concrete *takeaways and best practices*.

Regarding practice, knowledge from the dairy farming context *guided the search* for relevant HRI theories and *validated* their applicability to this particular context. It also *informed user research*, indicating which issues were crucial to discuss during interviews with stakeholders. All information and examples in the code were based on real-world phenomena and experiences, a quality that was a significant asset during company evaluations. Similarly, knowledge from Lely's professional practice *validated* the need for such a code of conduct and ensured the end design outcome would *seamlessly fit* into the company's workflow and culture.

We consider our design outcome akin to a "bridging concept", as described by Dalsgaard and Dindler [19], positioned between strong concepts [42] and conceptual constructs [77]. The former is developed inductively by drawing from instantiations to form a more generalizable concept that can be employed in design practice. On the other hand, the latter departs from theory to be represented in particulars with the objective of enriching the theoretical foundations of HCI. These two intermediate-level knowledge constructs represent opposite positions, which bridging concepts aim to connect by facilitating exchange both ways between overarching theory and practice [19]. Articulating our design outcome in the form of a bridging concept prompts us to formulate knowledge in a way that specifies the accountability to both theory and practice.

This accountability is important for discussing how the code can be meaningfully employed in practice and on what grounds it should be evaluated. From the practice side, the positioning of the code between abstraction and specificity aims to provide robot developers with guidance that is concrete enough to inform design activities, yet generic enough to be applicable in different problems and/or robots. Being embedded at the company during the project, engaging many employees in various activities, and closely studying the company's professional practice supported the relevance of the code for practitioners. The code was crafted to be action-oriented, concrete, and pragmatic, specifying insights for dairy farming in accessible, non-research terminology, and using numerous examples. We consider that meeting these criteria was an important factor for the excitement the code generated at the company, as also indicated by [29] for an increased uptake of research by design practice.

While Lely may need to systematically test and validate the outcomes from applying the guidelines to assess the impact of the document, the guidelines have already been influential in another sense: The participatory process heightened ownership of the document and created awareness in the company about the relevance and breadth of HRI research. This echoes the observations of Yildirim et al. [89] regarding the use of Google+AI guidebook. Companies use these guidelines to build a culture around human-centered AI within the teams and organization. Similarly, managers at Lely emphasized the importance of having a shared language on HRI across the company and noted the success of the code in accomplishing this. The code has been acting as an educational and capacity-building tool, familiarizing employees with human-robot interaction issues and inspiring them to study the farming context in more detail.

The design guidelines were specifically crafted for a particular client and were not intended as a universally applicable guide to human-robot communication. Different companies, even within the same sector, may prioritize distinct values, interpret them differently, and have unique requirements that necessitate a different approach to communicating guidelines. Consequently, the generalizability of the project for HRI design practice is limited. Our aspiration is that the process and outcome can serve as inspiration for other companies seeking to develop their knowledge base around a specific HRI issue.

However, by framing the design outcome as a bridging concept, we acknowledge accountability to HRI theory. While the guidelines themselves were not the primary focus of this paper (and thus not extensively discussed in the main text but included as supplementary material), we intended to make a knowledge contribution to the HRI research community through the framework elucidating the interplay between practice and research. This interplay would be generalizable to numerous design research projects within the HRI field. Researchers can leverage the various theory/practice exchanges to reflect on their own design research processes, externalize how they utilize knowledge from theory and practice, and explore alternative ways of employing them effectively in their projects. Furthermore, we argue that the generalizability of these theory-practice exchanges makes a compelling case for demonstrating that design research processes are dialectical between theory and practice, contributing to the HRI epistemology, especially regarding the repertoire of designerly ways of producing knowledge in HRI.

One of the challenges of the project was to continuously shift back and forth between designerly and academic orientations. The "designer" tasks involved investigating the stakeholders and context, identifying problematic situations, envisioning possible means of intervention, creating prototypes, and evaluating them in situ. On the other hand, the "researcher" tasks involved assessing the relevance of recent theories, translating them to the context, generalizing beyond the specific design situation, and distilling rich detail of practice into theoretical understanding.

This dual purpose and the intertwined relationship between theory and practice demanded a non-linear process. Designers pursue novelty by conducting research of diverse natures—they sometimes follow a systematic and structured logic to generate knowledge that will be useful to the project, while other moments the process is more intuitive and less controlled so that unexpected elements emerge [74]. Often, the act of designing implies working with incertitude, taking risks, and building several possible paths in a non-linear way [40]. That is why in this paper we chose to describe how theory and practice complemented each other in an anecdotal manner rather than presenting a systematic process. We are not even sure whether we would be able to. As typical of many explorative design projects, there were many parallel activities and iterations, with ideas inspiring action several steps later or insights not necessarily culminating in the final design outcome for various reasons. Through these anecdotes and examples, we aimed to demonstrate the chain of reasoning leading to the code of conduct document.

Desjardins and Key [21] describe a design-oriented research project as a "a mesh of lines that cross" than a straight line, emphasizing the meandering, splitting, pivoting, or folding nature of the process. In contrast, HRI epistemology traditionally follows a linear path of knowledge generation, primarily through hypothesis testing [15]. However, recent calls within HRI advocate transcending a singular, standardized approach and embracing qualitative research methods to develop theories rooted in social contexts and human perspectives [85]. Additionally, there is a growing acknowledgment of designerly approaches to knowledge generation, recognizing that HRI knowledge can manifest within a robotic artefact or the process leading to it [56, 57]. One of the intentions of this work is to provide a conceptual tool, in the form of intermediate-level knowledge, to the HRI community, encouraging exploration of diverse HRI epistemologies and embracing currently "non-standard" ways of generating knowledge.

Furthermore, we aspire that our delineation of the convergence between HRI theory and practice throughout the project, along with our methodological approach, can serve as a means to bridge the gap between academic research and practical application in HRI. Beck and Ekbia [4] propose to use "continuum" as a metaphor to depict the essential mutual agreement, harmony, synergy, and support required between research and practice. We extend an invitation to both the academic and practitioner communities in HRI to actively pursue and establish these fruitful and harmonious collaborations. Additionally, we encourage exploration of various avenues, such as leveraging intermediate-level knowledge, to sustain the vitality of the continuum between research and practice in HRI.

REFERENCES

[1] Iina Aaltonen, Timo Salmi, and Ilari Marstio. 2018. Refining levels of collaboration to support the design and evaluation of human–robot interaction in the manufacturing industry. *Procedia CIRP* 72, 93–98.

[2] George Adamides, Georgios Christou, Christos Katsanos, Michalis Xenos, and Thanasis Hadzilacos. 2014. Usability guidelines for the design of robot teleoperation: A taxonomy. *IEEE Transactions on Human-Machine Systems* 45, no. 2, 256-262.

[3] Peter Bailis, Simon Peter, and Justine Sherry. 2016. Introducing research for practice. *Commun. ACM*, 59(9), 38–41. http://doi.org/10.1145/2909474

[4] Jordan Beck and Hamid R. Ekbia. 2018. The Theory-Practice Gap As Generative Metaphor. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18).* ACM, New York, NY, USA, Article 620. https://doi.org/10.1145/3173574.3174194

[5] Jenay M. Beer, Cory-Ann Smarr, Tiffany L. Chen, Akanksha Prakash, Tracy L. Mitzner, Charles C. Kemp, and Wendy A. Rogers. 2012. The domesticated robot: design guidelines for assisting older adults to age in place. In *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction (HRI '12).* ACM, New York, NY, USA, 335–342. https://doi.org/10.1145/2157689.2157806

[6] Kathleen Belhassein, Víctor Fernández-Castro, Amandine Mayima, Aurélie Clodic, Elisabeth Pacherie, Michèle Guidetti, Rachid Alami, and Hélène Cochet. 2022. Addressing joint action challenges in HRI: Insights from psychology and philosophy. *Acta Psychologica* 222, 103476.

[7] Andrew Booth. 2003. Bridging the research-practice gap? The role of evidence based librarianship. *New Review of Information and Library Research 9*, 1, 3–23.

[8] Jan O. Borchers. 2000. A pattern approach to interaction design. In *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques (DIS '00).* ACM, New York, NY, USA, 369–378. https://doi.org/10.1145/347642.347795

[9] Kelly Bronson. 2018. Smart farming: including rights holders for responsible agricultural innovation. *Technology Innovation Management Review* 8, no. 2, 7-14.

[10] Elizabeth A. Buie, Susan M. Dray, Keith E. Instone, Jhilmil Jain, Gitte Lindgaard, and Arnold M. Lund. 2010. Researcher-practitioner Interaction. In *CHI '10 Extended Abstracts on Human Factors in Computing Systems (CHI EA '10).* ACM, New York, NY, USA, 4469–4472. DOI: https://doi.org/10.1145/1753846.1754176

[11] Deborah Butler, Lewis Holloway, and Christopher Bear. 2012. The impact of technological change in dairy farming: robotic milking systems and the changing role of the stockperson. *Journal of the Royal Agricultural Society of England* 173, no. 622, 1.

[12] Michael Carolan. 2018. Smart farming techniques as political ontology: access, sovereignty and the performance of neoliberal and not-so-neoliberal worlds. *Sociologia ruralis* 58, no. 4, 745-764.

[13] Craig R. Carter. 2008. Knowledge production and knowledge transfer: closing the research-practice gap. *Journal of Supply Chain Management* 44, no. 2, 78-83.

[14] Nazli Cila. 2022. Designing Human-Agent Collaborations: Commitment, responsiveness, and support. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22*). ACM, New York, NY, USA, Article 420, 1–18. https://doi.org/10.1145/3491102.3517500

[15] Nazli Cila, Cristina Zaga, and Maria Luce Lupetti. 2021. Learning from robotic artefacts: A quest for strong concepts in Human-Robot Interaction. In *Proceedings of the 2021 ACM Designing Interactive Systems Conference (DIS '21).* ACM, New York, NY, USA, 1356–1365. https://doi.org/10.1145/3461778.3462095

[16] Lucas Colusso, Cynthia L. Bennett, Gary Hsieh, and Sean A. Munson. 2017. Translational Resources: Reducing the Gap Between Academic Research and HCI Practice. In *Proceedings of the 2017 Conference on Designing Interactive Systems (DIS '17*). ACM, New York, NY, USA, 957–968. https://doi.org/10.1145/3064663.3064667

[17] Lucas Colusso, Ridley Jones, Sean A. Munson, and Gary Hsieh. 2019. A Translational Science Model for HCI. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19).* ACM, New York, NY, USA, Paper 1, 1–13. https://doi.org/10.1145/3290605.3300231

[18] Alma Leora Culén, Jorun Børsting, and William Gaver. 2020. Strategies for Annotating Portfolios: Mapping Designs for New Domains. *In Proceedings of the 2020 ACM Designing Interactive Systems Conference.* 1633–1645. https://doi.org/10.1145/3357236.3395490

[19] Peter Dalsgaard and Christian Dindler. 2014. Between theory and practice: bridging concepts in HCI research. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14).* ACM, New York, NY, USA, 1635–1644. https://doi.org/10.1145/2556288.2557342

[20] Diana L. Deadrick and Pamela A. Gibson. 2007. An examination of the research–practice gap in HR: Comparing topics of interest to HR academics and HR professionals. *Human Resource Management Review* 17, 2, 131-139.

[21] Audrey Desjardins and Cayla Key. 2020. Parallels, Tangents, and Loops: Reflections on the 'Through' Part of RtD. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference (DIS '20).* ACM, New York, NY, USA, 2133–2147. https://doi.org/10.1145/3357236.3395586

[22] Audrey Desjardins, Ron Wakkary, Will Odom, Henry Lin, and Markus Lorenz Schilling. 2017. Exploring DIY Tutorials As a Way to Disseminate Research Through Design. *Interactions* 24, 4 (June 2017), 78–82. https://doi.org/10.1145/3098319

[23] Carl DiSalvo and Jonathan Lukens. 2011. Non-anthropocentrism and the non-human in design: Possibilities for designing new forms of engagement with and through technology. In M. Foth, L. Forlano, M. Gibbs, & C. Satchell (Eds.), From social butterfly to engaged citizen: urban informatics, social media, ubiquitous computing, and mobile technology to support citizen engagement (pp. 421-437). MIT Press.

[24] Alan Dix, Janet E. Finlay, Gregory D. Abowd, and Russell Beale. 2003. *Human-Computer Interaction* (3rd Edition). Prentice-Hall, Inc., Upper Saddle River, NJ, USA.

[25] Renate L. Doerfler, Christina Lehermeier, Heike Kliem, Erich Möstl, and Heinz Bernhardt. 2016. Physiological and behavioral responses of dairy cattle to the introduction of robot scrapers. *Frontiers in veterinary science,* 3, 106.

[26] Judith Dörrenbächer, Diana Löffler, and Marc Hassenzahl. 2020. Becoming a Robot - Overcoming Anthropomorphism with Techno-Mimesis. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20). Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3313831.3376507

[27] Clemens Driessen and Leonie FM Heutinck. 2015. Cows desiring to be milked? Milking robots and the co-evolution of ethics and technology on Dutch dairy farms. *Agriculture and Human Values* 32, 3-20.

[28] Callum R. Eastwood and Alan Renwick. 2020. Innovation uncertainty impacts the adoption of smarter farming approaches. *Frontiers in Sustainable Food Systems* 4, 24.

[29] Daniel Fallman and Erik Stolterman. 2010. Establishing criteria of rigour and relevance in interaction design research, *Digital Creativity*, 21:4, 265-272, DOI: 10.1080/14626268.2010.548869

[30] Luciano Floridi, Josh Cowls, Monica Beltrametti, Raja Chatila, Patrice Chazerand, Virginia Dignum, Christoph Luetge et al. 2021. An ethical framework for a good AI society: Opportunities, risks, principles, and recommendations. *Ethics, governance, and policies in artificial intelligence,* 19-39.

[31] Eduard Fosch-Villaronga and Jordi Albo-Canals. 2019. "I'll take care of you," said the robot: Reflecting upon the Legal and Ethical Aspects of the Use and Development of Social Robots for Therapy. *Paladyn, Journal of Behavioral Robotics* 10, 1, 77-93.

[32] Ken Friedman. 2003. Theory construction in design research: criteria: approaches, and methods. *Design Studies*, 24, 507-522.

[33] Bill Gaver and John Bowers. 2012. Annotated portfolios. *interactions* 19, 4 (July + August 2012), 40–49. https://doi.org/10.1145/2212877.2212889

[34] Sabine Geldof and Joannes Vandermeulen. 2007. A Practitioner's View of Human–Computer Interaction Research and Practice. *Artifact*, 1(3), 134–141. DOI: http://doi.org/10.1080/17493460701800181

[35] Bill Green. 2009. Introduction: Understanding and researching professional practice. In Green, B. (ed). Understanding and researching professional practice. Sense Publishers.

[36] Elizabeth Goodman, Erik Stolterman, and Ron Wakkary. 2011. Understanding interaction design practices. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems (CHI 2011),* 1061. http://doi.org/10.1145/1978942.1979100

[37] Colin M. Gray and Yubo Kou. 2017. UX Practitioners' Engagement with Intermediate-Level Knowledge. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems (DIS '17 Companion).* ACM, New York, NY, USA, 13–17. https://doi.org/10.1145/3064857.3079110

[38] Colin M. Gray, Erik Stolterman, and Martin A. Siegel. 2014. Reprioritizing the relationship between HCI research and practice: bubble-up and trickle-down effects. In *Proceedings of the 2014 conference on Designing interactive systems (DIS '14).* ACM, New York, NY, USA, 725–734. https://doi.org/10.1145/2598510.2598595

[39] Bjørn Gunnar Hansen. 2015. Robotic milking-farmer experiences and adoption rate in Jæren, Norway. *Journal of Rural Studies* 41, 109-117.

[40] Peter Hodges, Stan Ruecker, Celso Scaletsky, Jaime Rivera, Roberto Faller, and Amanda Geppert. 2017. Four criteria for design theories. *She Ji: The Journal of Design, Economics, and Innovation* 3, 1, 65-74.

[41] Guy Hoffman, Oren Zuckerman, Gilad Hirschberger, Michal Luria, and Tal Shani Sherman. 2015. Design and Evaluation of a Peripheral Robotic Conversation Companion. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction (HRI'15).* Portland, USA, 3-10. DOI: https://doi.org/10.1145/2696454.2696495

[42] Kristina Höök and Jonas Löwgren. 2012. Strong Concepts: Intermediate-level Knowledge in Interaction Design Research. *ACM Trans. Comput.-Hum. Interact.* 19, 3, Article 23 (Oct. 2012). https://doi.org/10.1145/2362364.2362371

[43] Emma Jakku, Bruce Taylor, Aysha Fleming, Claire Mason, Simon Fielke, Chris Sounness, and Peter 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-Wageningen Journal of Life Sciences* 90, 100285.

[44] Siddarth Jain and Brenna Argall. 2019. Probabilistic Human Intent Recognition for Shared Autonomy in Assistive Robotics. *J. Hum.-Robot Interact.* 9, 1, Article 2 (December 2019). DOI:https://doi-org.tudelft.idm.oclc.org/10.1145/3359614

[45] Malte Jung and Pamela Hinds. 2018. Robots in the Wild: A Time for More Robust Theories of Human-Robot Interaction. *J. Hum.-Robot Interact.* 7, 1, Article 2 (May 2018). https://doi.org/10.1145/3208975

[46] Peter H. Kahn, Nathan G. Freier, Takayuki Kanda, Hiroshi Ishiguro, Jolina H. Ruckert, Rachel L. Severson, and Shaun K. Kane. 2008. Design patterns for sociality in human-robot interaction. In *Proceedings of the 3rd ACM/IEEE international conference on Human robot interaction (HRI '08).* ACM, New York, NY, USA, 97–104. https://doi.org/10.1145/1349822.1349836

[47] Alexandra Kapeller, Heike Felzmann, Eduard Fosch-Villaronga, Kostas Nizamis, and Ann-Marie Hughes. 2021. Implementing ethical, legal, and societal considerations in wearable robot design. *Applied Sciences* 11, 15, 6705.

[48] Elizabeth Kim, Rhea Paul, Frederick Shic, and Brian Scassellati. 2012. Bridging the Research Gap: Making HRI Useful to Individuals with Autism. *Journal of Human-Robot Interaction* 1.1, 26-54.

[49] Tobias Kopp, Marco Baumgartner, and Steffen Kinkel. 2021. Success factors for introducing industrial human-robot interaction in practice: an empirically driven framework. *The International Journal of Advanced Manufacturing Technology* 112, 685-704.

[50] Nicole C. Krämer, Sabrina Eimler, Astrid Von Der Pütten, and Sabine Payr. 2011. Theory of companions: what can theoretical models contribute to applications and understanding of human-robot interaction?. *Applied Artificial Intelligence* 25, 6, 474-502.

[51] Min Kyung Lee, Sara Kiesler, Jodi Forlizzi, Siddhartha Srinivasa, and Paul Rybski. 2010. Gracefully mitigating breakdowns in robotic services. In *5th ACM/IEEE International Conference on Human-Robot Interaction (HRI),* 203-210.

[52] Ronald Leenes, Erica Palmerini, Bert-Jaap Koops, Andrea Bertolini, Pericle Salvini and Federica Lucivero. 2017. Regulatory challenges of robotics: some guidelines for addressing legal and ethical issues. *Law, Innovation and Technology*, 9:1, 1-44, DOI: 10.1080/17579961.2017.1304921

[53] Jonas Löwgren. 2009. Toward an articulation of interaction esthetics. *New Review of Hypermedia and Multimedia* 15, 2, 129-146.

[54] Jonas Löwgren. 2013. Annotated portfolios and other forms of intermediate-level knowledge. *interactions* 20, 1 (January + February 2013), 30–34. DOI: https://doi.org/10.1145/2405716.2405725

[55] Christina Lundström and Jessica Lindblom. 2021. Care in dairy farming with automatic milking systems, identified using an Activity Theory lens. *Journal of Rural Studies* 87, 386-403.

[56] Maria Luce Lupetti, Cristina Zaga, and Nazli Cila. 2021. Designerly Ways of Knowing in HRI: Broadening the Scope of Design-oriented HRI Through the Concept of Intermediate-level Knowledge. In *Proceedings of the 2021 ACM/IEEE International Conference on Human-Robot Interaction (HRI '21).* ACM, New York, NY, USA, 389–398. https://doi.org/10.1145/3434073.3444668

[57] Michal Luria, Marius Hoggenmüller, Wen-Ying Lee, Luke Hespanhol, Malte Jung, and Jodi Forlizzi. 2021. Research through Design Approaches in Human-Robot Interaction. In *Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction (HRI '21 Companion).* ACM, New York, NY, USA, 685–687. https://doi.org/10.1145/3434074.3444868

[58] Ayoola Makinde, Muhammad Muhaiminul Islam, and Stacey D. Scott. 2020. Opportunities for ACI in PLF: Applying Animal- and User-Centred Design to Precision Livestock Farming. In *Proceedings of the Sixth International Conference on Animal-Computer Interaction (ACI '19).* ACM, New York, NY, USA, Article 13, 1–6. https://doi.org/10.1145/3371049.3371055

[59] Maja Matarić. 2018. On relevance: Balancing theory and practice in HRI. *ACM Transactions on Human-Robot Interaction* (THRI) 7, 1, 1-2.

[60] Christopher Miles. 2019. The combine will tell the truth: On precision agriculture and algorithmic rationality. Big Data & Society 6, 1, 2053951719849444.

[61] António B. Moniz and Bettina-Johanna Krings. 2016. Robots Working with Humans or Humans Working with Robots? Searching for Social Dimensions in New Human-Robot Interaction in Industry. *Societies* 6, 3, 23. DOI: https://doi.org/10.3390/soc6030023

[62] Bilge Mutlu. 2021. The virtual and the physical: two frames of mind. *Iscience*, 24, 2.

[63] Donald A. Norman. 2010. The Research-practice Gap: The Need for Translational Developers. *Interactions* 17, 4 (July 2010), 9–12. DOI: https://doi.org/10.1145/1806491.1806494

[64] William Odom, Tom Jenkins, Kristina Andersen, Bill Gaver, James Pierce, Anna Vallgårda, Andy Boucher, David Chatting, Janne van Kollenburg, and Kevin Lefeuvre. 2017. Crafting a Place for Attending to the Things of Design at CHI. *Interactions* 25, 1 (Dec. 2017), 52–57. DOI: https://doi.org/10.1145/3161605

[65] Anastasia K. Ostrowski, Cynthia Breazeal and Hae Won Park. 2021. Long-Term Co-Design Guidelines: Empowering Older Adults as Co-Designers of Social

Robots, *2021 30th IEEE International Conference on Robot & Human Interactive Communication (RO-MAN)*, Vancouver, BC, Canada, 2021, pp. 1165-1172, doi: 10.1109/RO-MAN50785.2021.9515559.

[66] Malak Qbilat, Ana Iglesias, and Tony Belpaeme. 2021. A proposal of accessibility guidelines for human-robot interaction. *Electronics,* 10, 5, 561.

[67] Christian Remy, Silke Gegenbauer, and Elaine M. Huang. 2015. Bridging the Theory-Practice Gap: Lessons and Challenges of Applying the Attachment Framework for Sustainable HCI Design. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15).* ACM, New York, NY, USA, 1305–1314. https://doi.org/10.1145/2702123.2702567

[68] Sara L Rynes. 2012. The research-practice gap in I/O psychology and related fields: Challenges and potential solutions. *The Oxford handbook of organizational psychology,* 1, 409–452.

[69] Kelly Rijswijk, Laurens Klerkx, Manlio Bacco, Fabio Bartolini, Ellen Bulten, Lies Debruyne, Joost Dessein, Ivano Scotti, and Gianluca Brunori. 2021. Digital transformation of agriculture and rural areas: A socio-cyber-physical system framework to support responsibilisation. *Journal of Rural Studies,* 85, 79-90.

[70] Jack Rodenburg. 2017. Robotic milking: Technology, farm design, and effects on work flow. *Journal of Dairy Science* 100, 9, 7729-7738.

[71] David J. Roedl and Erik Stolterman. 2013. Design Research at CHI and Its Applicability to Design Practice. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13).* ACM, New York, NY, USA, 1951–1954. DOI: https://doi.org/10.1145/2470654.2466257

[72] Corina Sas, Steve Whittaker, Steven Dow, Jodi Forlizzi, and John Zimmerman. 2014. Generating Implications for Design Through Design Research. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14).* ACM, New York, NY, USA, 1971–1980. DOI: https://doi.org/10.1145/2556288.2557357

[73] Bob R. Schadenberg, Dennis Reidsma, Dirk K. J. Heylen, and Vanessa Evers. 2021. "I See What You Did There": Understanding People's Social Perception of a Robot and Its Predictability. *J. Hum.-Robot Interact. 1*0, 3, Article 28 (September 2021). DOI: https://doi.org/10.1145/3461534

[74] Donald A. Schön. 1983. The Reflective Practitioner: How Professionals Think in Action. New York: Basic Books

[75] Vasant Srinivasan and Leila Takayama. 2016. Help Me Please: Robot Politeness Strategies for Soliciting Help From Humans. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16).* ACM, New York, NY, USA, 4945–4955. DOI: https://doi.org/10.1145/2858036.2858217

[76] Erik Stolterman. 2008. The nature of design practice and implications for interaction design research. *International Journal of Design* 2, 1.

[77] Erik Stolterman and Mikael Wiberg. 2010. Concept-driven interaction design research. *Human–Computer Interaction* 25, 2, 95-118.

[78] Egil Petter Stræte, Jostein Vik, and Bjørn Gunnar Hansen. 2017. The social robot: a study of the social and political aspects of automatic milking systems. In *Proceedings in System Dynamics and Innovation in Food Networks*, 2202-33. DOI: http://dx.doi.org/10.18461/pfsd.2017.1722

[79] Lisa Tambornino, Dirk Lanzerath, Rowena Rodrigues, and David Wright. 2018. D4. 3: Survey of REC approaches and codes for Artificial Intelligence & Robotics.

[80] Sam Thellman and Tom Ziemke. 2021. The Perceptual Belief Problem: Why Explainability Is a Tough Challenge in Social Robotics. *J. Hum.-Robot Interact.* 10, 3, Article 29 (September 2021). DOI: https://doi.org/10.1145/3461781

[81] J. Gregory Trafton, Paula Raymond, and Sangeet Khemlani. 2021. The Power of Theory. J. *Hum.-Robot Interact.* 10, 1, Article 11 (March 2021), 3 pages. DOI: https://doi.org/10.1145/3439716

[82] Rik van den Brule, Gijsbert Bijlstra, Ron Dotsch, Pim Haselager, and Daniël H. J. Wigboldus. 2016. Warning signals for poor performance improve human-robot interaction. *J. Hum.-Robot Interact.* 5, 2 (September 2016), 69–89. DOI: https://doi.org/10.5898/JHRI.5.2.Van_den_Brule

[83] Simone van der Burg, Marc-Jeroen Bogaardt and Sjaak Wolfert. 2019 Ethics of smart farming: Current questions and directions for responsible innovation towards the future. *NJAS: Wageningen Journal of Life Sciences*, 90-91, 1, 1-10, DOI: 10.1016/j.njas.2019.01.001

[84] Juan P. Vasconez, George A. Kantor, and Fernando A. Auat Cheein. 2019. Human–robot interaction in agriculture: A survey and current challenges. *Biosystems engineering* 179, 35-48.

[85] Louise Veling and Conor McGinn. 2021. Qualitative research in HRI: A review and taxonomy. *International Journal of Social Robotics* 13, 1689-1709.

[86] Jostein Vik, Egil Petter Stræte, Bjørn Gunnar Hansen, and Torfinn Nærland. 2019. The political robot–The structural consequences of automated milking systems (AMS) in Norway. *NJAS-Wageningen Journal of Life Sciences* 90, 100305.

[87] Tian-Miao Wang, Yong Tao, and Hui Liu. 2018. Current researches and future development trend of intelligent robot: A review. *Int. J. of Automation and Computing* 15, 5, 525-546.

[88] Steve Whittaker, Yvonne Rogers, Elena Petrovskaya, and Hongbin Zhuang. 2021. Designing Personas for Expressive Robots: Personality in the New Breed of Moving, Speaking, and Colorful Social Home Robots. *J. Hum.-Robot Interact.* 10, 1, Article 8 (March 2021), 25 pages. https://doi.org/10.1145/3424153

[89] Nur Yildirim, Mahima Pushkarna, Nitesh Goyal, Martin Wattenberg, and Fernanda Viégas. 2023. Investigating How Practitioners Use Human-AI Guidelines: A Case Study on the People + AI Guidebook. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23).* ACM, New York, NY, USA, Article 356, 1–13. DOI: https://doi.org/10.1145/3544548.3580900

[90] John Zimmerman, Erik Stolterman, and Jodi Forlizzi. 2010. An analysis and critique of Research through Design: towards a formalization of a research approach. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems (DIS '10).* ACM, New York, NY, USA, 310–319. DOI: https://doi.org/10.1145/1858171.1858228