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The Imbrication of Technologies and Work Practices: The Case of Google Glass in Danish Agriculture

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The Imbrication of Technologies and Work Practices

The case of Google Glass in Danish agriculture

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Abstract. Modern organizations are knowledge intensive and experience an ever-increasing demand for information processing due to unrelenting competition, digitization-enabled real-time data access and analysis, improved technological processing capabilities, and increasing regulation and bureaucratization. This analysis reveals that information requirements in agricultural organizations grows with specialization, and that farmers handle increasing amounts of information-intensive work practices. These practices are supported in varying degrees by adopted technologies. In this study, we investigate Google Glass as an embedded part of farmers' everyday work practices. Our analysis shows how actors compare past experiences, present applications, and future possibilities in evaluating requirements for digital innovation of work practices. By drawing on the concept of sociomateriality, we show how Google Glass facilitates simultaneous performance of situation-specific and information-related work practices through the imbrication of technologies and work practices. For the imbrication to take place, certain demands with regard to technologies and work practices must be met. We discuss the novelty of this perspective on technology in work practice.

Keywords: digital innovation, process innovation, Google Glass, sociomateriality, imbrication.

1 Introduction

The dominating management discourse dictates that organizations must innovate continuously to survive in today's competitive environment (Teece et al. 1997; Day 2011). Along the same lines, Information Systems and organization science researchers are in-

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terested in how organizations achieve and sustain competitive advantages using, among other things, technology as an innovation driver.

Among recent technological developments, wearables introduce organizations to new possibilities by integrating digital technology into wearable objects such as watches, textiles, and eyeglasses (Dvorak 2008; Giordano and Puccinelli 2014). These developments are the result of technologies becoming smaller and more advanced and therefore enabling the "[…] embedding of computing capabilities into everyday artifacts" (Yoo 2010). This also means that wearables are increasingly capable of supporting large information flows and communication across time and space, which in turn enable more timely and efficient decision-making in organizations (Laursen and Thorlund 2010). Accordingly, wearable technologies provide organizations with innovative solutions to problems of not having relevant, complete, accurate, current, and cost-effective information at their disposal. In turn, these technologies become means of coping with competitive pressure.

OHMDs (Optical Head-Mounted Displays) are a particular type of wearables that enables presentation of information on displays worn as eyeglasses (Rolland and Hua 2005; Nee et al. 2012; Sawyer et al. 2014). They permit the use of both hands for purposes other than controlling the technology while the user is able to move around and simultaneously access and register different kinds of information. OHMDs have been objects of invention and interest for decades. McCollum filed the first patent in 1945 (McCollum 1945), while Sutherland and Sproull constructed the first physical OHMD in 1966 (Sutherland 1968). Since then, OHMDs have been commercialized and introduced to the mass market although not very successfully (Rolland and Cakmakci 2009). Nevertheless, diffusion and adoption of OHMDs within personal and professional domains are predicted to increase exponentially during the next five to ten years (Gartner 2014; PWC 2014).

As OHMDs are attracting attention of organizations, more companies are working to develop the technology. Google Glass is an experimental OHMD that supports information exchange through augmented reality technology. The technology encompasses a screen, camera, and speakers in a spectacle frame, which enables a blending of the physical and virtual reality by facilitating immediate access to and registration of information through Internet connectivity. Google Glass is controlled primarily via voice command, which allows for hands-free usage. Its use and ongoing development is seen within different professions such as biohazard handling (Chang et al. 2015), the police (Christian et al. 2014), surgery (Muensterer et al. 2014; Schreinemacher et al. 2014), and now in agriculture.

Danish agriculture represents an interesting and relevant case of digital innovation as farmers face increasing customer and regulatory demands while also experiencing hostile competitive environments. The profit margin is diminishing concurrently with increasing employee salaries and decreasing product prices. Farmers are also challenged by growing registration requirements, which affect their work practices and administrative burdens. As a consequence, farmers are forced to seek novel solutions in solving these challenges. The solutions include adopting technologies for work practice optimization and process innovation to comply with legislative demands (SEGES senior consultant; SEGES cattle consultant). This paper investigates the use of Google Glass (Explorer Edition) as a means to deal with the challenges faced by four Danish dairy cattle farms. Google Glass is a particularly interesting technology because it offers real-time information processing on the spot and supports digitization of administrative work practices. In investigating the digital innovation potential of the technology, this paper addresses the following research question:

To what extent does Google Glass support work practices in agricultural organizations?

The contributions of this paper are twofold. The first contribution is an explanation of farmers' complex evaluation of the required investments for successful innovation of work practices through adoption of Google Glass. The evaluation of investments occurs when farmers draw on past experiences, present applications, and future possibilities for technology in use. The second contribution is a description of the potential that the technology holds for innovation of farmers' work practices. More specifically we will describe how Google Glass enables simultaneous performance of situation-specific and information-related work practices.

Following this introduction, we provide a brief introduction to the concept of sociomateriality which serves as theoretical framing of our reflective analysis. We also introduce key papers on the temporal dimension of technology use which relate to our findings. In section three, we describe our research methodology, including the use of grounded theory as well as theory in this multiple case study. We then present our findings through a case analysis and subsequent reflective analysis. The case analysis contains relevant empirical observations of technology use and work practices in the four agricultural organizations. In addition, it explains how farmers evaluate the requirements for successful use of the Google Glass technology within their organizations. The reflective analysis draws on sociomateriality concepts to discuss the innovation potential in an imbrication of the technology and work practices. Last, but not least, we discuss the value of our findings in relation to work practices in general.

2 Theorizing technology and organizational interaction

This paper contributes to research on the interplay between technology and work practice. We base our reflective analysis on Leonardi's (2008; 2011; 2013) critical realist perspective on sociomateriality due to the fact that it is well-aligned with the results of our inductive case analysis. Our analysis shows that 1) technologies and work practices co-evolve through mutual influence and interdependency, though human actors clearly distinguish between work practices and technologies; and 2) the temporal aspect of this evolution is key to the design of processes as well as technologies. We now turn our attention to extant literature related to these findings.

2.1 The concept of sociomateriality

By describing the co-evolution of technologies and work practices, this study is closely related to previous research on sociomateriality. Extant literature on sociomateriality is grounded in one of two competing ontological premises: agential versus critical realism; a subject matter that has been discussed extensively (Kautz and Jensen 2013). Agential realism challenges the dichotomy between the material and the social (Orlikowski 2007, 2010). Drawing on Barad's concepts (Barad 2003) to describe sociomateriality, Orlikowski argues that it is not possible to separate the social and material except for purposes of analysis, and she claims that it is impossible to conceive of them as stable entities. Instead, the focus should be on the concept of performativity, which recognizes materiality and social aspects of practice as dynamic entities, entangled through constantly developing relationships in what Orlikowski terms 'sociomaterial assemblages' (Orlikowski 2007, 2010; Orlikowski and Scott 2008; Introna 2013).

This perceived inseparability of materiality and social aspects of practice makes investigations of technology use in organizational settings difficult, which leads Leonardi (2013) to propose a distinction between materiality and social interaction. Basing his conceptualization of sociomateriality on critical realism, he elaborates this distinction by introducing the concepts of realms of structure and action. According to Leonardi (2013, p.72)

> materiality is thought to be a structural property while social interaction occurs in the realm of action [and] the realms of structure and action are distinct. They are not recursive […] but they are interactive in that phenomena such as organizations are constituted at their confluence.

Sociomaterial practices thus represent the space within which the realm of action and structure become imbricated.

By using the concept of imbrication, Leonardi illustrates that, when seen from a distance, the realms of structure and action *look* as if they are the same phenomenon (Leonardi 2011; Leonardi and Rodriguez-Lluesma 2013). The realms of structure and action have separate agencies, but "[…] when they become imbricated—interlocked in particular sequences—they together produce, sustain, or change either routines or technologies" (Leonardi 2011, p. 149). In terms of social interaction, human actors have goals, whereas—from a structural perspective—technologies have affordances enabling human actors to pursue these goals. Ultimately, human actors have intentions, which they act upon, and therefore human activity accelerates the imbrication process; when technologies constrain human goals, actors seek to adapt and change technology. In turn, this process affects human actors in both predicted and unpredicted ways, because actors are unable to completely control technology and the direction in which organizations develop. The notion of imbrication thus explains how human actors and technologies change, but also how they interlock in developing and shaping the organization.

2.2 The temporal dimension in organizational practice

As mentioned above, this study describes the imbrication of technology and work practices from a temporal perspective: how past experiences, present applications, and envisioned future possibilities of technology use relate to one another and drive technology investment decisions. Thus, our research relates to extant literature that foregrounds the temporal dimension of technology use in organizational practice. Thus, our research relates to extant literature that foregrounds the temporal dimension of technology use in organizational practice. Part of this literature focuses on how long-term expectation guide human actors in their present work practices (Steinhardt and Jackson 2015), the need for short term goals in order for developers to understand the product being developed (Karasti et al. 2010), and tensions in long-term planning of infrastructure development (Ribes and Finholdt 2009), and introduces new theoretical concepts, e.g.,'project time', 'infrastructure time', and 'strategy of the long now'. Whereas these three papers share a constructivist research approach that leaves little room for the agency of technology, Barrett et al. (2012) and Venters et al. (2014) include both technology and human actors in their studies.

Both Barrett et al. (2012) and Venters et al. (2014) are inspired by Pickering's (1995) 'mangle of practice' and include temporal aspects of technological and organizational development. Both papers describe materiality as performed relationships and reference the literature on the concept of performativity (Orlikowski 2007; Orlikowski and Scott 2008), which is based on an agential realist perspective on sociomateriality. Barrett et al.'s (2012) study of robots in pharmacy work extends Pickerings' concept of tuning by describing materials as performed relations, meaning that materiality emerges when materials are intertwined with social behavior in ongoing, situated practices. Venters et al. (2014) describe time as a coordinating mechanism between organizational practice and digital infrastructure in their study of particle collisions. They provide insight into how the past and envisioned future alter coordination practices as well as the tensions that emerge during coordination (Venters et al. 2014). Common to these studies is the foregrounding of the material, social, and temporal dimensions of practice. These concepts are foundational in the sense that they shed light on how the relationship between technology and human actors come into being over time.

Although these contributions to the sociomateriality literature are valuable, they provide incomplete knowledge of the relationship between technology and work practices, because of their grounding in agential realism (Orlikowski 2007, 2010; Orlikowski and Scott 2008; Scott and Orlikowski 2014). Agential realism does not adequately support investigations of innovation and dynamic developments within organizations, because of the ontological inseparability of materiality and social aspects of practice that it enforces (Mutch 2013; Leonardi 2013). More specifically, the agential realist perspective on sociomateriality is problematic because the notion of performativity describes any action as a dynamic, sociomaterial process (Kautz & Jensen 2013) that leaves no room for a separation of entities (i.e., technologies and human actors) in trying to understand their influence on organizational development and practice (Mutch 2013).

The critical realist perspective on sociomateriality presupposes a separation of entities (the realms of structure and action) and their attributes, which enables researchers and practitioners to focus on the redesign of processes and technologies separately while recognizing their interdependency. Accordingly, it supports studies of how organizations emerge (Leonardi and Rodriguez-Lluesma 2013). Papers subscribing to the critical realist perspective on sociomateriality share a common design interest (Ulmer and Pallud 2014; de Vaujany and Vaast 2014; Leonardi 2011; Ktistakis and Akoumianakis 2014).

Subscribing to the critical realist stance, we base our reflective analysis on Leonardi's conceptualization of sociomateriality, because it is well-aligned with the purpose of our research and our case study approach. This analytical framing enables us to address the research question by 1) allowing us to pay equal attention to the realms of structure and action, and 2) supporting our investigation of in the context of organizational change and development through the concept of imbrication.

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3 Research methodology

The empirical data were collected as part of a multiple case study of four Danish cattle farms. First, we provide an introduction to the context of cattle farming and Danish agriculture. Second, we describe our research approach including data collection and analysis.

3.1 Case description

The GlassCow project. The use value and innovative potential of Google Glass as part of farmers' everyday work practices were investigated in collaboration between Aarhus University, Business Academy Aarhus, SEGES (knowledge center for agriculture covering various aspects of farming and farm management) through development and testing of a Google Glass Explorer Edition application called "GlassCow". The application was developed for use in and support of Danish cattle farmers' work practices in close collaboration with farmers and based on extensive ethnographic studies of cattle farming. GlassCow features solutions to identified agricultural challenges such as being able at any time and anywhere to access and register information about the health of cattle, milk production, and reproduction of animals. Figure 1 contains two screenshots of the GlassCow app interface.

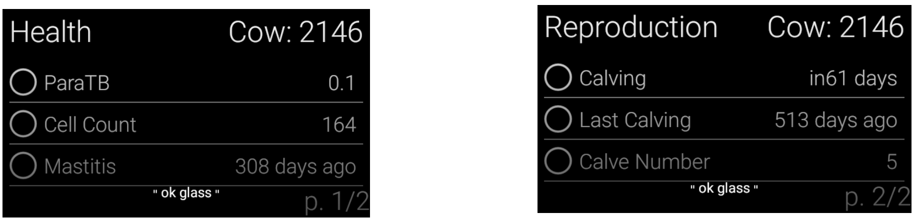

Figure 1. Screenshots of GlassCow interface

Development of Danish cattle organizations: an historical account. Since the 1960s, Danish farms have gradually grown in size and become more specialized. According to SEGES, in 1965 135,000 Danish cattle farms had an average of 10 cows; by 2013 there were 3,200 farms with an average of 162 cows (SEGES).

With growth and specialization, it is becoming increasingly important to store, access, and use large amounts of information to ensure appropriate and timely decisions regarding insemination, animal health, fodder, milk production, etc. In the 1950s, it was decided to collect and systematize information to support decision-making with regard to insemination and breeding. Contemporary with this development, emerging technological opportunities made it possible and convenient to store large amounts of data. In 1982, a new identification system was introduced by the Danish Cattle Federation, and since 1998 data on all cattle have been stored as part of the Central Husbandry Register (CHR), which provides for livestock identification, registration, and traceability. Furthermore, since 1999 Danish and European laws have mandated that farmers register certain information regarding cattle. The Danish Ministry of Environment and Food has formed a partnership with various agricultural organizations regarding the future development of the database. As a result, legislative demands for information have grown, increasing the administrative obligations and tasks of farmers (SEGES Cattle Consultant).

The database is, however, an important resource for both farmers and public authorities. It enables the authorities to conduct in-depth investigations into numerous aspects of livestock and farm performance. Furthermore, Danish farmers and consultants within the agricultural industry are able to utilize the information that they register and share through the database for, e.g., quality improvements and production optimization (SEGES Cattle Consultant).

The increasing demands on agricultural organizations in terms of registration, information processing, and efficiency improvements have over the years necessitated an increasing use of technologies. Farmers depend on many different information systems which are accessed through computers, smartphones, and robotic systems (e.g.,for automatic milking). Among these is the smartphone app "SmartCow" which enables mobile access to and registration of cattle information.

Life of a Danish cattle farmer. A typical day of a Danish cattle farmer revolves around the caretaking of the animals. He goes to the barn very early in the morning where he is greeted by the many cows that loudly express their eagerness to be milked. The milking process is handled either manually by the farmer or by a robotic milking system. The farmer begins by walking from one end of the barn to the other to make sure the cattle are fit and healthy, look for newborn calves, and drive the cattle toward the milking parlor. The milking process consists of cleaning the udder, then attaching pumps to the tits, and finally washing the udder with fluids to prevent mastitis by killing bacteria around the tits. The farmer is moving around all the time and attends to one cow while another one is being milked. Milking is routine-based and swiftly executed by the farmer without much conscious thought processing. More energy goes into evaluating the health of each cow during the milking process. This is the time of day where the farmer is closest to his animals. If a cow shows signs of illness or being in heat, the farmer walks over to his computer in his farm office to register his observations or validate them against

CHR. This situation often occurs many times during the milking process. However, at farms with Automatic Milking Systems (AMS) the process differs substantially with the installation of robotic stations in the barns. The cows walk freely into the robotic stations which register the cows by their identification tags. The milking process is fully automated by the AMS which is capable of accessing and storing cattle information in computer systems. Nevertheless, the farmer needs to check every morning if some of the cows have not entered the robotic stations by themselves and herd them into the stations. He must also observe and register information manually in CHR.

Subsequently, the farmer mucks out the barn unless he already did this before the milking process. He uses a large shovel to collect manure and a tractor to spread out hay. This is also routine work, and he is carefully observing the cows for signs of illness or their being in heat while doing the job. If so, he registers his observations and validates them against previous registrations as a basis for deciding what to do.

Another important task is feeding the cattle. This is not only a matter of distributing the fodder but also mixing it to balance energy sources and, on the one hand, keep the cows fat enough to produce milk and, on the other hand, lean enough to stay healthy. To complicate the matter even further, the mix of compounds differs depending on gestation period and whether it is a heifer or dairy cow. The task is particularly challenging due to the difficulty in navigating the tractor when trying to achieve precision in weighing the fodder on the scale. The farmers need both hands when operating machines like tractors while concentrating on the situation at hand.

During the day, the farmer will also encounter unexpected tasks such as those associated with injuries or illnesses; cows calving; machinery in need of repairs; inspections of the farm etc. The day is spent outdoors working on situation-specific tasks. Some tasks are specific to the time of year. For example, work in the crop field takes place between spring and fall, whereas repairs to farm buildings and machinery are mostly carried out during winter.

When finished with the outdoor tasks, the farmer returns to his desk. Work in front of the computer starts with processing information that was not registered during the day (newborn calves, health and injuries, heat time etc.), but it also entails accounting, calculating fodder mixtures, activity planning, etc.

The GlassCow farmers. The GlassCow test revolved around four Danish cattle farmers who differ in certain respects, for instance with regard to their use of technology (See Table 1).

Farmer	*Age*	*Year of purchase*	*Size of farm (acres)*	*# of cattle*	*Employees*	*Information systems adopted to support work practices*
Nis	55	1982	105	110	One employee	Conventional milking system; computers; smartphones
Mikkel	34	2011	180	130	Mikkel's parents and one additional employee	Milking robots (automatic milking); activity trackers; computers; smartphones
Eskild	61	1977	200	145	Eskild's wife and two students	Milking robots (automatic milking); computers
Wim	45	1995	164	210	Wim's wife and one employee	Conventional milking system; activity trackers; computers

Table 1. Presentation of farmers

Nis is 55 years old. Nis inherited his farm, which he has worked on for the past 32 years. Nis takes care of his 105-acre farm with its 110 dairy cows while also working a part-time consultancy job. The productivity and yield of his farm therefore largely depend on his one employee. Nis' consultancy job in a large company has made technological devices an integral part of his everyday life. Nis uses his smartphone to register observations and access information about his cattle. His computer also plays an important role in supporting his everyday work practices at the farm.

At age 34, *Mikkel* is the youngest of the four farmers. He finished his Agricultural Economics education in 2004 and has since 2011 owned a 180-acre ecological farm, including 130 dairy cows, together with his parents. They are, in addition to Mikkel's one employee, still actively involved in the day-to-day work. Mikkel's technological experience is extensive. He not only uses smartphone apps like SmartCow for registering and accessing information about cows, Mikkel also owns an automatic milking system.

Eskild took over his farm in 1977, which has been passed down through generations, and in time Eskild's son will inherit the farm. Eskild owns 145 dairy cows and more than 200 acres of crop fields. Eskild teaches farm management to two students who work for him. Eskild operates an automatic milking system, which requires knowledge of different computer systems. Except for calling, texting, and checking his alarm system, Eskild does not use his smartphone, and information about cows is memorized or written down on notepads before being entered into the database or used in the field.

Wim is 45 years and has been a farmer for 20 years. Wim's farm is 164 acres and is home to 210 dairy cows. Wim and his wife bought the farm in the mid-1990s. To assist him on the farm, Wim has help from his wife and one employee. Wim is not very interested in technology. He brings information to and from the computer by writing notes on his hand.

3.2 Research design

Our study follows Corbin and Strauss' (2008) qualitative research method for data collection and analysis. Thus, we set out to collect and analyze empirical data about technology in work practices without any preconceptions. However, we recognize our subjectivity in trying to understand the cases under investigation. Following Corbin and Strauss' (2008) sensitivity notion, we made conscious use of our existing knowledge and experience in conducting the case study while giving preference to the collected data. Thus, our existing knowledge and interest in, for example, sociomateriality

> provide the mental capacity to respond to and receive the messages contained in data—all the while keeping in mind that our findings are a product of data *plus* what the researcher brings to the analysis (Corbin and Strauss 2008. p. 33).

In the following, we describe how data were collected and analyzed. We explicate our deviations from Corbin and Strauss' (2008) methodological guidelines.

Data collection. Data were collected in the spring of 2015 by the two researchers and included four Danish dairy farmers who were chosen, because they differ from one another in terms of both personal backgrounds and professional experiences, which provide for an in-depth and comprehensive case study (Glaser and Strauss 1967). The case study included different stages of research:

- *Pre-observations:* We visited the dairy farmers over a couple of days to gain an awareness of the farmers' work practices and use of technology through ethnographic observations and informal interviews. This amounted to 32 hours of pre-observations.
- *Test introduction:* Each farmer was given an introduction to Google Glass and the GlassCow application before the test started. Each introduction lasted one to

two hours. The farmers were subsequently given the rest of the day to experiment with the glasses without our being present.

- *Test:* Each farmer spent seven days testing and using the glasses in everyday work practices. Pictures from the test are shown in Figure 2. During the test, we visited the farmers and made ethnographic observations throughout the work day and conducted informal interviews during mealtimes and breaks. We spent 90 hours observing, which—together with the informal interviews—yielded 168 pages of transcription. Furthermore, a field diary was used to write down thoughts and reflections based on the observations since these were considered valuable to subsequent analyses as suggested by Corbin and Strauss (2008). A software engineer from the GlassCow development team was on standby to offer the farmers technical assistance if needed.
- *Telephone interviews:* During the test, we conducted 10 telephone interviews on days when we did not visit the farmers. Each interview lasted approximately 15 minutes, was semi-structured in nature, and served both to assist and inspire the farmers to use the glasses, which corresponds to Thaler and Sunstein's (2009) notion of nudging.
- *Closing interview:* We conducted four semi-structured interviews at the end of the test when we went to collect the glasses. The interviews lasted up to an hour. The 3 hours and 30 minutes of interviews were subsequently transcribed which resulted in 69 pages of transcription. The purpose of these interviews was to give the farmers an opportunity to share their experiences with Google Glass while also comparing these to other technologies. The researchers therefore started the interview with questions about the farmer's use of smartphones and computers (e.g.,"can you describe which of your work practices involve the use

Figure 2. Farmers working with Google Glass

of computer or smartphone?") before moving on to questions about their use of and experience with Google Glass (e.g.,"in which situations have you used the GlassCow?"). This approach facilitated a comparison of the technologies and an assessment of the overall value of Google Glass to the farmers.

One of the researchers spent 21 days observing the GlassCow farmers while the other researcher probed and questioned these observations. Furthermore, an agricultural student assisted during the pre-observations and test introduction, and acted as a form of translator between the farmers and the researchers, for example by ensuring that important details were provided during the test introduction. Both researchers took part in the closing interviews to ensure that all relevant questions were asked. All observations, interviews, and phone conversations were audio recorded.

We deviate from Corbin and Strauss' (2008) methodological guidelines in the following ways: Firstly, because of the limited timeframe of the test of Google Glass, it was not possible to analyze the transcribed data and then return to the field with new questions for the purpose of ensuring saturation. In recognition of this limitation, we spent as much time as possible in the field during the test. During off-hours, we revisited and reflected on our the field notes and returned to the field with clarifying questions. Secondly, we were limited by the choice of farmers and contexts, which were selected before the test. This limited us in our ability to collect data relating to questions that appeared on the basis of our analysis of previously collected data. Our theorizing was therefore limited by the data relating to these particular contexts. Thirdly, we deviate from the tenets of grounded theory by audio recording all interactions for documentation purposes. This approach is not typical of grounded theory because of the risk of drowning in data. Again, due to the limited timeframe, the risk was assessed as being low.

Data analysis. Following Corbin and Strauss (2008), all audio recordings were carefully examined by comparing the transcriptions with diaries and field notes before coding began. The documents were loaded into the qualitative data analysis software NVivo in which an iterative coding and analysis process following Corbin and Strauss' (2008) methodological guidelines was executed. In total, we categorized 2100 text passages, adding memos to explain the reasoning behind each categorization.

Analyzing the data resulted in five categories in total. Three categories emerged from the empirical data while the remaining two were derived from the sociomateriality literature (part of the reflective analysis). In the following, we describe how the analysis was performed and how the categories emerged through open coding of the empirical data. Table 2 and 3 summarize the categories and provide an overview of the subcategories that were identified through inductive analysis and in turn lead to the five high-level categories.

Our open coding began by describing at a conceptual level the meaning expressed in different parts of the data. As an example, the category 'past' emerged as informants continually mentioned past experiences with other technologies and work practices when reflecting upon their use of Google Glass. As a consequence, we used 'technology experience' and 'work practice experience' as subcategories. The open coding was a highly iterative process, during which we repeatedly revisited categorized passages to check and verify their accuracy. This was done whenever we came across parts of the data which reflected other aspects or dimensions of the same category (Corbin and Strauss 2008). The three categories ('past', 'present', and 'future'), which were derived in this grounded manner, express time perspectives on technology use as part of work practices. The past encompasses reflections upon experiences farmers had with other technologies and work practices; present use of Google Glass and reflections upon current opportunities and constraints are contained within the 'present' category; and goals and ideas concerning future usage were categorized under 'future'. The categories and subcategories are summarized in Table 2.

The remaining two categories ('realm of structure' and 'realm of action') are theory-based and were used deductively as part of our retrospective analysis. The categories were introduced as the farmers reflected upon their work practices and technology use, inviting us to apply a sociomaterial perspective in our reflective analysis. We used these categories without any biased or predefined interpretation of meaning, which is to say that we used the concepts of realm of action and realm of structure, but our understanding of their meaning emerged inductively as the data were analyzed and categorized. The subcategories are testimony of our grounded method in the sense that they are case specific. As shown in Table 3, the subcategories of the realm of structure include, e.g., 'computer functionality', 'smartphone functionality', 'Google Glass functionality', and 'technology comparison'. Overall, the categories describe the realm of action of farmers' work practices and considerations regarding the role of technology in farming. This analytical distinction between the realms of structure and action presented some challenges in determining whether farmers were in fact reflecting upon technology or work practices. These difficulties occurred as parts of the empirical data describe both affordances and constraints of technology with regard to specific work practices. Such instances were subjects of discussion among the researchers, and by practicing check coding a high degree of intercoder reliability (Miles and Huberman 1995) was ensured. Some parts of the data are coded as belonging to both categories. An example is the answers farmers provided to an interview question regarding their use of tools during

Categories	*Description*	*Subcategories*
Past	Previous experiences with technology prior to Google Glass. Used as past references when describing present use of Google Glass and future possibilities.	Technology experience Work practice experience
Present	The present applications of Google Glass. The past and future are referred to during present use.	Technology in use Key work practices
Future	Thoughts concerning future usage of Google Glass. Describes requirements for extended use of the technology and value realization. Is referred to during present use and in comparisons to the past.	Potential of technology Possibilities for work practice support and innovation Technological requirements Social requirements (of, e.g., an organizational and human nature)

Table 2. Grounded categories

normal work days. In general, the farmers answer this question by explaining which technologies they apply, but also how they apply them and for what purpose. The sociomateriality based categories and subcategories are summarized in Table 3.

Categories	*Description*	*Subcategories*
Realm of structure	The functionality of different technologies and comparisons across technologies. Is often mentioned while talking about work practices.	Computer functionality Smartphone functionality Google Glass functionality Technology comparison
Realm of action	Social issues and organizational aspects of farmers' work practices and their use of technologies to accomplish various tasks. Comparisons of means of completing tasks. Thoughts on handling multiple tasks. Demands on farmers in integrating technology into work practices. Is often mentioned while describing use of technologies as tools.	Human memory Work practices using computers or smartphones Work practices with Google Glass Farm practice characteristics Work practice comparisons Multitasking Integration of technology into work practices

Table 3. Theory-based categories

The categories and our understanding of them evolved during the iterative coding process as a result of comparisons across parts of the data. Properties, dimensions, and subcategories emerged while we questioned, compared, and looked for negative cases within the empirical data sets. Every time we categorized text passages, a memo of variable length was attached to record the thought process behind the interpretation. These memos were invaluable and instrumental in analyzing the data when certain parts proved difficult to categorize, as they provided a firm basis for comparing and contrasting similarities and differences in categorization across data sets. This was an iterative exercise as we continually returned to previously coded data to re-examine the rationale behind our categorization (Corbin and Strauss 2008). As an example of evolving realizations that forced us to re-examine our coding, we noticed that it was sometimes difficult to understand farmers' comparisons of different technologies. When we investigated this analytical problem, we became aware of farmers not only comparing technologies but simultaneously comparing work practices. This example also highlights the close link between open coding where concepts emerge from the data and axial coding where patterns between different categories become apparent (Glaser and Strauss 1967; Corbin and Strauss 2008). Having completed the open coding, we found ourselves gradually comparing categories and identifying patterns between them. Axial coding therefore commenced intuitively and naturally.

4 Case analysis

In this section, we present the findings from our study of the four cattle farms. From observing the farmers, it is apparent that information systems are vital to their work practices. They work with large amounts of information concerning animal health, heat time, production, age, milking processes, etc. that support the farmers in taking care of the animals and managing the farm business. In presenting the findings, we focus on the farmers' use of information systems technology as part of their everyday work practices and their implications. In doing so, we describe how past experiences, present applications, and future possibilities are all parts of the farmers' reflections upon their use of Google Glass in support of work practices.

Table 4 describes the findings for each farmer in terms of a temporal perspective ('past', 'present', and 'future') on technology use in work practices. The table is divided into past experiences with technologies and work practices; current use of technology and how it is applied in support of work practices; and thoughts on the future role of technology in supporting an innovating work practices. The thoughts regarding the future also include requirements for successfully realizing the potential and value of technology.

Looking across the temporal perspective and the four cases, we identify patterns which we describe in the following. Our aim is to present our first contribution; that past experiences, present applications, and future possibilities are both distinct and interdependent aspects of evaluations of requirements for digital innovation of work practices.

Farmer	*Past*	*Present*	*Future*
Nis	*Technology experience* • Computers for information processing • Smartphones for phone calls, text messages, and the SmartCow app *Work practice experience* • Use of computer requires walking to the office and back • Smartphone usage is problematic due to it requiring both hands • Trying to remember and forget information before documenting it • Implementing new technologies requires coordination with employees to align knowledge and expectations of use	*Technology in use* • GG for phone calls, e-mails, text messages, and information processing • Audio problems and difficulties reading the screen in sunlight *Work practice application* • GG to access information about cows while milking, mixing fodder, feeding, and moving the cattle • Support of decision-making (e.g.,placement of pregnant and non-pregnant cows) • Identification of and zooming in on areas of concern (e.g.,symptoms of illnesses) • Immediate response to calls and messages	*Technological possibilities* • Crop-related app *Work practice possibilities* • Video conferencing with agricultural experts and vets providing consultancy on demand and reducing expenditures *Technological demands* • Better audio quality • Better screen readability *Social demands* • Investing time discovering possibilities in GG and increasing use knowledge • Organizing GG use with employees

Farmer	*Past*	*Present*	*Future*
Mikkel	*Technology experience* • Computers for information processing (e.g.,information from the automatic milking system) • Smartphones for phone calls, text messaging, and information search using SmartCow *Work practice experience* • Memorizing information resulting occasionally in information loss • Registering information on smartphone though it is distracting and an obstacle during animal caretaking (requires undivided and two-handed use) • Integrating smartphones into daily routines takes time due to familiarization with functionalities	*Technology in use* • Google Glass (GG) for phone calls, text messages, e-mails, and apps (e.g.,a timer) • Registration and search of information • GG worked well in the barn environment, were comfortable to wear, and provided relevant information • Ability to enter legally required registrations is missing • Poor audio quality during phone calls and wrong recognition of voice commands *Work practice application* • GG enabled access to and registration of information while engaged in work activities • Information supports decision-making (e.g.,whether to move cattle, inseminate them, or treat injuries and illnesses) • Convenience of discretely receiving pop-up text messages in GG • A GG timer app is useful when mixing fodder	*Technological possibilities* • Tracking cattle with sensors in the field and in barns *Work practice possibilities* • Mobile (wearable) information access supporting decision-making during work practices • Using GG in other agricultural areas (e.g.,crops) *Technological demands* • Availability of additional information (automatic milking system & censor-based localization of cows) • Remove some information & register other differently (age of cows in years and months instead of days) • Support legally required registrations • Better audio quality during phone calls • Improve voice control *Social demands* • Time to familiarize oneself with GG

Farmer	*Past*	*Present*	*Future*
Eskild	*Technology experience* • Computers for information processing • Smartphones for phone calls • SmartCow is impractical due to lack of integration with DelPro as the primary information system *Work practice experience* • Information is written on hands, paper, or memorized resulting in information overload or loss • Retains most information about cattle in memory and rarely needs verification • Needs time to learn how to use smartphones	*Technology in use* • GG for incoming phone calls, taking pictures, and accessing data • Lack of integration and access to registered observations in DelPro • Audio problems during phone calls • GG unable to recognize his pronunciation *Work practice application* • Use (student) of GG to validate observations (e.g.,heat time and injuries) while mucking out in the barn • GG is distracting because of the need (student) to stop and think about how to use the technology • Lack of fluency in the English language (student) inhibits understanding and communication	*Technological possibilities* • Videos for teaching agricultural practices • Displaying fodder related information • Diagnosing plant diseases • Information exchange between GG and the automatic milking system *Work practice possibilities* • Teaching students about agricultural work practices in novel (learning enhancing) ways • Information at hand when working with plants • Accessing information during fodder mixing • Accessing information from the automatic milking system *Technological demands* • Integration between GlassCow and DelPro • Greater battery capacity • Better audio quality during phone calls • Improve voice control • Danish language pack for GG *Social demands* • Need to become familiar with GG

Farmer	*Past*	*Present*	*Future*
Wim	*Technology experience* • Computer usage • Smartphones for phone calls • SmartCow registration and data access is too slow *Work practice experience* • Forgetting to register information due to distance between office and barn • Becoming familiar with smartphones is time consuming	*Technology in use* • GG for taking pictures, phone calls, and accessing information • Using GG in an agricultural work environment is challenging (poor audio quality during phone conversations; inability to use touch panel while wearing gloves) • Current functionality is inadequate as it does not support legally required registrations *Work practice application* • Using GG for phone conversations and checking heat time information for insemination purposes while working • Instant access to cattle information	*Technological possibilities* • Registration of medication usage Work practice possibilities • Completion of administrative and manual labor-intensive work practices simultaneously *Technological demands* • Support of statutory registrations • Faster response time • Improve voice control • Better audio quality during phone calls *Social demands* • Need to become familiar with GG

Table 4. Within-case descriptions of the four farmers

4.1 Past, present, and future

The categories 'past', 'present', and 'future' capture the temporal perspectives farmers express in the empirical data. More accurately, the 'present' represents the current test and application of Google Glass. In comparison, the 'past' reflects the farmers' experiences before the introduction of Google Glass, and the 'future' relates to possible uses of the glasses. In this case analysis, we describe similarities and differences across the four cases. Table 5 presents an overview of our findings.

Patterns	*Past*	*Present*	*Future*
Similar-ities	*Technology experience* • Computer usage *Work practice experience* • Information processing is separated from situation-specific work practices • Technology adoption requires time and effort	*Technology in use* • GG provides access to valuable information • Registration of observations is cumbersome • Use of voice control is challenging but valuable • OHMD is useful • Problems with audio quality *Work practice application* • Accessing information from CHR in situation-specific work practices • Conferring with colleagues using GG in situation-specific work practices	*Technological possibilities* • Information access in relation to cattle feeding, activity tracking, and crops monitoring *Work practice possibilities* • Use of information during situation-specific work practices *Technological demands* • Support legally required registrations • Improve audio quality and phone call functionality • Improve voice control functionality Human demands • Time and effort in familiarizing with and integrating technology into work practices
Differ-ences	*Technology experience* • Use of smartphones • Use of software applications *Work practice experience* • Information processing takes place in situ in the field but interferes with situation-specific work practices • Variations in adoption practices	*Technology in use* • GG used for e-mail, text messaging, and applications from the app store • Challenges: non-responsive touchpad, difficulty seeing the screen, voice recognition problems, and lack of database integration when using other software such as DelPro. *Work practice application* • Emerging information-related tasks throughout the work day; accessing information during morning routines, while teaching students, and during milking	*Technological possibilities* • Teaching students through instructional videos, tracking cattle using sensors, and registering medication usage Work practice possibilities • Teaching students in situation-specific work practices and localizing cattle in pastures or barns. *Technological demands* • Integrating with other databases, software, and tools; better understanding of Danish accents (English) Human demands • Coordinating and organizing use of GG with colleagues; learning to use the technology

Table 5. Comparison of past experiences, present applications, and future possibilities

Past. With regard to past experiences, we discovered similarities between farmers considering the type of technology previously used and how. All farmers use desktop computers to some extent and experience the same kinds of challenges. Although desktop computers offer convenience and speed in accessing information, they are not mobile. Consequently, computers are placed in offices and require the farmers' undivided attention when working on information-related tasks. Desktop computers therefore make timely and accurate registration of and access to information difficult. In terms of past experiences regarding technology implementation, all farmers emphasize that learning and adapting to new technologies require time and effort. Investment in terms of time is important in facilitating the use of technologies in work practices (Mikkel; Eskild; Nis; Wim).

We also discovered differences in the farmers' past experiences with technology. Eskild and Wim, for instance, always bring their smartphones with them, but only use them to get in touch with colleagues, consultants, and experts. Eskild explains that he does not register and access information on his smartphone, because the SmartCow app is not integrated with his dairy management system, DelPro. For his part, Wim perceives his smartphone as too slow. By contrast, smartphones are valuable resources to both Mikkel and Nis. They describe the smartphone as a faster and more accurate way of registering and accessing information. They, however, also find smartphones distracting, because they require their attention and both hands for operation. We furthermore discovered that the farmers have different experiences with technology in support of work practices. While Nis stresses that technology integration into work practices requires planning and joint decision-making with employees to decide how and when to use technology, Mikkel wants to explore the features and functionality of different technologies himself. Adoption is often described with reference to previous experiences with technology and tools. Mikkel, for example, emphasizes becoming accustomed to wearing glasses.

Present. The farmers all agree that Google Glass in general—and the GlassCow application specifically—holds valuable information. However, the farmers find it difficult to register observations to a lesser or greater degree. They are interested in being able to make registrations required by law. The farmers also find the voice control and audio quality during phone conversations wanting. The voice commands are not always recognized, and the glasses are slow to respond. Apart from these challenges, the farmers agree that voice control and wearability are valuable properties of the technology, allowing them to move around and use their hands while operating Google Glass. In terms of actual use, all farmers access information in CHR, which is used in validating observations while working with the cattle. They furthermore use the phone calling functionality to get in touch with consultants or employees while working (Mikkel; Eskild; Nis; Wim).

Differences in the use of Google Glass are also discernable. Wim and Eskild use the glasses to access information through GlassCow, make phone calls, and take pictures; Nis also uses them for e-mailing and text messaging; and Mikkel even installs additional applications including a stopwatch and timer app. The farmers also experience different challenges. For instance, Eskild points to the lack of integration between GlassCow and DelPro, and Wim mentions that the touchpad will not respond when he wears rubber gloves. Nis stress the difficulty in seeing the text on the Google Glass screen in bright sunlight. The differences in use can in part be ascribed to differences in the situations in which Google Glass is used. Mikkel, for example, finds the glasses useful in support of various information-related work practices throughout the day; Wim uses Google Glass in confirming observations of cows in heat against information in GlassCow during his morning routine; Nis uses Google Glass to check cattle information during milking and reading e-mails periodically; and Eskild gives his student the glasses for checking the accuracy of her observations against already stored information. These differences show that the use of Google Glass is bound by the organizational context in which it is used.

Future. Similarities in terms of wishes for future developments of the technology are evident in the farmers' interests in being able to register information about their cattle. The farmers agree that Google Glass should support legally required registrations (Mikkel; Eskild; Nis; Wim). This is paramount to Google Glass easing the increasing administrative burdens of information-related tasks (Eskild; Wim). They also emphasize that the audio quality needs improving to facilitate conversations with experts and colleagues. Concerning voice control, the farmers experience operational challenges suggesting a need for improvement. With regard to future work practices, more time experimenting and learning is needed for the purpose of integrating and securing acceptance of the technology (Mikkel; Eskild; Nis; Wim). Eskild stress that Google Glass will not benefit him unless he is able to pose questions and ask for help conveniently and easily.

The farmers also offer many suggestions for future use in support of work practices. Eskild suggests that Google Glass be used for teaching purposes while Mikkel would like to use the technology to locate cows when it is time for milking. Eskild imagines that Google Glass could guide students through instructional videos, and Mikkel envisions Google Glass connecting with sensors in helping him localize individual cows.

Different possibilities for future integration into work practices are identified in all four organizations (Mikkel; Eskild; Nis; Wim). Additional ideas for future developments of the technology includes, for instance, Eskild's request for an integration between DelPro and GlassCow.

4.2 Temporal interdependency

Through the cross-case analysis, we identify patterns across the organizations. Not only are the concepts of 'past', 'present', and 'future' relevant in each of the cases, they are also interdependent affecting each another. In the following, we shed light on these patterns by providing examples from all four cases.

The complex temporal interdependencies is explained through two sequences. The one sequence begins with past experiences which translate into present applications and future possibilities. The other sequence starts off with future possibilities which motivate present applications and are interpreted through past experiences.

Beginning with the former sequence, past experiences influence current applications of Google Glass, constraining or supporting action within the present context of technology use and work practices. These past experiences and current applications further influence the farmers' ideas about future possibilities. An example is seen when Eskild quickly decides not to use Google Glass because he knows from past experiences with SmartCow that it does not integrate with DelPro. Furthermore, past experiences lead him to conclude that Google Glass is more useful in the hands of his student Emma, who has difficulty remembering all the relevant cattle information. This example shows that past experiences not only constrains Eskild's experimentation with Google Glass but that they also influence the present applications of Google Glass in support of work practices. Additionally, Eskild's past experiences influence the envisioned future possibilities as he describes the potential benefits of instructional videos for teaching purposes (Eskild).

The latter sequence illustrates how ideas for future use of the technology in support of work practices emerge when present applications in specific contexts inspire farmers in relation to past experiences. Moreover, these visions for the future influence current applications and recollection of past experiences. For example, Mikkel describes the future possibility of locating individual cows using Google Glass while he is walking his pastures in search for a specific cow. Additionally, he describes the need for becoming accustomed to using Google Glass while referring to the feeling of getting used to wearing a pair of glasses (Mikkel).

Each case shows how interactions with Google Glass and considerations regarding future use are shaped in an interdependency between the past, present, and future. Thoughts about future possibilities are always tied to past experiences and vice versa, and farmers' present applications are influenced by both past experiences and their ideas concerning future possibilities (Mikkel; Eskild; Nis; Wim). The difference between the two examples is that Eskild interprets present applications and future possibilities based on past experiences, while Mikkel thinks of future possibilities and projects these onto his present applications of the technology and interpretation of past experiences. These sequences are identified across the four farms, and all the farmers explain their applications and perceived value of the technology through these temporal perspectives (Mikkel; Eskild; Nis; Wim). Considerations regarding the future and the value of the technology are context-bound, in the sense that the farmers report distinct yet similar past experiences, present applications, and future possibilities.

5 Imbrication of technologies and practice

In this section, we reflect upon the analysis results by drawing on sociomateriality and the concept of imbrication. After accounting for the sociomaterial aspects, we describe past experiences, present applications, and future possibilities as elements in an evaluation of requirements for technology and work practice imbrication. Our aim is to describe our second contribution, the innovative potential of Google Glass in enabling simultaneous performance of practices related to situations and information relevant to those situations. Table 6 serves as a guide through the reflective analysis to show the realms of structure and action and their temporal imbrication.

5.1 Realms of structure and action

The Google Glass test shows that it is possible to distinguish between actions associated with technologies and human actors. Whereas technologies accomplish certain tasks, farmers accomplish others (Mikkel; Eskild; Nis; Wim). In describing the automatic milking system, Eskild for example says: "it shows that robots do a better job at milking than a distracted human." When farmers recall experiences with technology that acts, they are not referring to the realm of action, though they recount personal experiences of using technology. In the above example and similar situations, the farmer explains what the technology—rather than he—does. Conversely, just because a technology affects the realm of action, the specific action is not technological in nature. As human actors carry out particular practices, they are inherently social in nature even if the technology changes how the farmers perform them. These observations correspond to Leonardi's (2008; 2013) distinction between the realms of structure and action. In the following, we present our findings according to this distinction.

	Past	*Present*	*Future*
Realm of Structure	Stationary computers at specific locations requiring farmers' undivided attention. Smartphones with mobile information processing capability requiring farmers' undivided attention and both hands for operation	GG with mobile information processing capability. Wearable technology that enables hands-free use while performing situation-specific work practices	GG with additional programs, improved voice control functionality, and support of legally required registrations
Realm of Action	The situation-specific and information-related practices are interrelated but separated in space	The situation-specific and information-related practices are interrelated and mostly performed at the same location	The situation-specific and information-related practices are performed concurrently
Imbrica-tion	Computers allow farmers to store and access information about cattle. Farmers document events (information) away from action or use other means of documentation. Smartphones allow farmers to perform information-related work practices irrespective of location, though the technology reinforces a separation between situation and information	GG introduces possibilities for successful imbrication but fails. Requirements for future imbrication relate to both the realms of structure and action: GG needs additional apps, improved voice control functionality, and support of legally required registrations. Farmers need to learn and familiarize themselves with it	2 types of imbrication: 1) The materiality of GG and farmers' work practices are imbricated. 2) Farmers' situation-specific and information-related practices are imbricated

Table 6. Description of temporal changes to the realms of structure and action

Realm of structure. We have investigated the characteristics and use of different technologies used by the farmers in order to understand their limitations as well as their potential. Computers, smartphones, and Google Glass have all been used in the agricultural organizations (i.e., the farms) to access and register information. Computers are placed in offices and used for registering and displaying information about various operational aspects of the organizations (Mikkel; Eskild; Nis; Wim). They are described with reference to their large memory capacities, allowing information to be stored reliably and securely (Eskild). The computers have different software programs containing different information. The Viking program, for instance, allows the farmers to access information about insemination and breeding, and enables them to request assistance from inseminators (Wim; SEGES Cattle Consultant; pre-observations). The DLBR and DelPro programs give the farmers access to all cattle data in the CHR and provide them with the means to make legally required registrations or access information about culling, medicine and health, heat time cycles, etc. DLBR and DelPro are integrated with other technologies, which contain information from, e.g., automatic or manual milking systems (SEGES Cattle Consultant).

Unlike computers, smartphones are mobile yet allowing information to be stored and displayed like on computers. In addition to making phone calls and text messaging, the smartphones support the farmers in making legally required registrations and accessing CHR information through the SmartCow app (Mikkel; Nis). The SmartCow app only integrates with the DLBR and not DelPro (Eskild). Although the smartphones are mobile, they require use of both hands and the user's full attention (Mikkel; Nis).

Compared to smartphones and computers, Google Glass is wearable, but like the other two technologies it supports information storage and retrieval. Information is accessible through the GlassCow application. GlassCow is capable of presenting information about individual cows concerning health, heat time, age, milk production, and more. It also enables registration of observations in general but not the legally required registrations specifically. Google Glass features voice control, meaning that information about the cows is accessed and registered by voice commands. However, a problem with using this functionality is its lack of ability to reliably register farmers' voice commands (Mikkel; Eskild; Nis; Wim). Moreover, Google Glass can be controlled by means of an integrated touchpad on the side of the spectacle frame, although it does not always work as intended (Wim). Google Glass has a camera, which allows the user to take pictures (Mikkel; Eskild; Nis; Wim) and make video-supported phone conversations.

The three technologies share the ability to access and register information, but they differ in terms of how they support and accomplish these tasks. When revisiting the temporal perspective (past experiences, present applications, and future possibilities), we see similarities in farmers' accounts of these differences across technologies. The farmers recall past experiences with computers confined to specific locations that require their undivided attention (Mikkel; Eskild; Nis; Wim). Past experiences with smartphones are described with emphasis on the need for both hands and the user's full attention to operate them (Mikkel; Nis). Looking at present applications of Google Glass, the possibilities of operating them hands-free and being able to focus simultaneously on the virtual world on the screen and the real world of manual labor-intensive work practices are underscored (Mikkel; Eskild; Nis; Wim).

Realm of action. Interpreting the empirical data zooming in on the realm of action reveals two types of social work practices. In one sense, farmers are engaged in certain work practices in specific *situations*, including caretaking and treatment of cattle. These work practices are bound to the particular context, which includes the cow, the needed treatment, and the surrounding environment in which it took place. Examples of such tasks include gathering cows for milking, mucking out, feeding, moving cows to other pens, scattering straw, insemination, repairing tools, fences, and machines, and much more. These work practices often require the farmer to move around while using both hands to hold tools (such as brooms, shovels, or carts), drive agricultural machines like tractors or Bobcats, gather and move cows to other pens, manually milk cows, examine udders or hoofs, etc. These situation-specific work practices also require the farmers' attention (read: eyes focused on the task at hand) to cope with the different situations, and to observe and analyze cattle behavior (Mikkel; Eskild; Nis; Wim).

Generally speaking, such situation-specific work practices generate considerable amounts of *information* as farmers or machines monitor, analyze, and document the condition and well-being of the cattle. Information-related work practices therefore entail documenting and accessing current as well as previous incidents and status. Information is registered and accessed to facilitate more timely and appropriate decisions in different situations. Examples of the different kinds of information the farmers work with relate to animals' health, heat time, cattle cycles, pregnancy, drying off time, age, breeding, culling, and milk production, and the common cattle breeding index: NTM. These information-related practices draw on different technologies (Mikkel; Eskild; Nis; Wim) that provide the farmers with the means of registering, storing, and accessing the information.

The *situation-specific* and *information-related* practices are closely connected (Mikkel; Eskild; Nis; Wim). Effective decision-making and sound decisions about how to respond in any given situation are essential to the survival of farms in the fiercely competitive agricultural sector. As Wim stresses: "[…] that's why we get the cows pregnant and that's why all of it, it all falls or stands with that. And so, it is really important that we manage it well." Wim's statement sheds light on the importance of making accurate and correct decisions, which is achieved by establishing close links between situations and the information specific to those situations, which ensures high production efficiency and low production costs. Furthermore, closely linking information-related practices and situation-specific work practices allows for more accurate data, because farmers are able to register observations on the spot and take appropriate action if needed at that very moment instead of having to access or register information at a later stage with the risk of missing it (Mikkel; Eskild; Nis; Wim). Ultimately, the survival of the organization depends on it, as accurate and timely information translates into opportunities for optimization (Wim).

Using the concept of imbrication (Leonardi 2011; Leonardi and Rodriguez-Lluesma 2013), we continue in section 5.2 by describing the performance of and interaction between, on the one hand, technologies and, on the other hand, the situation-specific and information-related work practices. Applying a temporal perspective, it becomes evident that the performance and interaction in question depend upon the technologies used in support of the work practices.

5.2 The practice-technology imbrication

With the analysis of the realms of structure and action in mind, the concept of imbrication is revisited (Leonardi 2011; Leonardi and Rodriguez-Lluesma 2013). We draw on this concept to explain the imbrications of technologies and work practices. Looking at the realms of structure and action of farm work in Danish agriculture provides us with an understanding of past and current imbrications in addressing the research question, i.e., to what extent Google Glass supports work practices in agricultural organizations now and in the future.

To facilitate an understanding of the challenges that Google Glass helps farmers manage, we first describe the situation, i.e., imbrications, before Google Glass. As mentioned, computers were originally introduced in agricultural organizations due to their storage capacity. This feature enables farmers to conveniently store and access vast amounts of information. Previously, only information regarding insemination was available, but as farms grew in size and became more specialized additional information was stored and made available in the CHR database. Farmers became increasingly dependent on technology and information storage, because the growth of farms made it impossible to keep track of all relevant cattle information without technology. Furthermore, the information was vital to farming and farm management. As a result, and due to Danish law mandating certain registrations, farmers are today registering an increasing amount of information (SEGES Cattle Consultant). The use of computers resulted, however, in a separation of situation-specific and information-related work practices, because the computers were often—and still are—located in offices removed from the manual labor-intensive work environment (Mikkel; Eskild; Nis; Wim). Consequently, farmers either depend on information-related work practices away from the action or rely on other means of capturing and documenting information, such as using paper notes (Mikkel). This account describes the first imbrication of technology and work practices, as it shows how the structure of technology is implemented to address certain challenges, and how it thereby changes social aspects of work practices.

Smartphones were later introduced as a solution to the problem of immobility. Smartphones are characterized by their information storage capacity, processing capability, and mobility. This technology allows farmers to perform information-related work practices irrespective of location. Although it encourages some farmers to register and access information on the go, the farmers in our case study experience the use of smartphones as distracting and inconvenient (Mikkel; Nis). Among the problems documented in the empirical findings is the lack of integration between the smartphone app SmartCow and other information systems (Eskild). Smartphones are also perceived as too slow (Wim). Other farmers, who use smartphones daily, find that the technology reinforces a separation between *situation* and *information*, because smartphones require the use of both hands and the users' full attention (Mikkel; Nis). In other words, smartphones do not enable concurrent situation-specific and information-related work practices. While some farmers use smartphones to access and register information, they also rely on computers, their personal memory, and physical notes (Mikkel; Nis). Smartphones have nevertheless changed farmers' work practices in introducing the possibility of, for example, conducting phone conversations on location, which means that farmers can more easily consult colleagues and others during their work day (Mikkel; Eskild; Nis; Wim). This is another example of an imbrication of technology and work practices, in the sense that it shows technology being introduced as a solution to certain challenges and changing farmers' work practices in the process.

With regard to present applications of Google Glass, our reflective analysis of the realms of structure and action draws attention to the potential for imbrication. An imbrication of the glasses and farmers' work practices makes it possible to provide information about a situation as it unfolds. Like smartphones, Google Glass provides storage, processing power, and mobility. However, unlike smartphones, Google Glass affords hands-free operation. Famers can access and register information using voice commands. Moreover, the farmers are able to simultaneously pay attention to both information on the virtual screen and real-world situations at hand. The GlassCow application is used as a decision support tool, allowing farmers to validate observations against stored information and to register observations on the spot. This capability renders the distinction between situation-specific and information-related work practices meaningless as they can be performed concurrently, which in turn improves information and decision accuracy. Nis, for example, stresses that with Google Glass

> I don't have to stop during my daily work practice and find either my phone or paper and pen, and then either get information or save an observation I have made about an animal. I can do that without interrupting the work practice I am performing—I mean the physical work practice I am performing, whether it is milking, gathering cows for milking, or whatever I am doing." He elaborates by saying that "obviously, I need to learn how to operate the glasses with my voice

Nis clearly distinguishes between the manual labor-intensive work practices in specific situations and the information processing needs related to those situations that are manifest in information-related work practices. Nis also makes a distinction between work practices in the past, present, and future. In past situations, he had to "[…] stop during [his] work […]", whereas in the present "[…] I can do that without interfering with the work practice I am performing […]", but to do so efficiently in the future "[…] I need to learn how to operate the glasses […]". Both work practices and technologies change over time (Nis). Thus, Nis' statement underscores that technologies are closely related to both the temporal perspective and shifting work practices.

However, the farmers report various barriers to Google Glass adoption, which challenge such an imbrication of technology and work practices (Mikkel; Eskild; Nis; Wim).

Human and technological requirements. The complex interdependency between, on the one hand, past experiences, present applications, and future possibilities and, on the other hand, the notion of realms of structure and action gives us an understanding of the value of Google Glass to farmers. This understanding emerges through the comparison of past and future scenarios of the interplay between technology and work practices with the present situation. Moreover, it constitutes an evaluation of farmers' needs for future developments both in terms of the structure of technology and social action of work practices. These developments are prerequisites for imbrication of Google Glass and farmers' work practices. The needs become evident in farmers linking past experiences and future possibilities to the present situation (Mikkel; Eskild; Nis; Wim).

Examples of farmers' technology requirements are improved voice control functionality and the ability to make registrations mandated by law. As previously seen, these requirements relate to the farmers' past experiences with challenges of using computers, smartphones, and other technologies. The value of computers and smartphones is their support for the legally required registrations, while one of their drawbacks is the need to use both hands. Conversely, one drawback of Google Glass is that it only allows registration of general observations, while its value is the enabling of hands-free usage. Therefore, for the technology to support simultaneous performance of situation-specific and information-related work practices, the farmers require improvements of the voice control functionality and that the GlassCow application allows them to make the compulsory registrations in the future. In terms of work practices, technology adoption requires time to learn the functionalities of Google Glass and to become accustomed to wearing and using the glasses while working. These requirements are articulated as the farmers reflect upon their past experiences with technology and their present applications of Google Glass. These requirements also highlight the needed investments on the part of the farmers in order to implement the technology into work practices (Mikkel; Eskild; Nis; Wim).

Looking across the cases, it is evident that the farms differ greatly although they share the same practices with regard to cattle caretaking. Past experiences, present applications, and future possibilities for the imbrication of technologies and work practices vary, because their work practices are context-bound. Technology and human requirements are numerous, and the farmers' perspectives on the future value and need for investments differ. For example, Eskild requires technological integration between Google Glass and DelPro, whereas Nis is more preoccupied with human aspects and the need to plan and coordinate the use of Google Glass with his employee.

Innovating work practices in information rich situations. In the future, information-related and situation-specific work practices become more imbricated to the extent that the human and technological requirements are met. This is the key to innovation as information-related work practices have become separated from and disruptive of famers' manual labor-intensive work practices. Because information processing in situation-specific work practices distract farmers from the manual labor at hand, there is a risk of overlooking, forgetting, or neglecting relevant information (Mikkel; Eskild; Nis; Wim). Wim, for example, admits that he often forgets to register medications, because he has to stop what he is doing and walk over to the computer: "I have to walk to the computer, and then it is that, I will [register the information] instead if I walk inside, and then I forget it and then… suddenly a week has gone by."

When looking at the demands of situation-specific work practices, it is apparent that actors need to be mobile, able to use their hands, and focus their attention on the work at hand. Information-related work practices require continually accessing and registering information. Google Glass is potentially useful, because it supports mobility, hands-free use, information access, storage capacity, and allows users to focus simultaneously on the virtual screen and the physical world. Similarities between farmers' requirements support this conclusion, as they require support for making legally required registrations and improvements to the voice control functionality (Mikkel; Eskild; Nis; Wim). Eskild, emphasizes the need for adaptation and technological flexibility as a prerequisite for successfully integrating Google Glass into work practices. Thus, Eskild stresses the need to invest time and effort in getting to know Google Glass to the extent of becoming "[…] integrated with the glass, so that you feel that they are a part of you and that you can, so that you can, that it is not a problem to ask about anything." When Google Glass is fully integrated into farmers' everyday life, it has the potential to function as an external memory that enables access to and registration of information while they perform other activities as part of situation-specific work practices. This has numerous advantages, for example better support for decision-making, information capture and retention, and more timely actions (Mikkel; Eskild; Nis; Wim).

The analysis of the empirical data shows that actors' requirements are of both a human and technological nature, and that both are evaluated in deciding whether to invest in new technology. To facilitate imbrication of technology and work practices, these requirements have to be met. The investment calculation and evaluation of Google Glass' potential value is context-bound, because farmers base it on different past experiences, present applications, and future possibilities. As a consequence, both technology and work practices must evolve in order for imbrication to take place as suggested by Leonardi (2011). When technology changes to fit human intentions and goals, work practices change with technological affordances.

6 Discussion

In the discussion below, we highlight our twofold contribution to state-of-the-art knowledge of technology support for work practice innovation. Firstly, we show the tight coupling between technology and work practices across time, which translates into human as well as technological requirements in order for organizational changes to happen. Secondly, we discuss how Google Glass as a particular type of technology enables imbrication of not just technology and work practices but also an imbrication of two types of work practices (situation-specific and information-related). This offers a new outlook on technology in work practice. These contributions are illustrated and discussed by means of Figure 3 in which we show the findings from both the cross-case and reflective analyses. The figure is a simplification of the evaluation of investments, including the human and technological requirements (referred to as 'technological demands' and 'human demands' respectively) as well as the input to such investment decisions.

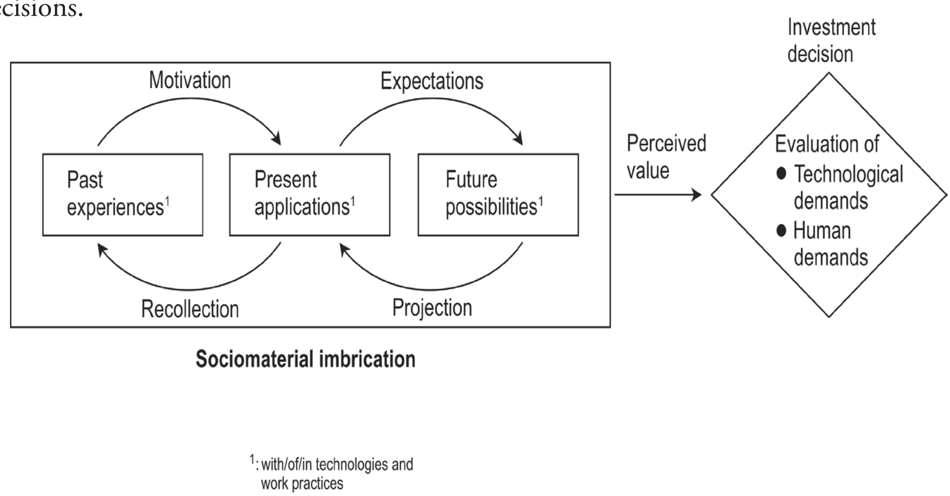

Figure 3. Evaluation of investments in technology

As mentioned in section 4.2, there is contextual interdependency between actors' past experiences with, present applications of, and future possibilities for technology use in work practices. This interdependency is explained through two sequences. In the one sequence, past experiences motivate present applications and lead to expectations regarding future possibilities. In the other sequence, future possibilities are projected onto present applications which in turn influence the recollection of past experiences. These interdependencies show how actors evaluate investments in technology in terms of required technological developments and changes to work practices in order to benefit from technology use. If these demands are met, imbrication of work practices and technology becomes possible in support of information processing related to any situation the human actor finds him- or herself in. Google Glass enables this integration of information-related and situation-specific work practices. Work practices will not change fundamentally but can be performed simultaneously. Thus, Google Glass facilitates imbrication of previously separate work practices.

In summary, we have found that technology and work practice are connected, and that for either one of them to function properly in a particular context, the other has to adapt. We have also found that Google Glass enables the performance of two types of work practices at the same time and enables information processing in the situation in which it is needed. Our theoretical contribution corresponds to what Gregor (2006) categorizes as a Type II (Explanation) theory, because it explains how and why these phenomena occur by describing the relationship between technology and work practices. The details of this contribution to IS research is discussed in the following.

6.1 Temporal imbrication

In section 2.2 we describe previous studies on the subject of time in technology development and work practices. Studies by Steinhardt and Jackson (2015), Karasti et al. (2010), and Ribes and Finholdt (2009) look at how different plans and goals affect the development of technology and work practices. Although highly relevant studies, our research challenges their underlying premises: 1) All three papers focus on the future perspective, but as shown in this paper an understanding of the complexity of the imbrication of technologies and work practices must also include past and present perspectives; 2) they take a constructivist approach by foregrounding human actors. Privileging the human perspective on the subject ignores the complexity of human-technology interaction and the influence of technology on human action. This study differs by including both the realms of structure and action.

Pickering (1995), Barrett et al. (2012), and Venters et al. (2014) offer different perspectives on the limitations of the aforementioned studies by dealing with the 'mangle of practice'. As opposed to the previously mentioned literature (Steinhardt and Jackson 2015; Karasti et al. 2010; Ribes and Finholdt 2009) Pickerings' (1995) 'mangle of practice' framework includes the perspectives of the past, present, and future as well as human-technology interaction. While these studies offer valuable contributions, they build on an understanding of sociomaterial performativity where the entanglement of the social and the material is inseparable except analytically (Orlikowski 2007; Orlikowski 2010; Orlikowski & Scott 2008). Our research is based on Leonardi's conceptualization of sociomateriality by recognizing temporal aspects of imbrication. Our observations of the realms of structure and action as separate entities support design and redesign of technologies and work practices (Kautz and Jensen 2013; Leonardi 2013; Mutch 2013).

Leonardi (2013; 2011b), in particular, focuses on *when* an organization changes and the underlying future goals. His research pays less attention to the past in molding and shaping changes to current practices. Although Leonardi recognizes the past as an influential catalyst for change, he does not investigate *how* it influences the change process.

Throughout this paper, we have argued that time is an important factor in the development of technology and work practice. The analysis reveals that past experiences, present applications, and future possibilities are separate yet contextually interdependent. They influence the development of an organization through technology use and support of work practices. The realms of structure and action therefore weigh in on actors' investment calculations and evaluation of the value of technology in work practices.

6.2 The practice-practice imbrication

With regard to our second contribution, theory describes imbrication between the realms of structure and action of organizational life (Leonardi 2008; 2011; 2013). Through our analysis of how actors compare different technologies and work practices, we became however aware of the complexities and plurality of work practices. Not only are these comparisons concerned with separate instances of technology and work practice in the past, present, and future, but the comparisons are also evidence of past, present, and future imbrications.

Analyzing these comparisons across time reveals that Google Glass potentially eliminates the boundaries between situation-specific and information-related work practices, although the technology does not change the practices themselves. The promise of Google Glass is an imbrication of two work practices into one. If the farmers' requirements are met, Google Glass will in the future drive innovation of their work practices by imbricating labor intensive work practices in specific situations and work practices of accessing and registering information about those situations (realm of action).

This contribution adds to Leonardi's perspective on imbrication. It suggests that in the search for explanations concerning imbrications of the realms of structure and action, sociomateriality research has overlooked the fact that both materiality and practice may be plural during imbrications. Leonardi (2011, p. 155) writes that "[…] the imbrication of *an* existing material agency with *a* new human agency (*material –> human*) constitutes *a* routine […]" and, furthermore, that " […] the imbrication of *an* existing human agency with *a* new material agency (*human –> material*) brings changes to *a* technology at some level […]" (emphasis added). Understanding the plurality of technologies and work practices is important due to the fact that any given technology may affect more than one work practice during imbrication and, conversely, a single work practice may affect several technologies.

Human actors depend on an increasing number of technological tools in their work and private lives. The interconnectivity between these tools is complex and extensive, and human networks interacting with the tools add to this complexity in their organizational use (Contractor et al. 2011). When work practices change, technologies are affected and vice versa.

Our case shows, for example, that Eskild and Mikkel imagine information flowing between different technologies, e.g.,the automatic milking system and Google Glass. Eskild expresses the potential future usefulness of Google Glass by stating that "[…] if it worked with the program, DeLaval's program [the automatic milking system], DelPro, then I would be able to see the small list and bring it to the cows, to find cows […]". Eskild elaborates by explaining why Google Glass was not considered useful presently

> because it, yes, it was, it was annoying, right? It was that … registering notes about every single cow was not something for us, because we would need to go in [to the office] and register them in the DelPro program anyway.

While the lack of information on Google Glass discourages Eskild from using Google Glass in the present, he imagines it being more useful in the future. This vision emerges based on his current applications of Google Glass and past experiences with other technologies as part of his work practices. This vision challenges the farmers' experiences with stationary technology such as automatic milking systems and computers. Experiences with the wearable and mobile properties of Google Glass mixed with their dependency on information from the automatic milking system lead the farmers to suggest combining and changing both technologies. The milking system would need to interface and integrate with Google Glass, whereas the glasses would need to be able to show and edit the information.

6.3 Furthering imbrications in research and practice

Several implications for practitioners and researchers are identified.

In terms of practical implications, being able to simultaneously perform situation-specific and information-related work practices suggests the following: Firstly, managers in organizations should consider Google Glass and similar technologies as enablers of digital innovation. Using this type of technology, employees are able to access and register information—traditionally considered desk jobs—while working on other activities. In light of our findings, it should however be noted that such innovation may result in unanticipated changes to the applications of other technologies or work practices. Managers are encouraged to realize the innovative potential and prepare by investigating past, present, and future imbrications within their own organizations.

Secondly, designers of emergent technologies should consider that the utility of technologies depend on their imbrication with work practices, but that they have potential to help solve pressing organizational challenges surrounding the growing need for information in all situations where employees engage in work practices. As evidenced by our case study, further development of technologies like Google Glass is needed to break the barriers between situation-specific and information-related work practices. Our research shows that technological development may render information-related work practices as office and desk jobs a thing of the past.

With regard to research implications, we found using Leonardi's concept of imbrication for analytical purposes challenging, which implies that the concept does not fully capture the complexity of imbrication in the realms of structure and action. Firstly, it requires that present applications of technologies are interpreted in the context of past experiences, future possibilities, human actors, other technologies, and the organizations in which they are used. Past experiences are not necessarily tied to one specific technology or practice. Human actors have multiple experiences with technologies and practices which influence the requirements for, as well as the impact of, technologies used in support of work practices. Moreover, it is insufficient to understand only the future, the present, or the past as these time perspectives are interdependent. Understanding an organization and its development in terms of technology use and work practice evolution depends on all three. This means that the context-bound experiences with previous technologies in work practices shape other technologies and work practices dynamically as human actors enter and leave the organization.

Additionally, researchers should be mindful that imbrications are not necessarily isolated events related to single practices and technologies, but that they are interdependent and potentially affect each other. We claim that research from a purely human or technology-centered perspective is problematic in studying technologies in work practices. The strength of sociomateriality lies in incorporating both the realms of structure and action and how they influence each other. However, while sociomateriality has been preoccupied with disentangling the boundaries between social and material entities, other boundaries have been building within the realms of structure and action. Until now, sociomateriality has been concerned with the relationship between these two realms. We encourage researchers to not only keep investigating technologies and work practices, but also to broaden their view by examining the imbrication of multiple work practices and technologies in organizations. New perspectives on technologies in work practices will provide us with greater understanding of organizing and innovation in organizations, which in turn enable us to guide practitioners in adopting, adapting, and using technologies for innovation purposes. In the process, we will better understand how imbrication takes place, which technologies and work practices are affected, and how the imbrication of multiple work practices and technologies impact the organization. In our theorizing imbrication, we are limited by our empirical data which are restricted to the agricultural industry. We invite other researchers to investigate whether our findings hold true in other industries.

With regard to limitations, our paper does not address the technological changes to Google Glass as a technology in its own right. During the writing of this paper, Google Glass has undergone several changes. In January 2015, Google pulled the Glass Explorer Edition, which is used for our research project, from sales. Since then Google has been working on an Enterprise Edition that specifically targets organizations and their work practices rather than private consumers and their needs. In July 2017, the Enterprise Edition was released, and it is now available to businesses of all sizes. The challenges that Google Glass Enterprise Edition is meant to solve in modern businesses are remarkably similar to the ones we explore in this paper, focusing on bringing information and situation closer to one another (Levy 2017). Other researchers are invited to examine whether the technological changes genuinely bring about the imbrication between technology and work practices that we are anticipating in this paper.

7 Conclusion

This study of Google Glass in Danish agriculture shows that human actors connect and draw on past experiences with, present applications of, and future possibilities for technology use in support of work practices when assessing and evaluating the value of an investment in technology. The past, present, and future influence requirements of both a material and social nature. Human actors have certain demands (i.e., requirements) of both a social and technological nature depending on the context, and imbrication between technologies and work practices is possible when these demands are met.

The future value and innovative potential of Google Glass in agricultural organizations and other industries lie in enabling simultaneous performance of situation-specific and information-related work practices. Our research describes how the Google Glass technology enables breaking down the barriers between and imbricating the different types of practices. The defining characteristics of Google Glass, such as mobility, voice control, as well as information storage and retrieval, enable farmers to complete manual labor-intensive work practices that require both hands and their attention while being able to concurrently access and register information related to the situation at hand. Google Glass does not change the practices but allows farmers to perform them simultaneously.

The study makes two valuable contributions to the research field of technology in work practice. Firstly, our theoretical model of evaluation of investments in technology provides insight into how human actors determine the value of technology based on technological affordances and constraints as well as the social context of technology use. Based on the concept of sociomateriality, this study investigates the importance of contextual factors, structure, and social action of adopting and adapting a technology like Google Glass for innovation purposes. Consequently, it addresses shortcomings of previous studies and responds to their call for additional research. Secondly, Google Glass as a particular type of technology has not been investigated within the stream of research on technology in work practice. The novelty of this research lies in identifying the innovation potential of such a technology in organizations.

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