European Journal of Information Systems (2008) 17, 305–320
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www.palgrave-journals.com/ejis

Interactive innovation of technology for mobile work

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Abstract

Despite the increasing popularity of mobile information systems, the actual processes leading to the innovation of mobile technologies remain largely unexplored. This study uses Action Research to examine the innovation of a mobile RFID technology. Working from Activity Theory, it departs from the prevalent product-oriented view of innovation and treats technology-in-the-making as a complex activity, made possible through the interaction of manufacturers, their organisational clients and their respective mobile workers. The lens of a normative Interactive Innovation Framework reveals distinctive interaction problems that bear on the innovation activity. In addition to difficulties emerging from dissimilar motivations for the innovation project, the mobile setting presents unique contradictions based on the geographical distribution of its participants, the diverse role of mobile technology, the complexity of interacting through representations and the importance of the discretion with which mobile work activities are carried out today.
European Journal of Information Systems (2008) **17,** 305–320.
doi:10.1057/ejis.2008.18

Keywords: interactive innovation; mobility; technology for mobile work; mobile technology; action research; activity theory

Introduction

The past decades have unveiled an impressive trajectory of mobile technology, marked primarily by the advancements from early mobile telephones, available to the elite few, to the highly advanced and diffused mobile devices of today. Intrigued by new technological affordances (Gibson, 1977), Information Systems (IS) scholars increasingly turn their attention to the impact of mobile devices on individuals and organisations. In the meanwhile, manufacturers, concerned with staying competitive in an industry actively rivalling for corporate accounts, are starting to invite their future users to participate in the process of innovation.

These evolving cooperative innovation projects between manufacturers and users are highly complex and benefit from an innovation approach that clearly defines the roles and responsibilities of each participant. Some lessons can be learned from fairly recent co-constructive developments; however, these lessons are largely based on single organisational contexts, non-mobile computing devices and a dialogue between innovators and users in fixed-location settings. But since mobile settings and technologies that span time and location fundamentally challenge the interaction habits subsumed by non-mobile contexts, manufacturers and innovators support a fresh approach for interactive innovation within mobile environments.

Commissioned by a leading mobile device manufacturer, our research focused on first developing a conceptual framework for interactive

Received: 7 August 2007
Revised: 4 December 2007
2nd Revision: 12 June 2008
3rd Revision: 24 June 2008
Accepted: 25 June 2008

innovation in mobile settings, and second assessing such framework in a real innovation project. A fundamental assumption of this inquiry was that innovation as an interactive activity in mobile work settings involves categorically different participants, including innovators, primary and secondary users. The aim of this paper is to analyse how these groups and their respective work activities established an influential context for the interactive innovation of new technologies for mobile work.

We pursued this research objective in a 1-year Action Research study. The technology under development was a synchronous, mobile radiofrequency identification, or 'mobile RFID' device, and the innovation activity was driven by the innovator, a handset manufacturer anonymised here as Nalle. The company, experienced in developing personal mobile devices, understood that it needed to ground this organisational innovation within real mobile work settings. Nalle found an appropriate sponsor for its project at Morrison Patrolling, a security services company that had an interest in learning more about how their mobile security guards conducted work.

Morrison Patrolling's problem was that the organisation only had a basic understanding of how its mobile security guards carried out work. Essentially, a mobile security guard arrived at work, collected a car and navigated an enormous terrain throughout his workday to secure buildings, check the status of schools, patrol the perimeter of construction areas, etc. Throughout this time, Morrison had no information about the specific location of each guard and the status of the premises. When a guard was needed for an emergency, a suspected break-in for example, all guards who could possibly be in the vicinity needed to be called via their mobile phones. This uncertainty also affected clients, who never knew if their premises had been checked, and therefore called Morrison's managers, who then had to contact the guard via mobile phone. By and large, the information flow to and from those in the field was very inefficient, and a solution to Morrison's problems was sought.

Morrison and its mobile workforce decided to participate in the interactive innovation activity of mobile RFID, a technology that promised to address many of these mobility-based shortcomings. RFID essentially consists of two components. A number of transponders, or tags, in the shape of small stickers, would be attached to various elements of the premises patrolled by Morrison's guards (e.g., to a gate). The main innovation was the mobile transceiver, a synchronous reader that communicated with the tags once they were in close proximity. Once tag and reader had connected, the guard could select a message on the reader, for instance 'all ok'. Immediately, the serial number of the tag, tied to the specific premise, would be sent along with a time-stamp and the selected message to Morrison's office. This synchronous information exchange would also update the field data stored on an extranet, so that Morrison's managers as well as the company's clients knew where the mobile guard had been and what the status of each premise was.

In the process of developing this innovation, both Nalle and Morrison relied on the help of Morrison's mobile employees. These mobile workers formed the primary users for the interactive innovation activity, those who would use the actual artefact under development. As secondary users of Nalle's technology (Friedman & Cornford, 1992), Morrison's managers would not use the technology directly but would benefit from tying information gathered from the field with the help of mobile RFID into existing corporate IS.

The empirical findings were analysed using Engeström's interpretation of Activity Theory (AT). Particularly his framework of activity systems allowed the researcher to examine interactive innovation as a complex process that involved different groups of participants. AT's premise of contradictory motivations played an important role in the analysis of the individuals' contribution to the collective activity of developing the handheld, synchronous RFID device. The resulting discussion acknowledges both social and technical constituents of IS that are tied to mobile work practices; it does not specifically focus on mobile RFID affordances (Angell & Kietzmann, 2006). To understand how participants actually interacted, the principle of mediated actions enabled the researcher to look at the role of tools, including mobile technologies, and explicit and implicit rules that affected the activity and its outcome.

This study yielded a number of interesting results. Specific to the scope of the project, it led to many refinements of the mobile RFID systems within Morrison's organisational settings. Beyond the study, it helped Nalle innovate its mobile RFID technology for a much wider audience. More conceptually, the study led to the development of an Interactive Innovation Framework that was evaluated empirically during the study. Here, the theoretical result of its analysis quite clearly underlined that interactive innovation is different when conducted in mobile environments. The very specific complexity of the activity of innovation, in AT parlance, resulted from unique contradictions of motives of its participants, from the effects of geographical distribution and modalities of mobility and from contradictory roles that technology assumed. Further contradictions emerged from representations as boundary-spanning objects and contradictory interaction requirements of the discretionary practices of mobile workers and the interactive, knowledge-sharing innovation activity.

The following section briefly introduces aspects of mobility and innovation that are relevant to this study. Next, AT with its focus on motivation, object-orientedness and transformation is introduced as a theoretical foundation. Contradictions, as the impetus for change within these activities, are emphasised as the main analytical tool. After setting the theoretical foundation, the individual stages of Action Research provide the structure for the subsequent sections of this paper. The

diagnosis outlines the motivation for the interactive innovation project, the planning stage provide details of the normative interaction framework that was developed for it, the action taking stage describes the introduction of the mobile RFID technology, and the evaluation and learning stages outline the results, for scope of the project and more generally for interactive innovation of technology for mobile work.

The messiness of mobile work and innovation of technology

In the midst of recent advances of mobile technology and emergence of new mobile devices, it is hardly surprising that *mobility* is at the fore of academic work, too. New developments are theorised as emerging mobile (Sørensen & Pica, 2005), pervasive (Hansmann *et al.*, 2003), nomadic (Lyytinen & Yoo, 2002b) and ubiquitous (Lyytinen *et al.*, 2004) constellations of work and interaction.

In the course of these conceptualisations, some authors primarily study technological aspects of mobility (e.g., Pierre, 2001; Izadi *et al.*, 2002; Kim *et al.*, 2003), while others examine mobility from a social (e.g., Castells, 1996; Ling, 1998; Urry, 2000; Agre, 2001; Fortunati, 2001; Plant, 2001) or a socio-technical research perspective (e.g., Kristoffersen *et al.*, 1998; Wiberg & Grönlund, 2000; Lyytinen & Yoo, 2002a; Pedersen & Ling, 2003; Pica & Sørensen, 2004). Contrary to earlier arguments that proclaimed the proverbial *Death of Distance* (Cairncross, 1997) and *Anytime, Anywhere* computing (Kleinrock, 1996), this abundance of recent mobility-related research projects and publications highlight that space, location and the distribution of data, individuals and devices continue to be important factors of human interaction (Olson & Olson, 2000; Wiberg, 2001).

In this context, mobility is associated with the conscious, rational choice of people to move, to meander and to change location, often in a fluid, unstable way and at times unpredictable to themselves and to others (Kakihara & Sørensen, 2001; Brown & O'Hara, 2002; Lilischkis, 2003). Various modalities of mobility delimit mobile work according to the mode of transportation and use of technology (i.e., travelling occurs when people move in vehicles), the time spent at any one site (i.e., visiting occurs when a person temporarily stays at one place on a transitory basis before moving on) and location (i.e., wandering occurs when a person moves about a building or specific premises) (Kristoffersen & Ljungberg, 2000). Throughout their workdays, most mobile workers negotiate a multitude of modalities and contexts (Scheepers *et al.*, 2006); they may drive or walk, then spend time at a specific place, perhaps wander about and then continue to drive to different sites.

At first sight, the affordances of mobile technology suggest that others could easily relate to such diverse mobile work activities from a distance, that mobile information systems provide the communication link between those in the field and those in the office. However, the cooperation, coordination and collaboration (Kaptelinin & Nardi, 1997) with mobile workers and the connection to mobile work continue to present a considerable struggle. What truly happens in the field is really only known to mobile workers. The rich information from the multitude of contexts they navigate is often reduced to paper logs or summarised through voice conversations with mobile phones. In this process, important contextual detail gets lost, requiring frequent verification and validation between communication partners. Similarly, not all mobile work contexts are suitable for all mobile technologies, and mobile workers select how to deploy and appropriate technologies in correspondence to their actual needs in the field. It appears that mobile technologies do not fully respond to the needs of mobile work, and at times exacerbate rather than improve mobile work and managerial efforts (Wiredu & Sørensen, 2005).

In order to address these difficulties and to improve the interaction among mobile and non-mobile individuals, manufacturers are busy innovating new devices. Caught in the traditional trajectory of invention–innovation–diffusion, mobile devices are often developed before users become actively involved. The actual mobile work activities that these innovations are to serve are black-boxed, and users are only involved in testing the functionality and interface design. At this stage, the innovations are already conceptually fixed, closed, and non-malleable, and the primary concern of innovation studies is the technology's *effect on the user*. Examples include innovations that are regarded as eliciting disembodied changes to knowledge and skill sets (Cohen & Levinthal, 1990), leading to competitive advantage (Porter & Millar, 1985; Davis & Devinney, 1997), or introducing key changes in production or process management in the work organisation (Whipp & Clark, 1986; Christensen, 1997; Tidd *et al.*, 1997, p. 23; Porter, 2001). In most cases, these effects are examined post-innovation, based on historical accounts and before-and-after comparisons. The innovation practice is treated purely as an outcome, the *opus operatum,* rather than in concert with the activity of innovation, the *opus operandi* (Bourdieu, 1977).

Those who involve the user as a valuable input into the innovation process often pay close attention to how consumers and lead-users modify existing products. Bricolage, user-innovation and technologies that emerge *in situ* demonstrate how the use of technologies can differ from their intended application (Ciborra, 2002; Shah & Tripsas, 2004; Haddon *et al.*, 2005; Von Hippel, 2005). Nonetheless, these phenomena still do not describe co-constructive activities or the underlying motivation of the various parties involved. However, they underline the disconnect between existing innovations and the actual needs of their users.

With a focus on the *causal involvement of the user and the activity of co-constructive efforts*, studies have been conducted in non-mobile environments. An essential

premise is that developers and users are teams of different experts (Bjerknes & Bratteteig, 1987), and that innovations 'should be done with users, neither for them nor by them' (Ehn & Kyung, 1987, p. 54). Participatory Design, for instance, underscores the involvement of users in the planning and designing of information systems (Floyd *et al.*, 1989; Bødker & Grønbæk, 1991; Ehn, 1993; Jones, 1995, p. 72; Piller *et al.*, 2003). Particularly Bødker's participatory human–computer interface (HCI) design studies adopt such an activity-lens; however, Participatory Design and interactive innovation place the user in a fundamentally different role.

Participatory Design, with the underlying assumption that design is mostly concerned with *determining details to meet a particular purpose*, focuses on an emancipatory element that is guided by conflicts and concerns as perceived by the user. Examples include HCI work, in which the functional properties of the respective devices are already established and inscribed into the artefact. Users are involved to identify the drawbacks of current interfaces and are tasked with improving their usability and usefulness (Bødker, 1991), without a direct focus on the actual functions, the affordances, of the device.

Interactive innovation, on the other hand, is first and foremost concerned with *determining the purpose* of an innovation. In other words, innovators invite users to help develop the functions that the device is to serve. The resulting back-and-forth between innovators and users indicates that contradictions, perhaps between what is technically possible and what users demand, require further negotiation. Such a struggle emphasises that learning occurs when these two parties try to align their respective activities, which then informs the actual innovation process and the resulting product itself. Overcoming these contradictions during this collective innovation activity affects the actual purpose the innovation will serve, not just its design component.

Consequently, a practice-based approach to innovation, one that involves the interaction of a number of participants, motives and concurrent activities, responds most favourably to a mobile reality that is often messy, non-linear and not necessarily sequential. Nonetheless, despite calls for investigating these emerging practice-based activities (Fontana & Sørensen, 2005; Scarbrough & Swan, 2005) within the 'bewildering array of definitions and approaches' regarding innovation (Swan & Newell, 2000, p. 27), the causal involvement of the user has hardly been studied. The interactive innovation lens introduced below treats the process of innovation 'not in a normative or naturalistic way, but as a socially constructed constellation of activities and practices' (Scarbrough & Swan, 2005, p. 2) involving technology and mobile work.

Innovation and the theory of activity

An investigation that aims to examine the process of interactive innovation, not its outcome or its effect on the user, requires a theoretical framework centred on collective activities. We selected AT (Leontiev, 1974, 1978; Vygotsky, 1978; Engeström, 1987) as an analytical lens that focuses on the context of meaningful, goal-oriented and socially determined interaction between human beings and their material environment (Bannon, 1997).

AT lends itself to IS studies in general and to mobility studies in particular as it pays particular attention to the role of tools and artefacts as mediators of human activities. In this realm, a number of ISscholars (including Bødker, 1991; Nardi, 1995; Wiberg, 2001; Wiredu & Sørensen, 2005) have demonstrated the usefulness of AT. Especially Engeström's interpretation and extension of AT (1987), through his framework of activity systems (Figure 1), has become a recognised conceptual framework for describing the structure, development and context of computer-supported activities (Kuutti, 1996; Kaptelinin & Nardi, 1997).

In an A T approach to understanding human behaviour, 'all human experience is shaped by the tools and sign systems we use' (Nardi, 1995, p. 5). These so-called mediators are represented above through tools, rules and a division of labour that mould our interaction with objects in the real world. In AT, subjects' activities are motivated to transform these objects into desired outcomes (Vygotsky, 1978). For instance, a Nalle engineer used his tools, physical or intangible, to transform a regular mobile phone into an RFID-enabled handset. A mobile security guard used his keys to transform an unlocked building into a secured premise. Accordingly, each activity is expressed through a clear object-orientedness, and the motivation to transform each object into a new outcome.

Favourable for this study, Engeström's activity systems suggest a move from an instrumentalist approach of looking at discrete tools, etc. to an interactionist perspective that supports the holistic interplay of the inherent elements. In recognition of the impact of the supra-individual influences on activities, even when a subject is apparently working alone, the community component gives weight to the social and cultural context of the work environment and to neighbouring activities. For an interactive innovation study, this focus is of paramount importance, as it allows the researcher to

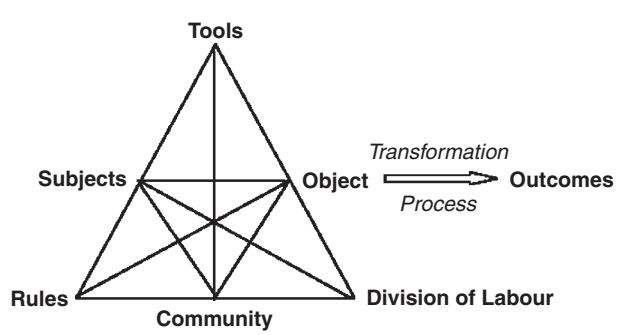

Figure 1 Engeström's framework of Activity Systems (1987).

examine the activities of Nalle, Morrison and the security guards and their impact on each other's activities.

In this complex view of activity systems, all the elements are interdependent and (re)shape each other throughout the duration of the collective activity. However, the framework of activity systems does not suggest harmony between all of its elements. On the contrary, the value of their interaction lies in the learning that occurs during the negotiation of problems that occur either between the nodes (for instance when a subject does not have the appropriate tools for the activity), or within them (for example when there are two rules that contradict each other). These problems, called contradictions in AT, may at first sight be seen as complications from an innovation perspective. Nonetheless, they also lead the activity system through constructive, expansive cycles, in which the negotiation of contradictions provides the sources of new knowledge and drives the resulting transformation of an object into an outcome.

When considering a complex collective activity such as interactive innovation, neighbouring activity systems of innovator, primary and secondary users add to the potential for problems and to the learning that can arise from their interaction. The fluid negotiation of contradictions within and between their activities permits a practice-oriented view of interactive innovation instead of a mechanistic product-oriented perspective of innovations. In combination with its premises of motivation, mediation, object-orientedness and transformation, AT allows us to examine interactive innovation as a process rather than a product, as dynamic and flexible as opposed to rigid, and as open rather than closed to interpretation.

In light of the growing mobilisation of work and the increasing diffusion of mobile devices, this study uniquely addresses the merger of three key interests for scholars and practitioners. First, it looks at co-constructive efforts, aimed at the innovation, not the design, of technology. Second, it examines innovation as an activity, not a product, and third, it questions how user involvement and mutual learning is affected by mobile work settings. With this background, the question that motivated this research project was: *How does the interaction with mobile work affect the innovating of technology*?

The method of action research

In pursuit of this question, the researcher needed to become part of the social forum that engaged with the innovative process. Especially for a study of mobile activities, which are not really 'observable' from a distance, proximity to all research subjects was essential. Further, the activity of innovation needed to take place within real, mobile settings. As a methodology that supports such intervention, while at the same time contributing to scientific knowledge, Action Research was adopted as the most suitable research method (Baskerville & Pries-Heje, 1999; Baskerville & Myers, 2004). In this case, all practitioners gained an insight into the dynamic aspects of their work through the eyes of a researcher and the researcher's findings were enriched through actual active participation in the complexities of work; 'research inform[ed] practice and practice inform[ed] research synergistically' (Avison *et al.*, 1999, p. 94).

The research study was grounded in a highly complex interactive innovation project that involved the manufacturing company Nalle, who as the primary *innovator* had set out to innovate a mobile RFID technology. Moreover, it involved the security services company Morrison Patrolling, as a secondary user and *innovation partner* that agreed to host a number of highly interactive trials within the boundaries of its organisation. Lastly, the *trialists* were Morrison's respective mobile security guards, the primary users of the technology (Table 1).

Empirical materials were collected over the course of a 12-month project in which the chosen AT lens was operationalised through Action Research. The principal researcher actively engaged in both action and research activities with the innovator Nalle, mobile workers as primary users and Morrison as a secondary user of mobile RFID. Evidence was collected through logs of interviews, audio and video recordings of work activities, with and without the new mobile RFID device, drawings of work practices and server data (Table 2). Through the interaction of the participants and the interdependency of their activities, AT principles were applied in Action Research to develop an interactive innovation framework.

The Action Research project took place in 2005, and strictly adhered to the basic stages of (a) diagnosing, (b) action planning, (c) action taking, (d) evaluating and (e) specifying learning (Susman & Evered, 1978; Baskerville, 1999), which are discussed in the same sequence throughout the remainder of this paper.

A case of interactive innovation of technology for mobile work

Before this particular innovation project, RFID was at a very interesting junction; it had existed for quite some time as asynchronous *or* mobile systems. Synchronous, mobile handheld RFID devices had been heralded as a 'killer combination not killer application' (Roberge, 2004, p. 1). The potentially enormous impact of contactless interaction on work encouraged the three different parties' involvement with the interactive innovation

Table 1 Interactive innovation participants

Subject	*Individuals*
Innovator: Nalle mobile solutions	Nalle product innovation, R&D and IT managers
Innovation partner: Morrison patrolling	Mainly managers and IT staff, secondary users of mobile RFID and field data
Trialists: Mobile workers	Mobile security guards, traffic dispatchers, primary users of the technology

Table 2 Action and research activities

Subject	*Location/medium*	*Action and research activities*
Innovator (Nalle)	Various physical locations Meetings, conference calls, email, written reports, memos	Action: In meetings and interviews, we discussed the development of mobile RFID technology, its constraints and affordances, the role of the primary and secondary users. We worked on developing the device in accordance with the contradictions that emerged, within Nalle, but also at Morrison and its mobile workforce. Research: On a conceptual level, what was the motivation for involving other participants? How could the interaction between subjects be facilitated? How could empirical materials be collected and analysed?
Secondary user (e.g., Morrison patrolling)	Morrison headquarters and regional offices Face-to-face meetings, but also email and telephone communication	Action: In meetings, the technology and its objective affordances were introduced, including the fundamental properties of mobile RFID. We discussed the context of work at Morrison, but also out in the field, and designed trial applications accordingly. Further, we discussed the role of the technology for Morrison, potential trial difficulties, access to organisational data, research sites and how mobile RFID would be implemented throughout the geographically dispersed and mobile settings. Research: How do we trigger feedback from primary users? What was Morrison's motivation? What transformation was necessary? How could both action and research be staged at this company?
Primary users (e.g., Mobile security guards)	Regional offices, patrolling vehicles, public spaces, client sites, restaurants, etc.	Action: The researcher accompanied security personnel on day and night shifts to learn about the central activities of these mobile workers. Later, the researcher introduced the device, provided training, helped troubleshoot the technology if needed, tested its functionability and introduced the interaction protocol and fora that were to be followed throughout the project (contact details, issue logs, change logs, etc.). Research: Approximately 200 open-ended, formal and information interviews, conversations and field observations elicited what functions the technology should offer, but also how mobile RFID performed in the trials, how it changed mobile work activities and how the innovation could be improved. Also, how could these individuals interact with Nalle and Morrison to help negotiate the functionality of the actual device, etc? How did they interact?

project. However, each party participated for different reasons, or in AT terms each party was motivated to develop mobile RFID by its own real-world contradictions and problems. The first step in Action Research was therefore to diagnose these different motives according to the chosen Activity System framework. Built on this conceptual understanding of motivations in terms of object-orientedness and outcome-transformation for each participant, an action plan for interactive innovation was developed and executed.

Diagnosing the motivation for the interactive innovation project

As introduced earlier, mobile device manufacturers have been very successful at tailoring to the needs of private users. For the *innovator* Nalle, the current shift to the corporate clientele meant developing technologies that were not generic, off-the-shelve solutions, but that could be embedded within various organisational contexts.

Nalle spent immense time and energy on enabling the technological aspects of the mobile RFID system, but the real innovation of the technology and its business applications only began after the functionality of its synchronous communication and auto-identification technology was achieved. Nalle was motivated to compete actively in the corporate sector; however, a contradiction existed between the experience the company possessed, based on generic technologies, and the skills it now required. Nalle's previous activities were focused solely on device manufacturing; the company did not have the expertise needed to tie its technologies specifically to mobile work. Accordingly, Nalle's motive for the project was to gain this knowledge to extend its mobile RFID prototype into an auto-identification device that would enable new work practices and information flows across changing mobile work contexts. Based on the abovementioned contradiction of experience *vs* skills required, this meant that the technology needed to be grounded in actual work contexts, co-constructed by

those who would later use it. An interactive and activity-focused approach was seen as elemental to the success of this innovation. The project was further supported by the fact that interactive innovation had no precedence in mobile environments, which motivated the design of a interaction framework that would lay out how innovator, innovation partner and trialists would exchange information pertinent to the technology under development.

As an *innovation partner,* Morrison Patrolling was motivated to take part in this project to improve the company's ability to understand and manage mobile work. The diagnostic stage uncovered contradictions within the organisation between information sought from the field and information available from the workers. Morrison's interests in mobile RFID was further motivated by the promise to improve such organisational information flows and to overcome many other non-automatic interaction difficulties previously experienced between mobile workers and their stationary colleagues. Morrison was reluctant to wait until a suitable technology was available, and hesitant to buy an off-the-shelve solution that could not be tested thoroughly. Interactive innovation promised the development of a technology that was developed around Morrison's contexts, that would address the contradictions within its current mobile work activities and that could be improved throughout the various iterations of innovation cycles.

Although *trialists* did not instigate the innovation project directly, indirectly their actual mobile practices motivated it. Their participation, however, was motivated by their need to improve their professional relationship to their colleagues and superiors by enhancing the interaction and information flows with them. Contradictions within the mobile work activities emphasised a disjoint between the guards' central activity (ensuring the security of various premises), and the administrative tasks that often took most of their time. For example, recording every task via paper-based methods was not an appropriate solution for their demanding mobile work environments. Similarly, a guard's use of his mobile phone as a means of constantly updating others on his location and current job tasks interrupted his work and thereby contradicted with his central activity. As a result, mobile workers became involved in the project with the objective of actively interacting with their managers and with Nalle throughout the innovation process in order to improve mobile working conditions and practices.

Lastly, the *researcher* was interested in examining the effect of mobility on interaction and innovation. This desirable outcome was an empirically tested and practice-based understanding of innovation, interaction and mobility of work.

Applying the activity lens to the context of all participants in the diagnostic stage not only revealed many interesting contradictions within each activity, but also unveiled contradictions between them. Each party was motivated to overcome its own contradictions, but all three pursued a different object transformation and outcome (Table 3). The shared motivation that brought all parties together was their common desire for the final outcome of the interactive innovation activity, the mobile RFID system. In recognition of the uniqueness of the different perspectives (motivations and object transformations), and the complexity of an activity that aims to align them, all parties emphasised that an interaction forum was needed that also placed emphasis on the interactive activity itself. Based on these premises of AT, a practical framework need to be established that would outline an interaction system for the duration of the innovation activity, including who would communicate with whom about specific topics related to the project and how. This request provided the motivation for developing a methodology that would ensure the continued discourse between innovator, innovation partner and trialists.

Action planning: how should participants interact throughout the project?

During *action planning*, the researcher conducted a baseline study to set the start parameters for the innovation activity. This included reflecting on the results of the diagnosis stage, and facilitating the interaction between the different participants. For this purpose, the researcher and practitioners (innovation partner, Nalle and trialists) collaborated in designing a normative framework that

Table 3 Motivation for interactive innovation participants

Participant	*Transformation of object*	*Desired outcome*
Innovator Nalle	Exploit proof-of-concept (of mobile RFID) in a manner useful for mobile work contexts.	A mobile RFID device that responds to the requirements of mobile work environments.
Innovation partner Morrison	Improve existing information systems by embedding technologies throughout mobile work settings.	Improved organisational information flows at Morrison involving mobile work(ers).
Trialists mobile security guards	Reduce effort required to log work activities, replace paperwork with automatic data capture.	Ability to focus solely on central work activity, without need to report everything manually.
Researcher	Examine interaction and innovation in the context of technology and mobility of work.	Empirically tested and practice-based understanding of innovation, interaction and mobility of work.

would lay out how the interaction protocol for the duration of the innovation project.

Clearly, different sets of knowledge existed among the participants, which needed to be communicated and combined in order for interaction to be fruitful and innovation to be successful (Von Hippel, 2005). In recognition of the complexity of the parties involved, the acknowledgment of different, exclusive skills and sets of knowledge became an important factor in the development of technology for mobile work. In AT terms, the contradictions between these knowledge sets lead the interactive innovation activity into expansive cycles, in which the existing knowledge asymmetries can be balanced. This information exchange would anchor the innovation within the context of the mobile work setting and ensure that the technology under development was suitable for the organisational context.

The *innovator's* expertise was undeniably the development of mobile technology. In this setting, it was Nalle's know-how of building a synchronous, mobile RFID reader and driving the transfer of RFID data from the reader to the corporate back-end system. From an innovation perspective, Nalle took a solution-based approach by offering a technology aimed at solving organisational inefficiencies. *The innovator's knowledge, accordingly, was solution-based*.

The *innovation partner,* Morrison Patrolling, possessed a different set of knowledge. As experts within the context of their organisational setting, managers knew the capabilities and limits of their existing IS and how these were tied into their daily operations. In most settings, these practices involved technological IS and manual procedures, mobile security guards and office-based managers and traffic dispatchers. In other words, the innovation partner understood how mobile telephony, for instance, and asynchronous, often paper-based procedures existed side-by-side within the confines of their respective organisational objectives and contexts. In order to take advantage of these new developments for their organisational processes, the *innovation partner offered context-based knowledge to the interactive innovation project*.

The *trialists*, Morrison's mobile security guards, focused on the actual work to be completed. The immediacy to everyday tasks placed them into the remarkable position that they were the only individuals who really knew what happened out in the field. Although their superiors had access to paper-based logs and other asynchronous records of their work, these were merely accounts of a subsection of mobile work. Only mobile guards, the future primary users, understood their work environment in all of its finesse, and knew the skills and shortcuts needed to get the work done. Consequently, *trialists possessed needs-based knowledge*.

Next, these knowledge sets needed to be combined in a way that would allow individuals to transfer their respective knowledge to those who required it, to balance the information asymmetries that existed between them (Von Hippel, 2005). Three different sets of knowledge shaped the interactive innovation of technology for mobile work, which should interactively inform one another, eventually allowing the innovator to develop technology that is responsive to both primary and secondary users (Figure 2).

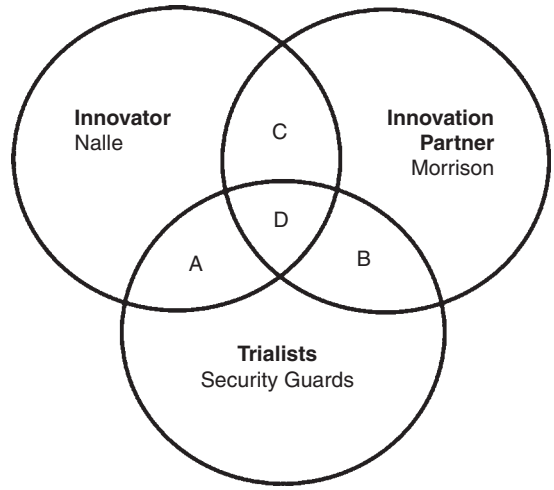

Figure 2 Interactive innovation framework.

Interaction in Innovation Space A: The interaction in this particular space involved the innovator and the trialists. While the former would provide input regarding the technological possibilities and the possible affordances of mobile RFID, the trialists would provide the needs-based knowledge of work requirements and practical feedback on the functionability of the technology. *This represented talk about work practices and technology development*.

Interaction in Innovation Space B: In the diagnosis stage, both innovation partner and trialists realised that the corporate understanding of mobile work was removed from its reality. The input from trialists was needed to balance their needs-based understanding of mobile work practices with the context-based knowledge of organisational requirements. Their interaction would provide input to the improvement of information flows and work at Morrison. *This represented talk about work practices and the future of mobile work*.

Interaction in Innovation Space C: In an effort to remain responsive to actual work practices, the innovator needed to place strong emphasis on the organisational contexts of the innovation partner. Similarly, for the innovation partner it was important to learn about the actual properties and capabilities of mobile RFID so that use-cases could be designed and work practices amended. It was elemental that Nalle and Morrison Patrolling closely interacted so that the new mobile RFID systems and corporate legacy systems could be prepared and integrated. *This represented talk about work contexts and systems development.*

Collective Interaction in Innovation Space D: Once combined, the knowledge exchanges from individual Innovation Spaces (A–C) include all of the different perspectives that should inform the innovation of a new technology. Solution-based, context-based and needs-based knowledge would coalesce as a united result from individual dialogues and negotiations within the respective Innovation Spaces. This does not suggest that all three parties needed to come together physically in Innovation Space D, but rather that the outcomes of the previous Innovation Spaces and the resulting knowledge bases needed to be combined and aligned. Through continuing interaction between innovator, innovation partner and trialists, the interactive innovation activity would always remain relevant and constantly validate the mobile RFID technology under development – in theory.

Action taking: enacting the interactive innovation framework

After diagnosing and planning the interactive innovation project, in the *action taking* stage it was time for Nalle and Morrison to execute their respective plans. This step involved the action researcher and managers from Nalle and Morrison intervening with the everyday work practices at Morrison. The interactive framework and mobile RFID system that were planned and prepared in the previous stage were now implemented.

All three parties were actively engaged with the new technology. At Morrison, many areas of the mobile work environments were equipped with RFID tags. Over 2000 tags were installed, and each security guard was trained how to use the mobile RFID reader throughout his work shift. Training sessions were hosted and manuals were distributed to patrolmen to ensure that participants were able to use their new tools. Throughout their subsequent workdays, these mobile workers read tags attached to a number of objects (e.g., at gates, doors and windows) and selected among responses from the menu on their RFID reader. For instance, when a property was checked, a security guard read its tag and selected 'secure' from the handset's menu. This tag event and the status update were then automatically and synchronously transmitted to Morrison's main offices. The auto-identification properties of the mobile RFID system virtually eliminated manual logs and worksheets and drastically reduced the time guards had to spend talking on a mobile phone to report on their whereabouts. Managers, too, had to spend much less time manually locating and coordinating the security guards, reports could be drawn up within minutes and Morison's customers could access RFID events via extranet sites.

The researcher was active with all three parties, helping Nalle reflect on the events in the field and learn from the contradictions that emerged, working with Morrison on improving the information flows and redesigning the actual functionality of the mobile RFID system and accompanying mobile workers throughout their work. As a result of these expansive cycles, various changes were made to the actual device, the RFID tag technology and work practices at Morrison.

One trialist was recorded saying: 'I no longer have to answer the phone to respond to the constant questions from the dispatcher. He knows my most recent stop, and I can concentrate on my job. The other thing that is really helpful is that he can look at the electronic log and find out what happened in the past days. I no longer have to come in to help him read my writing. Now, when we talk it's about topics that actually make sense'.

But feedback was not positive all the time, as one respondent pointed out: 'At the beginning, finding the tags was a bit of a problem. Different guards installed tags at different locations on the premises. Although we had agreed before where the tags would be, it often took time to find them'. Another trialist reported that 'tags were very good when they worked, and it was surprising how quickly we got used to the new system. The trouble was when a tag had fallen off, or when the reader malfunctioned. This hardly happened, but when it did we needed to figure out what was wrong, replace the tag or reboot the device, which was a nuisance and did not always fix the problem'.

In terms of interaction, Nalle and Morrison were in regular communication, via email, face-to-face meetings and telephone conversations. This interaction resulted in the improvements of the technology and the organisational information systems (Innovation Space C, above). The interaction of mobile workers with Nalle and with Morrison (in Innovation Spaces A and B), however, proved to be more complicated than anticipated, and primarily fuelled the evaluation stage of the action research project.

Evaluation of the interactive innovation activity

The mobile work at Morrison provided a suitable environment for an analysis and *evaluation* of interactive innovation in action. It allowed the researcher to compare the participants' ideal, normative interaction planned and expressed through the Interactive Innovation Framework to how these parties actually interacted, substantiated through the empirical evidence collected during the action taking stage.

The original assumption of various knowledge sets was quickly validated. Participants had no expert knowledge beyond their respective work domains. Nalle in fact knew nothing about security services, either practically or conceptually, and only provided solution-based know-how. Morrison added the much-needed organisational context and trialists offered their needs-based expertise grounded in their mobile work. The bird's eye view of this array of activities presented in the Interactive Innovation Framework suggested a well-balanced relationship between the three different parties, where the individual parties would interact through the Innovation Spaces. Together, it would appear, the subjects from each activity would form a collective of individuals with a common goal in the trial activities. But could their different sets of

knowledge really be communicated effectively or if they were too 'sticky' (Von Hippel, 2005, p. 8), too hard to transfer from one party to another? How did the tidiness of the normative framework hold up against the messiness of mobile work?

By and large, the interaction followed protocol. Individuals knew whom to contact to discuss problems, to ask specific questions or to offer suggestions. Mobile workers contacted their superiors to talk about misalignments between new information flows and the reality of their work, and they called Nalle's support-line for answers or recommendations specific to the device. Regardless, while the interaction procedures were followed, in principle, interaction did not occur as regularly or frequently as desirable or warranted by the contradictions that emerged. Mobile workers, above all, did not always interact with the other parties when they experienced problems in the field, or when they had improvements to suggest. This was evident when the researcher accompanied them, indicating that fundamental problems existed within the innovation activity that kept participants from interacting. The analysis of these contradictions unveiled important lessons for future interactive innovation studies.

Specifying learning

From a research perspective, the events that were observed during the action taking stage and outlined in the evaluation stage were the sources of learning. The problems that occurred, or in AT parlance the contradictions of the collective activities, illustrated an imbalance within and between the activity systems of innovator, innovation partner and trialists. Some of these contradictions could be resolved, leading to an improvement of technology, systems and work practices. For instance, electromagnetic interference (EMI) occurred between a tag and a container that it was mounted to, which led to the re-engineering and thus the improvement of the tag technology. From an innovation perspective, these contradictions were meaningful for the specific product under development, but they did not truly advance our understanding of interactive innovation as an activity.

Higher level contradictions, on the other hand, can focus on interaction difficulties beyond the setting of this trial. More generally, they emphasise if and how the uniqueness of mobility shapes the process of interactive innovation and vice-versa, and the expansive cycles provide the main contribution to the conceptualisation of interactive innovation.

Contradictions of motivation

From the outset of the trials, all three participant groups expressed collaboration readiness (Olson & Olson, 2000); however, they were each driven by different motives. Nalle was motivated by a need to innovate and develop synchronous mobile RFID as a grounded and practice-driven technology; the innovation partner was motivated by the need to improve its knowledge and control of mobile work practices. Mobile workers, on the other hand, were motivated to participate by a wider array of needs, including their own desire to advance their work practices, the felt animosity towards outdated, paper-based systems and the persistent need to justify their work to superiors.

These dissimilar motivations imply that participants had different predispositions towards the outcome, in terms of success or failure, of the trials and the interactive innovation activity. In this context, the *innovator* Nalle was fully aware that failure in the trial activities was a possibility, despite all efforts of negotiating the individual elements. However, even in such an occasion, the evaluation of the trials would still be considered a valuable source of learning for further innovation, research and development. At Morrison, the abovementioned EMI problem occurred when the RFID tags could not be mounted onto the steel containers, since these interfered with the electromagnetic field of the RFID communication. The tags had to be re-engineered to withstand the shielding of the containers. Although this presented a problem in the context of the innovation partner and trialists by affecting both the schedule and the budget of their operations, the continued interaction focused on the failing artefact, which enabled Nalle to advance its solution-focused innovation accordingly.

For Morrison as the *innovation partner*, on the other hand, the project was a considerable investment that was very clearly aimed at solving real, context-specific needs of their understanding of mobile work. Especially given the financial commitment and time investment, the trial had to succeed not to be seen as an ill-investment and waste of organisational resources. Success was not measured in terms of learning, and failure was most definitely seen as an entirely negative outcome.

Trialists measured the success of the trial against how it contributed to or infringed on their everyday work practices. In the event of failure of the innovation, there were no negative consequences, as trialists had no real investment in the project, and mobile workers would return to their usual work practices and tools. Nonetheless, the properties of the new technology would shape their future work practices, so their involvement and interaction in the innovation process had a definite bearing on their own welfare. In this light, trialists were placed in a difficult position. In addition to placing their own needs and interests first, they had to 'serve two masters'. Should a mobile worker focus his attention on helping Nalle develop a new technology or his employer, the innovation partner, understand mobile work and improve organisational information systems? This problem set aside, *how* should mobile workers interact with the other two parties?

Contradictions of mobility and technology

Important considerations for this study were the modalities of mobile work and their potential impact on the

innovative activity. From this perspective, the geographical distance, distribution and mobility of trialists led to contradictions unique to mobile interactive innovation. In the Morrison case, trialists moved across large geographical terrains, some wandered or visited and yet others travelled (Kristoffersen & Ljundberg, 1998). In that respect, they covered different distances from their main places of employment (e.g., Morrison Patrolling's main offices). The importance of these physical, geographical places of employment *vis-à-vis* their mobile places of work also introduced interesting contradictions for interactive innovation.

One security guard commented: 'If there's no one I can talk to about using the device, I will not. Sometimes the reader does not work and I need help, but in other cases there should be another function added. If someone was here, I would tell them, but later I don't remember … or I just want to go home after my round'.

In the Interaction Framework, the Innovating Spaces A and B focus on talk about work practices, mobile technology development and the improvement of organisational information flows. However, interacting with mobile workers is more easily said than done. For the innovator and the innovation partner it was difficult to get in touch with mobile workers, to get a practice-based understanding of the needs-based requirements during the action planning stage and throughout action taking. Interestingly, this importance of mobility, distance and distribution appeared to be valid from both sides, as mobile workers found it difficult, too, to interact with other project participants. The immediate needs of their central activity, for example, to check a gate at a specific time required that they moved from location to location, which stood in sharp contrast to the requirements of interactive innovation, for example, to return to the office to illustrate the shortcoming of the device or to take time to compose a detailed error log.

Another comment was: 'Sometimes, it [the device] acts up. I just don't know what to do; I just restart it and hope it goes away. I don't have time to try to fix it; I have my normal work to do. When I am back at the office I try to describe what happened, but then I cannot show them and it's hard to put what happened into words because I am no techie'.

In their very essence, mobile technologies are to address such problems of spatial, temporal and contextual distance, and to enable and facilitate interaction from a distance. In these interactive innovation trials, mobile technology adopted a dual role, as technology under development and technology in use (Bødker, 1991), it became the focus of innovation at the same time as it was used as a tool in its pursuit. Defined by the very nature of their profession and their respective motivation for participating in the interactive innovation projects, innovator, innovation partner and trialists treated technology quite differently, and in stark contradiction to one another.

As outlined above, the motivation of the *innovator* was to create devices in general and for the trial specifically. Here, Nalle transformed a mobile RFID reader based on the needs and context-based knowledge obtained in the Innovation Spaces. Contrary to mobile workers, Nalle did not work with mobile RFID at all. Rather, Nalle's activity involved working *on* the technology. Using a selection of other tools, engineers and programmers at Nalle saw the artefact as their immediate focus, the content and outcome of their work, not as a tool for mobile workers. The *Innovation partner*, on the other hand, was less concerned with the innovation of technologies for general use. Attention was closely placed within the context of the organisational work. The technology under development, as a result, was to improve the organisational information flows, to contribute to the overall access to and understanding of mobile work. Accordingly, the innovation partner desired to work virtually *through* mobile computing systems to reduce the distance to the situated, mobile spaces. *The trialists'* main objective was neither to improve generic devices by working on them, nor to gain access to others' work by working through them; mobile workers plainly worked *with* technology in the pursuit of their everyday operations. For trialists, interactive innovation aimed at developing tools to improve their working conditions and mobile work practices.

Viewed from these three perspectives, technology under development received a dramatically different focus and level of attention from the various participants. While at first sight mobile RFID appeared to be quite fixed in its ability to perform technical functions and support mobile workers, the various roles determined the degree to which individual parties were able to relate to one another. In other words, while a mobile worker saw and treated mobile RFID as a tool, he was less able to relate to RFID as an outcome (for Nalle's engineer). By the same token, mobile workers were unable to relate to the higher-level involvement of the technology for improved information flows for the innovation partner. Similarly, for Nalle's engineers and programmers it was difficult to view the technology as a tool through the eyes of a mobile worker or as an object for improved information flows in the organisational contexts. Nalle's engineers' expertise supported an outcome perspective, not a tool or object perspective. These object, outcome and tool lenses were intrinsically incongruent and did not allow participants to interact effectively.

In cases where the different participants desired to view the technology through a different lens, to balance their respective know-how and support each other's activities, mobile devices, although synchronous communication tools, did not always prove to be helpful. On the contrary, at times subjects found that reporting a technological or procedural problem over the mobile phone was particularly difficult and did not help bridge mobility-related contradictions. For instance, mobile workers often needed to call the innovator or innovation partner to report a limitation of the device or to ask for help. In many cases, this required that the device was used to

replicate an error (e.g., read a specific tag), which was difficult when the trialist was already navigating and holding his mobile phone. One security guard commented: 'Sometimes, something goes wrong and I call the Nalle helpline. Daniel [from the support team] asks me what happened, but in order to redo and describe the error I need to read a tag with the device – but I can't do that while I am on the phone'. This is an interesting re-occurrence of the contradiction between tools and objects outlined earlier. When a worker experienced a problem with the RFID device, it moved from being a tool (unconsciously working *with* it) to being an object of his labour (consciously working *on* it). When he tried to report this problem from a distance, via a mobile phone, he discovered that this, too, degraded from an otherwise common tool of his work to an object, leaving him essentially with two objects and no tools – another very interesting contradiction of tools based on the inherent mobility of the worker.

Representation and contradictory mediation

During the interactive innovation project, mobile workers used the technology under development and subjectively interpreted it within the context of their work. Relaying their experiences to other innovation participants (in the Innovation Spaces) fuelled the iterative innovation cycles. But given the mobility of the worker, the distribution of innovation partner and innovator and the ineffectiveness of mobile technology, this knowledge exchange rested on the exchange of representations. The actual device under development was the most obvious representation, which as shown before proved to be a highly contradictory mediator. Moreover, as a mediator it was ineffective since only Nalle could manipulate it.

One trialist was recorded stating: 'Some of the features are spot on, but some others could be improved. Some changes are very small and I know what the mobile RFID device should do to work better for me, but of course I cannot make any changes to it'.

Other representations included drawings, use case abstractions, flow charts and device menus. Here, the interaction of Nalle, innovation partner and trialists relied on the manipulation of these common objects, from a distance, as mediators of their subject-object-subject relationships, leading to two main contradictions of representations.

In their communicative roles, participants were to varying degrees used to express, or externalise, their cognitive understanding through mappings and abstractions of their respective work practices and the trial technology. While some participants were engineers who were used to group work and abstract notations, others drove security vehicles for a living and were seldom required to describe their work to outsiders. Accordingly, their experience with and ability to compose and comprehend representations of work activities were quite different. The sheer number of different subject categories (project managers, developers, security guards, traffic managers and dispatchers) made the notion of representations quite important and interesting. To request a summary of the actions and operations of security guards turned out to be quite difficult; their externalisations (e.g., drawings of maps, verbal summaries and demonstrations of their tasks) were often incomplete and even plain wrong. Reason for this incompleteness was the routine fashion with which they carry out their work; calling their unconscious operations back into the conscious out of the context of work was felt to be very problematic. Consequently, the activity of interactive innovation was partially based on representations that were difficult to derive and needed to be verified and validated throughout the trial activity, leading in some cases to a need to re-design use-cases and technological devices.

One security guard noted: 'It is good that you [the researcher] are here, since I would not know how to talk to the engineers at Nalle about our work, the technology and the changes. It's like they have to imagine what we do here and we have to try to tell them everything about our work to help. The other problem is that we almost speak two different languages. Sometimes what they say makes no sense to us. It's good, too, that we have our managers to talk to, although they're never where we are'.

This statement illustrates that problems emerged when these representations and externalisations were exchanged. In their boundary-crossing role (Star & Griesemer, 1989; Carlile, 2002), they shaped the interaction between innovator, innovation partner and trialists. The subjects' incongruent work contexts led to contradictions of representations as mediators in the Innovation Spaces. Nalle and the innovation partner were quite able to relate to one another's notations and models (Innovation Space C), including technical mappings of the design elements of mobile RFID, project management charts, charters and flow charts. On the other hand, the experience of the mobile workers had to be connected with the work of the innovation partner and Nalle's developers (Innovation Space A and B), so that future improvements of workflows, hardware, software, middleware and midlets could incorporate important fixes, minor corrections and relevant suggestions. Not only were these representations difficult to construct in the first place, especially for mobile workers, but also their interpretation was highly dependent on sender and recipient, their respective work know-how, work contexts and frames of reference. Interpreting even the most accurate descriptions out of context, by subjects with a different knowledge base, led to numerous misunderstandings in the interactive activity and correspondingly to ill alignments of technological developments, systems and work practices.

Contradiction of discretionary and standardised activities

Mobile work, although collaborative in nature and part of collective activities, is frequently carried out alone. Security guards, for instance, communicated through

mobile technologies and other representations with their peers and superiors, but conducted their central work activity of checking premises and securing buildings, etc. by themselves. The majority of contradictions they commonly encountered in the field did not require collaborative decision-making, and mobile workers used their discretion, their good judgement, to form their decisions. This was evident when contradictions emerged that required a quick decision, which were never documented but were part-and-parcel of being a good mobile security guard. For instance, if a guard faced a traffic jam, he prioritised between alternate routes and changed the sequence in which he visited his remaining sites. His familiarity with the mobile work environment defined him and his mobile peers as the only true experts of the mobile work environment, which allowed them to exercise various degrees of discretion in their decision-making in the field. Accordingly, discretionary decisions regarding the multiple contexts are fundamental to mobile work (Pinelle & Gutwin, 2003; Al-Taitoon, 2005), but interactive innovation challenges this discretionary work in two ways.

Interaction and knowledge exchange requires that work practices are formalised and exchanged. Developing abstract notations of otherwise unconscious operations was already discussed as problematic, as was the creation and exchange of representations that describe extraordinary events in the field. Moreover, mobile workers expressed ambivalence towards disclosing how they exercise discretion in the field. While they wanted to help the innovation of the mobile RFID device to advance their mobile work practices, they did not want to disclose the 'tricks of their trade', the shortcuts, the workarounds and the quick fixes that nobody had ever asked about or controlled before. For instance, one guard expressed: 'We always pinch 20 min here and there; we work long shifts and need breaks. In the meanwhile, the vehicle is empty – they [managers] don't like that. It's always been like that and they have always turned a blind eye if we did not overdo it and got the work done. And we always did. But now they have proof of where we are and when, and they have to act on it. They never did this before and we need to figure out a way around this'.

This testimonial shows how mobile workers used discretion to structure their workdays, and how their superiors tolerated this level of uncertainty. The interactive innovation project now required that such behaviour was disclosed. The notion of embedding such discretionary actions into the functions offered through a new product was seen as contradictory by both parties. Mobile work activities that are highly discretionary allow a continuous negotiation between mobile workers and superiors. Inscribing these activities into new innovations would put an end not only to the discretion of the mobile worker, but the inherent standardisation also prevents his ability to negotiate aspects of his work. For instance, the RFID system facilitated insights into mobile work that were previously not possible or required, which was met with resistance by mobile worker and led to an important contradiction for the interactive innovation of technology for mobile work. Perhaps surprisingly, this was also seen as contradictory by their superiors, who now had explicit data on the work conducted in the field, could no longer allow discretionary actions and had no choice but to reprimand their employees for behaviour that was previously tolerated.

Conclusion

For Nalle, the appreciation of Innovation Spaces, combined with the respective knowledge sets, was recognised as invaluable for staging interactive innovation projects. Moreover, the Interactive Innovation Framework had proven beneficial not only for setting out the normative interaction model, but also as an analytical tool for identifying interaction contradictions. All of the contradictions that emerged in this project (summarised in Table 4) directly affected the interaction between innovator, innovation partner and trialists, and indirectly shaped the technology under development.

Interactive innovation is different in mobile settings. Innovators of mobile technology, striving to involve their future primary and secondary users, face distinct challenges within mobile settings. Contradictions rooted in dissimilar motivations provide a complicated foundation for interactive innovation activities. The unique conditions of mobile work then add novel spatial, temporal and contextual contradictions, which mobile technology itself might be unable to resolve. In fact, the duality of a device-in-use and a device-under-development can be disadvantageous to the interaction between participants. As a result, the knowledge exchange with mobile workers rests on asynchronous representations, including notations of work practices and more abstract descriptions of workflows. However, such externalisations are hard to develop, especially by mobile workers who are not often required to reflect on their work practices, and difficult to exchange and interpret across the different activities of innovator, innovation partner and trialists. The fact that the different parties work either *on, through* or *with* technology adds further complication to interactive innovation, as individuals are much less able to relate to each other's work. Lastly, an important contradiction of discretion reveals how mobile workers might object to revealing their unique work practices in the field. Inscribing their actions and operations into new innovations suggests standardising previously flexible and discrete work practices. For mobile workers, this inherently reduces their future ability to negotiate work practices and to exercise discretion in the field, a contradiction that strongly influences their motivation to interact and support the innovation of a new technology for mobile work.

For manufacturers who desire to develop technologies tied to mobile organisational environments, interactive innovation activities are important sources of critical mobility-specific lessons. Although inviting a multitude

Table 4 Contradictions of interactive innovation

Contradiction	*Conflict*		*Impact*
Motivation	Innovator	Success desired, failure acceptable and not negative (solution-focus)	Interactive innovation is flawed if participants are motivated to transform the object into a different outcome and if success and failure of this transformation are to different degrees acceptable.
	Innovation partner	Success imperative, failure not acceptable (context-focus)	
	Trialist	Failure has no impact, success possibly positive or negative (needs-focus)	
Mobility	Innovator and innovation partner	Interactive innovation demands stopping work, potentially returning to the office, to report errors or to refine information flows, etc.	Interactive innovation is flawed if it requires different degrees of mobility. Trialists' primary concern is motivated by the mobility required by their central work activity, not the mobility of interactive innovation.
	Trialist	Mobile work activities demand continued mobility.	
Technology	Innovator	Working *on* technology	Interaction is flawed if parties are unable to relate to the central activity of each other (e.g., developers of technology do not know what it is like to work through it, or with it).
	Innovation partner	Working *through* technology	
	Trialist	Working *with* technology	
Representation	Innovator and innovation partner	Collaborative work externalised through abstractions of technology or work practices.	Interaction is flawed if trialists are unable to express their work practices in abstract terms. In any event, effective interaction is hindered through interpretation out of context (solution- *vs* context- *vs* needs-based).
	Trialist	Mostly isolated, individual work, collaborative mostly for exchange of explicit field data.	
Discretion and control	Innovator	Solution-based activity requires feedback from the field.	Mobile workers' motivation is to retain flexibility and ability to (re)negotiate working conditions. This opposes interactive innovation, which eventually supports closedness and standardisation. Information from trialists might therefore not support interactive innovation.
	Innovation partner	Context-based activity requires formalisation of mobile work practices.	
	Trialist	High degree of discretion is a primary condition of mobile work.	

of categorically different parties with different activities into the innovation process adds to its complexity, the interaction with organisational customers and end users promises access to solution, context and needs-based knowledge sets. Through their initial input, in combination with contradictions that emerge during the innovation activity, innovators are able to go through expansive cycles to improve the technology under development. However, for the interaction within the innovation activity it is elemental to recognise that mobile workers are motivated to support the development of the technology on the one hand, but on the other hand they might resist the impact innovation has on the future of their mobile work practices.

This activity-based discussion aims to complement the predominantly product-focused and diffusion-oriented body of innovation and mobility literature. We anticipate that as the mobilisation of work continues and the mobile technology industry matures, interactive projects will become increasingly imperative and activity-focused methodologies even more crucial for the successful innovation, and study, of technologies for mobile work. We believe that our findings are relevant for other innovation projects, and hope that they will not only help motivate research concentrating on the innovation, but also the design, adoption and appropriation of technologies for mobile work.

About the author

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