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ABSTRACT

New ICTs and intensive digital collaboration have potential for enhancing collaborative work. Much of modern work involves dealing with information representations of various types and forming insights and decisions based on that information. The objective of the study is to understand how accessibility of information is linked to the successfulness of coordination in distributed work. In distributed work, the collaborators and the resources of the work are spatially and temporally distributed. The goal for this study is to conceptualise and empirically specify the core drivers and shapers influencing information interaction performance in the coordination of distributed work. The research questions of the study are: What kind of coordinative practices does distributed work require, what factors shape these practices and how these practices influence information interaction performance.

The study contributes to coordination theory through examination of the challenges and performance of information interaction related to coordination in diverse work environments. The study analyses the nature of coordinative practices, the shapers of these practices and effects of coordinative practices on information interaction performance success. Maintenance of situation awareness and management of experience knowledge were approached as comprehensive, information-intensive coordinative practices applied in distributed work. The overall formation of coordination practices are hypothesized to be shaped by the nature of interdependencies, social capital, technological affordances and spatio-temporal dispersion between collaborators. It is proposed that these factors influence and enable success in information interaction performance in distributed work.

The study is an in-depth multi-method comparative multiple-case study executed in diverse real-life work contexts. The multiple case studies empirically examine the framework for explaining formation of coordinative practices and information interaction performance success developed in the study. The contexts studied in the case studies include process control in the chemical industry, technical support service in machine-maintenance business, service production in the telecommunications industry and security services in facilities' maintenance.

The study shows that the nature and characteristics of interdependence patterns within distributed activities and resources influence the coordination needs in distributed work. Interdependence complexity creates challenging coordination needs, in large numbers, the management of which requires coordination practices. The results of the study show that the interdependency complexity does not make successful coordination impossible. The better the fit between, on one hand, the scope and nature of the coordination mechanisms applied in the distributed work and, on the other, the level of coordination challenge involved, the

more successful and disturbance-free the information interaction performance will be. The appropriateness of the coordination practices with respect to the real-world coordination needs is directly reflected in the quality of the information interaction performance of the collaborative actors. High spatio-temporal dispersion among collaborators does not make good coordination impossible. However, in order to enable the best possible fit of coordination practice to associated coordination challenge, higher social capital among collaborators and higher variety of actually applied technological affordances in the coordination enhance the fit, regardless of the overall level of interdependence portfolio complexity.

The study provides practitioners of work design and work-process development with conceptual tools to analyse information interaction in distributed work and uncover the root causes of information interaction performance disturbances and successes. Conceptual tools assist practitioners in observing coordinative practices and factors shaping these practices, and in unlocking potential for current practices' enhancement.

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This dissertation is based on the following four publications:

Article 1 Franssila, H., Okkonen, J., Savolainen, R. & Talja, S. (2012) The formation of coordinative knowledge practices in distributed work: towards an explanatory model. Journal of Knowledge Management, 16(4), 650–665.

Article 2 Franssila, H. (2013) The Role of Knowledge Intermediaries in the Management of Experience Knowledge. Knowledge and Process Management, 20(4), 232–242.

Article 3 Franssila, H. (2013) Mobile Email as a Business and Personal Performance Driver in Everyday Knowledge Work – A Multi-method Case Study. Knowledge and Process Management, 20(4), 185–198.

Article 4 Franssila, H. (2016) Enhancing information interaction as a means for situation awareness maintenance in mobile field work. Cognition, Technology & Work, 18(3), 567–582.

Author's contribution:
Article 1: Heljä Franssila was the primary author of the article and responsible for final wording. She executed study design, data collection and analysis, and developed the theoretical model. Jussi Okkonen, Reijo Savolainen and Sanna Talja contributed to introduction, literature review, and conclusions.

Articles 2–4: Heljä Franssila was the author of the article. She executed the study design, data collection, analysis, reporting and final wording of the articles.

1   INTRODUCTION

1.1   Background

In day-to-day work, information is processed all the time. Information is a core resource of work. Getting things done requires timely and precise delivery and utilisation of information. Workers spend most of their working hours manipulating information with various information and communication technologies (ICTs). The information thereby processed is delivered in diverse formats and stored in a distributed manner. The everyday work environment of contemporary workers is a turbulent, information intensive ecosystem composed of a plethora of information systems. The work communities are often fragmented, in the sense of work location, time zone, and the nature of the work profile. Collaborative work is very often distributed – collaborators do not share same location (be it building or geographical area) or co-presence in time when executing their interdependent work duties. Employment relationships range from conventional fixed-term contracts with the enterprise to various kinds of flexible, non-traditional work contracts. Exchange, manipulation, and curation of information in frequently changing networks of relations is the lifeblood of the work processes involved, in both white- and blue-collar work. A need to interact emerges from the requirements to manage diverse interdependencies in shared work. Some of these interdependencies are obvious, recurrent, and stable, while others emerge sporadically, in an ambiguous way, and without prior knowledge.

Work design issues in distributed work are almost always related to information interaction and largely overlap with it. In the present work, *information interaction* is defined as activities related to seeking, selecting, verifying, filtering, integrating, receiving, and delivering information. It encompasses activities of documenting and communicating information via variable communication channels and media. The perspective adopted in this study entails examining how information interaction enables effective execution of work tasks and how information is managed as a practical production resource in distributed work. What kinds of access and delivery patterns and routings are required for efficient work performance? Surprisingly little is known about core factors and drivers influencing information exchange and use at work communities. How do the quality of the information, ICTs, and the work communities' communication practices shape the productivity and performance of work? Since most contemporary knowledge workers spend the majority of their working hours processing and applying information both with

and without a variety of ICTs, it is important to ask how the processes of information delivery and use at work can be enhanced.

The practical motivation behind the study is the recurrent observation that in distributed work, workers face problems in their efforts to make efficient use of organisations' information resources. In many work organisations, regardless of the widespread adoption of various ICTs, there is ongoing experience of the information not being accessible enough and of task-critical information being cumbersome to obtain and use when needed. The increased productivity promised as fruit of ICTs is far from fully realised in the day-to-day work flow of distributed collaborative work. Information as a core resource of organisations, groups, and individual workers is still tricky to manage and share efficiently.

1.2   Research goals

It is important to understand the activities humans perform with information in distributed work. Which information processing and information use activities cannot or could never be carried out solely by computers? Success or failure of information use at work is the great black box of our age. Heavy and rapid investments in ICTs do not necessarily yield productivity or quality gains without a basic understanding of the factors influencing needs for information interaction in collaborative distributed work. New ICTs have potential for enhancing collaborative work. Much of modern work involves dealing with information and forming interpretations and decisions based on that information. Work is about collecting and combining information in order to reach goals and design new activities.

The central objective of the study is to understand how accessibility of information is linked to the outcome of everyday work processes in distributed collaborative work. In distributed work, the collaborators and the resources of the work are spatially and temporally distributed. The role of new ICTs such as mobile email, instant messaging, context-sensitive and social applications as enablers of more efficient human–information interaction is analysed in this study.

This study conceptualises and examines the core factors, enablers, and constraints influencing information interaction in the coordination of distributed work. Understanding of these factors assists in enhancing work practices and ICTs applied to support information interaction in the coordination of distributed work.

The study contributes to coordination theory (Malone & Crowston, 1994) through examination of the challenges of information interaction as part of coordinative practices across diverse work contexts. The study seeks to pin down the shapers of these practices and effects of coordinative practices on information interaction performance. Maintenance of situation awareness and management of experience knowledge are coordinative practices applied in distributed work. The overall formation of coordination practices are hypothesized to be shaped by the nature of interdependencies, social capital, technological affordances

and degree of spatio-temporal dispersion between collaborators. I argue that these factors influence performance and success in information interaction in distributed collaborative work. The study highlights how information interaction related to coordination of various interdependencies in the work context is a central meta-work task in contemporary distributed work (cf. Gerson, 2008). Quality and efficiency of coordination as part of work is central to performance. Therefore, the study was conducted to unravel the factors influencing the success and failure of coordination in work. It highlights maintenance of situation awareness and management of experience knowledge as means, and social capital, spatio-temporality, and technological affordances as shapers of coordination of distributed collaborative work.

1.3   Research approach and methods

The research is based on an in-depth multi-method comparative multiple-case study executed in diverse work contexts. The case studies empirically test the framework for explaining the formation of coordinative practices and information interaction performance developed in the theoretical part of the study. The case studies include process control in the chemical industry, technical support service in the machine-maintenance business, service production in the telecommunications industry and security services in facilities' maintenance. The goal is to understand and conceptualise what is done with information when coordinating distributed work and how to make this information interaction more efficient and disturbance-free. Process control operators, technical support engineers, telecommunications business professionals and security service personnel are the informants in the case studies. Empirical data are collected via observation, interviews, diaries and surveys.

Many studies of computer supported collaborative work have analysed stable work groups such as teams working together daily (e.g., Costa et al., 2011; Mark, 2002; Ghosh et al., 2004; Espinosa et al., 2007; Espinosa et al., 2012; Cataldo et al., 2006) or work groups sharing a stable common physical work environment (e.g., Lutters & Ackermann, 2007; Bardman & Bossen, 2005). Performance drivers in interaction with information in distributed work are approached in this study via analysing everyday work practices in four, quite different kinds of work contexts. Special emphasis is placed on collaboration and the challenges experienced by practitioners in their work-related information interaction. Common to these work settings and work communities is that either the co-workers, their temporal co-presence or the physical work environments change frequently.

In line with the suggestion put forward by Malone and Crowston (2003), this study examines coordination practices in different settings to develop coordination theory. Malone and Crowston stressed that typologies of general dependency relations and coordination mechanisms should be tested and developed in an interdisciplinary manner in various fields of practical application. In addition, performance issues related to

coordination mechanisms should be explored, among them speed and accuracy (ibid.). New ICTs support less formal communication-intensive coordination arrangements, such as 'adhocracies' which as organizational forms rely on lots of unplanned coordination. Because communicating by electronic means is inexpensive and easier, the practical cost of coordination diminish (Malone & Crowston, 2003). However, it can be argued that the benefits brought by ease of communication have their limits too.

This study thus sets out to uncover interdependencies between work activities and the information resources needed in work. The study examines critical episodes of information interaction in distributed work settings to reveal and explain the factors that affect the success of these interactions.

The main interest lies in understanding what is critical for efficient and smooth information delivery and use in distributed collaborative work. The study aims at showing that there is a general need to manage interdependencies – coordinate – in distributed work, a need that must be addressed by the information interaction between collaborators. The efficiency and ease of the coordination is constrained and shaped by several factors. The research questions explored are:

> What kind of coordinative practices does distributed work require in four case contexts?

> How do interdependencies, spatio-temporal dispersion, social capital, and technological affordances shape coordinative practices?

> How do coordinative practices influence information interaction performance in distributed work?

1.4   The structure of the thesis

The thesis comprises of the summary and four journal articles. Each article reports results from a case study executed as part of the multiple case study design. Article 1 (sub-case in process industry) focuses on exploring the factors influencing formation of coordinative practices in distributed work and integrating them into a conceptual framework. Article 2 (sub-case in technical support centers) explores the management of experience knowledge as a coordination practice. Article 3 (sub-case in telecommunications business) analyses the role of mobile communication technologies as enablers of coordination. In article 4 (sub-case in security service business) the focus is on maintenance of situation awareness as a means of coordination and on the potential of a location aware mobile technology in security service work. The summary combines the results from the case studies and integrates them into a larger synthesis explaining the formation of coordinative practices. The summary collecting, comparing and synthesising the case study results extends and sharpens the initial explanatory framework (Article 1). It integrates sub-study results as evidence for examination of hypothesis derived from the framework. Based on examination,

suggestions are made about application of explanatory framework for analysing and developing coordinative practices.

The summary is structured as follows. In the second chapter, the theoretical background of the study is introduced. Theoretical and empirically oriented literature on interdependencies, coordination, and evaluation of information interaction performance are presented and discussed. Based on these bodies of literature, an explanatory framework for the formation of coordinative practices is proposed, and the research questions for the study and associated hypothesis for examination are presented. In Chapter 3, the research methods and empirical settings of the study are presented. The chapter describes the multiple-case-study contexts, the design of the study, and the factors in which variation among the empirical case contexts were explored. Chapter 4 presents results from the case studies and summarises the evidence that each case study provides in relation to the overall framework. In Chapter 5, the findings are summarised and the answers to the research questions are presented. Conclusions based on the study, its contributions, and directions for future research are presented in Chapter 6.

2 UNDERSTANDING COORDINATION IN DISTRIBUTED AND MOBILE WORK

This chapter presents theoretical background for the study of information interaction performance related to coordination of distributed work. The chapter introduces theoretical concepts to explain drivers and shapers of coordination and information interaction performance related to coordination. The discussion begins with an introduction of coordination as the management of interdependencies. How interdependencies feature in distributed work and how they drive the need to coordinate work are described. Coordination is considered from the standpoints of its *function*, its *means* and *mechanisms*. Different coordination mechanisms discussed in the literature are presented. After describing the functions that coordination serves in distributed work I introduce maintenance of situation-awareness and experience-knowledge management as possible new means of comprehensive coordination. The final part of the chapter presents social capital, technological affordances, and spatio-temporality as potential *shapers* of coordination practices. The performance of information interaction for coordinative purposes is approached in terms of eliminating information waste in interaction. Finally, the perspectives presented are brought together to form a theoretical model proposed as a framework for explaining coordinative practices and the success of information interaction performance in distributed work.

2.1 Interdependencies at work

Work can be conceptualised as a series of goal-directed activities. To execute one's share of distributed work activities, information resources are required. Information is needed also to enable appropriate decisions in the work. This information covers the state of the shared work objects and the state of one's plans and activities – past, present, and future. For the work to be accomplished, several kinds of information resources must be delivered. If distributed collaborative work is to succeed, these necessary resources have to be located and mobilised. There are at least two functions that information management serves in distributed, shared work activities. There is information that is utilised as a primary, elementary, or combinatory resource in our tasks, but there is also information that must be expressed, managed, and shared to enable coordination of activities among collaborators.

The latter efforts related to coordination can be characterised as a secondary but nonetheless critical part of distributed work, as practices that integrate practices (Schmidt, 2011b).

As a potentially powerful explanatory and analytical concept to characterise coordination in distributed work settings, interdependencies have attracted the interest of several disciplines. The attention to coordination has not been limited to information science and computer supported co-operative work (CSCW); the topic inspires interdisciplinary study. Malone and Crowston (1994) named this field of study as coordination theory. Organisation science and information systems research have equally maintained constant interest in the issues of synthesising multiple activity streams into a coherent ensemble, whether the systems involved are computer, human, or computer–human ones. How interdependencies form as more and more ICTs supporting shared work become available in work communities is one of the central topics demanding research.

DeSanctis et al. (1999, 82) defined interdependence as 'a state of being in which an entity (such as a person, organisational unit, or firm) is determined, influenced, or controlled by some other entity'. In interdependent relationships, information and other resources (such as social goods) are exchanged and shared. Malone and Crowston (1994) and Malone et al. (1999) defined coordination, in turn, as 'managing dependencies among activities'. Interdependencies constrain how tasks can be performed; therefore, they need to be managed. Interdependencies can take various forms and be managed with various means and practices.

Interdependencies are configurations of relations *between tasks and resources* and *within tasks and resources*. A task can present a goal or an activity that can reach a goal. A resource represents an actor in an activity and anything that is used or affected by that activity (Crowston, 2003). Managing dependencies between actors, activities, goals, and resources is necessary for efficient operation. In organisational settings, the actors might be employees, customers, and/or suppliers, and the activities consist of whatever processes and work duties are put toward goals such as creating value for clients. Many of the resources in work duties are information resources, of various types, and the interactive process of coordination requires an information management practice. Of particular interest in this connection are interdependencies wherein activities and information resources produced as output of a certain activity serve as input to another activity (Crowston, 1997).

Interdependencies can vary greatly in their structures and dimensions. An interdependence may have a *sequential*, *pooled*, or *reciprocal* structure (Thompson, 1967; Malone & Crowston, 1994). In addition, some interdependencies exist within tasks and others within resources, as noted above. Goals can be considered in terms of tasks contributing to reaching the goal in question, which requires the task to be broken down into sub-tasks. This entails *decomposition dependency*. There can also be *simultaneity dependency*, between tasks that must be executed simultaneously. Resources need to be correctly allocated for appropriate execution of the simultaneous tasks, and their utilisation needs to be synchronised if the relevant resource is not shareable (Crowston, 2003). According to

Malone (2004), interdependencies can be divided into three general types of dependencies – *flow, sharing*, and *fit*. These three are the elementary classes of interdependencies between an individual resource and multiple tasks. In flow dependency, one task produces a resource that is consumed by another task. A flow dependency is a producer–consumer relationship between tasks. An example is a simple work flow wherein one actor modifies an object in a certain way, after which another actor modifies the object further. In sharing dependency, a resource is shared by multiple tasks. For instance, there may be a need to share stocks of a limited raw material or time of expert among several actors to enable their tasks. Finally, in fit dependency, multiple tasks produce a single resource. An example of this kind of dependency is a situation in which multiple components are assembled into a finished product (Malone et al., 2003; Crowston, 2003).

Interdependencies vary in their complexity. Complexity depends, for instance, on the number of entities involved. They can also vary according to the level of formality in the exchange activities and the symmetry of influence. Schmidt (2011b) distinguished among the following dimensions of complexity in interdependencies: degree of coupling (is the dependence mutual or not?), level of uncertainty, and temporal and situational factors. There are three distinct systemic spheres of work, all of which influence complexity – the common field of work, co-operative work arrangements, and articulation work. The *common field of work* is the part of the world that is changed or influenced through the actors' co-operative activities. *Co-operative work arrangements* consist of the distribution, mobilisation, and implementation of interdependent activities of the actors. Finally, *articulation work* is a category of second-order work needed to coordinate and integrate distributed co-operative activities (ibid.). Work can be complex because the common field of work creates an interdependence. The field may be ambiguous, and changes in its state may generate unpredictable interdependencies; at the same time, the interdependencies may take various forms (ibid., 95). In particular, when the object of work is shared, changes to the object cannot be made without considering interdependencies between contributions of different actors. This is true in almost any cooperative work task wherein the overall goal is defined and respected by multiple participants.

2.2   Functions of coordination in distributed work

In essence, coordination of cooperative work is about observing and understanding interdependent relations in the work and ascertaining sound practical logic for their management. Coordination theory proposes that coordination is required when actors perform interdependent activities toward set goals and when those activities require the use of shared resources. In essence, coordination problem is about what kind of practical principles are applied in the collaboration to enable smooth interdependent activity.

Distributed work involving complex interdependencies generate the need to coordinate shared effort. What kind of practical goals does coordination serve in distributed work?

The practices of coordination serve goals such as maintaining mutual awareness, directing attention appropriately, allocating and dividing resources, sequencing and prioritising tasks, meshing activities with each other, and categorising objects and tasks (Schmidt, 2011a, 395; ibid.). Coordination creates conditions that enable smooth and efficient orchestration of interdependent activities. Coordination provides accountability, predictability, and common understanding of the organisation's work processes (Okhuysen & Bechky, 2009). Schmidt (2011b) outlined the following *coordinative functions* needed in co-operative work:

1) Specifying the properties of the results of individual contributions to make management of interdependencies easier

2) Expressing the state and development trajectories of a remote, partly invisible common object of work that is of global interest within the community

3) Synchronising otherwise unpaired, local activities for concurrent execution

4) Describing certain local activities that need to be performed consistently no matter which actor is performing them

5) Providing a standard for expression addressing issues of relevance across the spectrum of local practices

Coordination serves also functions of dividing responsibilities; allocating them; and scheduling, synchronising, interlacing, integrating, and meshing activities. Better coordination is associated with more effective and productive performance (Laukkanen, 2007; Crowston, 1997). At the same time, coordination becomes challenging as the number of interdependencies to manage continues to grow (Okhuysen & Bechky, 2009). In particular, there is a stronger need today than ever before for managing interdependencies that extend beyond the boundaries of teams and even entire organisations.

Collaborative work involves a variety of constituent interdependencies. Information resources are one sort of shared resource needed by various actors in distributed work. Accessibility and predictability of information resources is important. Diverse information resources are utilised for coordinative purposes (Schmidt, 2011b). An informational object can and, in fact, frequently is a key coordinative artefact enabling smooth collaboration. Yet the role of information objects as coordinative artefacts is often not fully understood in work communities and in the design of distributed work.

Based on the literature, we can be formulate a categorization of the functions that coordination serves in distributed work. Coordination enables

- aligning of goals and responsibilities in the shared value creation
- decomposition of activities between actors
- organization of resource utilization between activities
- securing consistency and assembly of various parts and contributions from activities to fit together
- ordering, sequencing and timing of interdependent activities

- expressing and acknowledging the status of the common object of work, shared resources and activity processes.

These categories of coordination functions are utilized as analytical lenses in the empirical part of this study when detecting and describing information interaction episodes as instances of coordination practices.

2.3 Coordination as means to manage interdependencies

Means of coordinating interdependencies can be categorised and characterised at several levels of abstraction. In this chapter different ways to distinguish and categorize coordination means in the literature are presented, in order to show the wide array of socio-technical possibilities available to coordinate distributed work.

Coordination mechanism has been applied as an umbrella concept to denote various techniques and approaches for managing interdependencies. In general, various authors have distinguished various coordination means, and named them as *coordination mechanisms* (e.g. Crowston, 2003; Mintzberg, 1979; Okhuysen & Bechky, 2009; Schmidt, 2011b; Thompson 1967). Coordination mechanisms can vary alongside the categorization into discursive and non-discursive (Schmidt, 2011b) and within the continuum from very formal to informal (e.g. Thompson, 1967). Schmidt (2011b) divides coordination mechanisms into two broad categories – they can be based on discursive interaction and non-discursive interaction. Examples of discursive interactions are telephone conversations, email exchanges and meetings. Non-discursive interactions rely on collections of artefacts (material or informational) that support alignment of concurrent, sequential and reciprocal action between co-operators. These artefacts can be various kinds of documents and materials of work reshaped during the work flow. (Ibid.) Coordination mechanisms can also vary based on which kind of coordination problem or specific dependency type they are proposed to solve (e.g. Crowston, 2003). A coordination mechanism can be either explicit or implicit. Those in the former class rely on conscious planning and explicit communication. Implicit coordination is achieved without explicit planning or ongoing communication (Rico et al., 2008; Srikanth & Puranam, 2011).

Schmidt and colleagues have pinpointed two kinds of elements that are necessary in coordination: *coordinative protocols* and *coordinative artefacts*. A coordinative protocol is a relatively firmly established set of interaction rules. It might take the form of expectations linked to a conventional way of doing things, a set of policies, or standard operating procedures. A coordinative artefact, in turn, can be defined as a stable information resource structured and expressed in standard format (Schmidt, 2011b, 16).

Coordinative artefacts and protocols reduce the complexity of coordination work and eliminate the need for *ad hoc* negotiation. Two examples of coordinative artefacts in combination with protocols are special-purpose reports, such as bug-documentation

reports in software design, and meetings with a certain agenda and work flow for resolving interdependence issues in distributed work. When put to good use, these artefacts can also reduce the boredom stemming from routine parts of human work. Among the coordination protocols cited by Schmidt (ibid.) are production schedules, office procedures, and other conduct conventions. Coordination artefacts include classification schemes, timetables, and checklists of various sorts, which serve as maps or scripts that support shared activity. Together, these elements form coordination mechanisms: the protocol names the conditions and defines procedures that are needed to manage interdependent activities, and the artefact is a symbolic representation that objectifies and gives permanence to the protocol. In other words, there is a behavioural convention and an artefact that supports that convention.

Though they play an important role in how the work is conducted, coordinative conventions can never explain, determine, or even illustrate the interdependent activity fully. As mentioned above, their status and level of formality vary, and these can even be contested. Coordinative practices can lie anywhere on a continuum from rather unconscious mutual awareness to strictly expressed and explicit guiding rules. When coordination poses few challenges, its success does not require explicit procedures or other formalities. It takes place naturally, without costly disturbances. In real-world settings, one can find a broad range of coordination practices, showing great variety (Schmidt, 2011b).

It is important to recognise that several kinds of resources need to be coordinated, and that there is variety also in the nature of the interdependencies that demand coordinative effort. The amount and nature of interdependences to be managed in certain work role can be understood as the *interdependence portfolio* of the work role. Together, these form the coordinative requirements of a certain work role, in response to which certain strategies and technologies may be applied to support work in line with these roles. A single work role can involve several kinds of coordinative requirements, and different strategies and technologies may support them.

In their review article, Okhuysen and Bechky classify coordination mechanisms, both explicit and implicit (tangible and intangible), into plans and rules, objects and representations, roles, routines, and proximity. Each type can fulfil several coordination functions. Plans and rules can define responsibilities for tasks, specify resource allocation, and embody agreement (Okhuysen & Bechky, 2009). Plans and rules can be devices such as protocols, standard procedures, schedules, and design rules (ibid.; Srikanth & Puranam, 2011). They simplify interdependencies management and reduce the need for ongoing adjustment and communication. Objects and representations, manifest in the form of information artefacts, support coordination by providing a common referent that aids in interaction, aligns the participants' work, and assists in creating shared meanings and views of the common work. Objects and representations enable indirect information sharing (Okhuysen & Bechky, 2009). Roles explicate and structure interactions and relationships between actors. Role-based coordination provides a means for monitoring interdependent

activities, obtaining updates about them, and substituting other actors when needed. Routines are repeated patterns of action guided by rules and conventions. They can vary in their rigidity and responsiveness to the specifics of the situation. Routines support coordination by providing stable and visible templates of task sub-composition. Routines also enhance work handoffs and create common understanding within distributed groups. Physical proximity aids in coordination by fostering greater familiarity between collaborators, better visibility of the common work, the possibility of monitoring and anticipating progress on the work tasks, and faster response to situational conditions. Physical proximity provides better access to shared information resources (ibid.).

Laukkanen (2007) has discussed the potential of ICTs to support coordination of activities within and between organisations, emphasising that IT enabled coordination devices should never be applied in isolation from other means of coordination. According to Laukkanen (ibid.), coordinative devices include 1) incentives and norms; 2) authority structures; 3) lateral relations and boundary-spanning structures; 4) information and knowledge sharing; and 5) specifications, standards, and controls. Incentives and norms align actors' interests, values, and beliefs; enable harmonisation of activities; and avoid partial optimisation in the work. Authority structures specify responsibilities and distribute decision-making rights among the actors. The 'lateral relations and boundary-spanning structures' item refers to organisation of interaction horizontally and in a way that cuts across various organisational boundaries and authority structures. Information- and knowledge-sharing support harmonisation of interdependent activities through active and multimodal information exchanges. Specifications, standards, and controls are planning-, scheduling-, and monitoring-based means of coordination suited to, in particular, recurring situations (ibid.). All of these integration and coordination devices can be supported by associated information systems and information interactions.

As a category of coordination means, awareness about activities of collaborators has generated plenty of research focused on fields in which virtual, distributed work has become more commonplace. In this stream of research (in a departure from the conceptualisation of situation awareness), awareness is understood as an effortless experience or state of mind that can be more or less supported by ICTs (Gross, 2013). It is an implicit coordination mechanism that in co-located work settings does not require much extra support. In distributed and mobile work settings, however, effortless maintenance of awareness is not as easy.

In their description, Okhuysen and Bechky did not discuss which coordination mechanisms would suit which type(s) of interdependence constellations described by Malone et al. (2003): fit, flow, and/or sharing dependencies. Coordination is accomplished via practical mechanisms deployed to manage dependencies. In general, all coordination mechanisms entail planning, decision making, and communication. However, to manage flow dependency certain activities need to be executed and completed at/within the right time, in the right place, and in the right way to enable the next phase of activity

in the sequence to start in time. Flow dependencies can be managed with coordination mechanisms such as notifications, use of inventory data, just-in-time production, detailed planning (e.g., transportation logistics), and product standards. A sharing dependency can be coordinated by prioritising the resource utilisation in a set manner, by means of a market-like mechanism, or through negotiation 'on the fly'. Typical coordination to address a fit dependency entails detail level planning enabling successful integration of parts into the whole (ibid.).

Recently, research into coordination has evolved to focus largely on studying the less formalised and context-bound practices people are beginning to apply to coordinate work (Okhuysen & Bechky, 2009). Many implicit and unplanned coordination mechanisms like reliance on shared team knowledge (Rico et al., 2008) and intensive communication when searching for shared sensemaking were found (Vlaar et al., 2008). Practices of coordinating in seemingly effortless way by rendering activities visible and audible, overseeing and interrelating local events and activities, and securing effective hand-off of responsibility and continuity have been studied in underline and air traffic control rooms (Heath & Luff, 1992; Heath et al. 2002; Berndtsson & Normark, 1999). However, interest to study more formal and artefact-based coordination mechanisms augmented with less formal ones (like integration of social software functionalities into interfaces of shared codebases, or informal but hierarchical communication structures) has been rising among studies which analyse means to enhance coordination in distributed software development projects requiring flexible but efficient coordination mechanisms without benefits of co-location (e.g. Boden et al., 2014; Bolici et al., 2015; Cataldo & Herbsleb, 2013; Giuffrida & Dittrich, 2015; Sharp & Robinson, 2008) and in off-shoring of businesses (e.g. Bayerl & Lauche, 2010; Cummings et al., 2009; Hinds & McGrath, 2006; Kumar et al., 2009; Meyer et al., 2015; Srikanth & Puranam, 2011). There is also studies were the very tight combination and interaction of the use of certain technological coordination devices like electronic whiteboards (Hertzum & Simonsen, 2015) and automated control and command systems (Luff & Heath, 2000) with oral communication together form a coordination practice for distributed work.

Based on the literature reviewed above, the following definition of coordinative practice is applied in this study: *coordinative practices are communicative and information interaction activities which serve coordinative functions and implement the set of coordination mechanisms applied in a certain context of distributed work*. The classifications of coordination mechanisms (Okhuysen & Bechky, 2009; Laukkanen, 2007; Schmidt, 2011b) presented above are utilized in the empirical identification and analysis of coordinative practices in this study. This study attempts to distinguish why in certain contexts of distributed work certain repertoire of coordination mechanisms is applied (or not).

2.4   Drivers of coordination success

How to evaluate coordination and coordination mechanisms is a core issue in coordination theory. A potential starting point for evaluation of coordination is to detect the logical interdependencies between work tasks and activities, and assess the scope of these interdependencies that current coordinative activities are able manage and acknowledge. This scope illustrates the level of socio-technical congruence between the coordination needs and actual coordination activities taken (Cataldo & Hersleb, 2013). The next step for the evaluation of coordination is to assess the need for reconsideration of current coordination mechanisms applied. A strategy to identify potential needs to enhance coordination means is to look what kind of disturbances occur in the interdependent activity (Crowston & Osborne, 2003). Crowston (1997) distinguished and analysed the interdependencies and coordination mechanisms applied in software bug-fixing processes in which multiple professionals participated. He found that coordination mechanisms can be evaluated in terms of the production cost, coordination cost and vulnerability to failures they generate for the bug-fixing process. In light of the cost, alternative mechanisms could be suggested. Higher production costs were associated with longer lead times in bug-fixing and higher coordination costs were associated to the need for additional information exchanges for coordination of the work process. New ICTs supporting coordination can influence both of these costs. Central to the evaluation of ICTs are the functions they can perform for coordinative purposes. However, comparing alternative coordination mechanisms on the basis of only direct performance costs they may generate when implemented is not sufficient. A sound analytical starting point requires considering also the work design and potential changes needed in the work processes. Factors such as social and motivational feasibility have to be considered too (ibid.).

Coordination of interdependencies requires information processing that extends between interdependent actors and units. Understanding the variety of interdependencies and the temporal pattern in how they unfold between collaborators should drive the choice of coordination mechanisms applied (Costa et al., 2011). In a study of coordination performance within a worldwide logistics support organisation, Sherman and Keller (2011) found that suboptimal assessment of interdependencies between units was reflected in suboptimal modes of integration being applied and in decreased coordination performance. In an analysis of distributed work in a government ministry where an electronic workspace was utilised to replace paper-based work processes, it was found that lack of conventions and of commitments regulating the use of shared electronic resources created performance losses. The difficulties in forming and maintaining conventions were related to weak social ties between collaborators and uneven payoffs of the acceptance of conventions and commitments (Mark, 2002). In a longitudinal study of a start-up software company, all digital communication activities that distributed teams carried out, over several years, were traced. It was found that coordination by means of general-purpose communication technologies – such as phone calls, email, and instant messaging within a distributed team

– was enhanced when communication norms for coordinating work were established (Ghosh et al., 2004). In a study of coordination delays within pairs of collaborators facing both spatial and temporal boundaries in their shared work it was found out that temporal boundaries were harder to overcome than spatial boundaries. The possibilities to apply informal, synchronous communication technologies like instant messaging and phone calls were limited. (Cummins et al., 2009.)

It can be concluded based on earlier research on drivers of coordination success that it is critical to apply appropriate combinations of different coordination means which corresponds to the coordination challenge the interdependence portfolio of the work role presents. What is absent from earlier research on coordination is the analysis of effects of the applied coordination means and practices on the information interaction performance of a single work role holder having a certain interdependence portfolio to be managed in the work role. In the present study the impact of applied coordination practices on information interaction performance is analysed in detail. In addition, earlier research evidence for factors influencing the efficiency of coordination indicates that alongside with the interdependence portfolio present in the collaborative relations and the appropriateness of applied coordination activities, a variety of social, spatio-temporal and technological issues shape the success of coordination in distributed work, and appropriateness of coordination mechanisms applied. Further, the influencing factors are interrelated. This means that changes in technologies applied in coordination cannot be made without considering the social context they are introduced to. In this study, the above reviewed drivers of coordination success are utilised as components of the proposed explanatory framework for the performance of information interaction in distributed work.

2.5   Maintenance of situation awareness as a means of coordination

In distributed work, "being on the top of things" is central for successful performance. In the CSCW research tradition, awareness as resource for coordination and orchestrating shared activity has been a central concern. Different conceptualizations of the phenomenon flourish, and there is no consensus about how to characterise and define awareness as researchable phenomenon in CSCW (Schmidt & Randall, 2016). In his review of 25 years of awareness research Gross (2013) postulates that in CSCW awareness has been understood either as a state of mind or activities taken related to information about co-workers, their activities and changes they made mainly into shared digital workspaces. One facet of conceptual confrontations considering understanding awareness in CSCW has dealt with what kind of entity can be aware – a person, a group or a system (Schmidt, 2016). The approaches to awareness in CSCW also differ with regard to their emphasis either on effortless and subtle, intersubjective character of shared awareness as a cognitive state, or on interaction based formation of awareness (Randall, 2016).

Schmidt positions shared situation awareness as one approach belonging to the set of various understandings of the awareness phenomenon in CSCW (Schmidt, 2016). Interestingly, the concept situation awareness (SA) in the Human Factors and HCI research traditions has been debated in a similar fashion as awareness in CSCW. In general, situation awareness refers to updated appropriate understanding of what is going on at work but there are multiple definitions given to the concept in human factors and human computer interaction literature. According the one of the most cited definitions, situation awareness refers to 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future' (Endsley & Jones, 2011, 13). Situation awareness researchers have been interested in the formation of both individual-level and team-level or collective SA (Endsley 1995; 2015a; Salmon et al., 2015; Stanton et al., 2010). The individual-level SA concept has been criticised for representing cognitivism and also for its somewhat unclear originality in comparison to the concepts of working memory and mental models. There is no consistency in definitions of team situation awareness either (Salmon et al., 2008). Some authors state that team situation awareness should be considered a system-level phenomenon (ibid.). Yet there is controversy as to whether an entity other than an individual can have or experience awareness and, furthermore, how distributed awareness could be empirically observed.

Schmidt (2002) emphasizes the difference between two understandings of awareness in CSCW – awareness as an implicit, tacit state of mind of some actor and awareness as an explicit, observable activities and interactions with the world. Schmidt posits that empirical study of practices and interactions within work environments as means to maintain awareness should be the focus of awareness research in CSCW, not theorizing about formation of effortless, possibly intersubjective group mind (Schmidt, 2002; 2016). In a similar fashion, scholars in Human Factors and HCI have also debated whether situation awareness is more a product or a process (Lundberg, 2015). There has been discussion what kinds of entities can possess situation awareness (Stanton et al., 2010), what types of processes are involved in maintaining SA (Endsley, 2015a), what its elements are (Endsley, 2015a; 2013; Scielzo et al., 2009), and what differences exist between team SA and distributed SA (Salmon et al., 2008). Several methods have been developed to enhance elicitation of SA requirements, such as goal-directed task analysis, or GDTA (Endsley, 2013). Work on individual-level SA has been criticised for lacking empirical support, because cognitive processes and states are difficult to observe empirically (Salmon et al., 2008). These problems are related to what actually is and can be contained in the active working memory of an individual at any one time to enable what is defined as being situation aware (Rousseau et al., 2010).

It is unsure whether people can really, in an introspective sense, describe their cognitive processes and ways of maintaining situation awareness as a mental/cognitive state. However, a position taken in this study is that work practitioners can be asked to describe their overt information interaction activities and their conscious goals and experience

during their pursuits of trying to be "on the top of the things". These may provide at least certain hints about cognitive processes, but necessarily accounts of their information interactions. Further, the idea that cognitive processes are something internal to the individual mind has been strongly challenged (e.g. Stanton et al., 2010). Stanton and colleagues (2006) have proposed that situation awareness maintenance can be observed in transactions between actors in collaboration, as an exchange of information between participants in the collaboration. This is in line with recommendation Schmidt gives for empirically studying awareness, as "practices through which actors align their distributed but interdependent activities" (Schmidt, 2002, 162).

It can be concluded, that differences between conceptualizations of awareness in CSCW and situation awareness in Human Factors and HCI are not impossible to bridge. Both traditions seek to develop better technologies, practices and methods to support awareness among collaborators in work environments where co-presence in the same place with collaborators is not possible all the time. Both traditions seek to understand the "what" of the awareness – what one needs to be aware of? While in CSCW the prime interest is to support awareness about other collaborators' activities and interactions with shared work objects and work environment, in SA tradition, the interest also includes issues related to maintaining awareness about self-changing status of non-human elements of shared work environment (like status of a technical object, weather conditions etc.) The empirical studies of awareness in CSCW has been conducted in various collaborative settings like control rooms, news rooms, police control centers, hospital operating theatres and software design (Heath et al., 1992; Tenenberg et al., 2016). The empirical studies of awareness have more often analysed work settings were collaborators share the same location and working time, and working merely realtime together. Empirical studies of situation awareness have analysed more often also distributed work settings and working together which extends co-presence. The concept of situation awareness was first introduced in military and aviation contexts (Endsley, 1993; Endsley, 1995; Lau et al., 2013). Since then, it has been applied in various industrial (e.g. Connors et al., 2007; Roberts et al., 2015; Salmon et al., 2008b), health-care (Brady & Goldenhar, 2014), and emergency-response environments (e.g. Autrey & Moss, 2006; Blandford & Wong, 2004). Academic studies of the topic have focused on, for instance, highrisk situations, accident analysis, and understanding of human error (e.g. Jentsch et al., 1999; Roth et al., 2006; Sneddon et al., 2006). Many practical applications based on the concept have been developed, and conceptual discussions flourish (e.g. Lundberg, 2015; Patrick & Morgan, 2010; Stanton et al., 2015). Situation awareness is most often subject to empirical study in connection with high-risk work with high reliability demands, of the sort often carried out in information technology intensive work environments.

In the present study, situation awareness is observed as a means of coordination. This is because of the sensitivity of SA also to changes in shared work environment which are not directly observable to collaborators and where collaborators don't share same location and

work even on the move. The focus is on active practices of situation awareness maintenance that collaborators apply in order to coordinate their individual and interdependent activities. It is not expected that situation awareness is some kind of isolated state of mind of a work role holder per se, but rather a purposeful coordinative practice he or she participates in which information interaction is central enabler. Empirically maintenance of situation awareness is studied via accounts of work role holders.

In the next sections conceptual tools to study maintenance of situation awareness empirically are introduced and earlier empirical results and insights from studies of situation awareness are introduced.

2.5.1 Elements of situation awareness

Which elements of the environment are of relevance for maintaining situation awareness at team or work-community level? Of what aspects of the situation must one be aware? What aspects of situations need to be captured? The elements of a situation perceived are generally those that are most relevant for the goals of the actor. The relevant elements might be the status and attributes of a core technical system, the state of other actors and systems, the state and status of collaborators' activities, and changes in a situation (Endsley 2013; Endsley 2015a).

What information needs do these requirements generate? According to Endsley and Jones (2013), the requirements are domain-specific and cannot be specified across domains. In other words, the specific elements of work environment to be observed reflect the domain. Endsley (1995) have postulated that SA is up-to-date knowledge of situation parameters, the critical features in widely varying situations, and status, attributes, and dynamics of relevant elements in the environment. Endsley (ibid. 33) has pointed out that

> "Acquiring and maintaining SA becomes increasingly difficult, however, as the complexity and dynamics of the environment increase. In dynamic environments, many decisions are required across a fairly narrow space of time, and tasks are dependent on an ongoing, up-to-date analysis of the environment."

When the state of the environment is constantly changing, often in complex ways, a major portion of the actor's job becomes that of obtaining and maintaining good situation awareness. At team level, the elements of the situation that need to be perceived are related to relationships between goals and activities. At the team-level, the elements of maintenance of SA are 'the status of other team members' tasks on oneself, the status of own tasks on others, the impact of one's actions on others and vice versa, and projections of the actions of other team members' (Endsley, 2015, 23). In other words, certain elements and parameters in the environment are of interest for the whole team, and maintaining awareness surrounding those elements is the essence of coordination in practice. Coordination and sharing of this information can be accomplished via verbal exchange, as a duplication of

displayed information in appliance interfaces or with other means. (Endsley, 1995). In practical operations, this information is managed, communicated, and observed with the aid of a host of information-providing devices, mechanisms, and processes employed to express, exchange, and communicate relevant situation information. When the team members are separated temporally and geographically, the means of maintaining team situation awareness involve more difficulty than when the members are co-located.

Stanton et al. (2006) proposed that, for maintaining collective situation awareness and performance, especially in distributed team work, it is critical for the group to be able to manage interdependencies between actor goals and activities. Millot (2015) has recently pointed out that understanding of how the management of these relationships is reflected in the structuration of collective situation awareness is incomplete. However, it can be safely stated that shared responsibilities, goals, and division of roles and labour form the basis the need to coordinate activities. This study elaborates in particular how information resources that are required by several participants of work activity, and the quality and ease of adoption resources enable or hinder smooth operation of individual work role holder.

2.5.2 Mechanisms of creating situation awareness

Schmidt emphasized that awareness studies should focus on how collaborators practically act and interact to make sense about their shared work and work environment (Schmidt, 2002). Methods of displaying one's actions to others, monitoring others' activities and activities changing the shared objects of work employ different means, depending on whether the context is of co-located or dispersed work (ibid.). The means how this monitoring and displaying is accomplished depend also on the time pressures of the activities – a single modality of displaying may not be enough. The work of Schmidt (2011b, 163) offers a reminder:

> "Actors regulate their monitoring quite delicately so as to adjust the degree of obtrusiveness to the requirements of the situation, and they similarly display their own work in a form and at a level of granularity which is attuned to the situation facing their colleagues."

In other words, the choice of timing and supporting technology for enabling awareness requires competent and deliberate decision from the practitioner. In situation awareness tradition this need to consider the means and information modalities that support practical maintenance of situation awareness in real world settings has been central concern, too (see e.g. Endsley & Jones, 2012).

Scielzo et al. (2009) postulate following components to team situation awareness: requirements, devices, mechanisms, and processes. The most interesting of these for purposes of the present research are requirements, mechanisms, and processes, because these are observable in behaviour. It is worth noting that team situation awareness

mechanisms are somewhat akin to coordination mechanisms. Next empirical research on how maintenance of situation awareness is accomplished as monitoring and displaying activities in distributed work settings and how ICTs and social factors can shape the success of these activities are discussed.

In a study conducted in the context of offshore drilling, Endsley's three-level model of situation awareness (involving perception, comprehension, and forecasting and anticipation) was utilised as a conceptual framework to elicit the cognitive components of SA and to distinguish them from other factors that have an impact on it (Roberts et al., 2015). As a result of the study, a preliminary model of situation-awareness components and influencing factors was developed. It was found that maintaining or improving situation awareness was accomplished in well operations in terms of several sub-processes. Appropriate perception of the state of the work objects was created via attention, cue-recognition, and gathering of information. Comprehension of the work objects' state was developed via creation of understanding, sharing of information, and individual-level observations with crew members. This entailed projecting the future state of a well via coordination and support among a crew. In general, participants in the study lumped these activities and their monitoring together under one label. Enabling factors were skills in effective perception, ability to concentrate, efficient searching for information from multiple sources when one was under time pressure, and skills in comprehending indicator measurements. Intermediary factors affecting SA formation were the variety of distractions, the level of expectations and of total experience, stress level, and overall work load. On the basis of prior experience and expectations arising from that experience, information on the status of the shared work object was communicated. Monitoring required accurate interpretation of operations data, and communication and coordination among crew members was crucial especially in more demanding situations such as 'shut-ins'. It was important to express one's observations to other members of the crew and to anticipate and coordinate operation procedures involving several crew members. Overall, the success of individual-level situation awareness and that of team-level SA were closely connected (Roberts et al., 2015). Communication within the crew (phone-based and spoken) was sometimes a distracting element when vigilant monitoring and concentration were critical; on other occasions it increased the vigilance level (ibid.). The offshore drilling study did not examine the effects of spatial and temporal distribution of operations and was focused mainly on specifying the communication processes involved in maintaining SA, not so much on practical, observable means and mechanisms of creating situation awareness. The role of various ICTs in crew-level coordination practices was not addressed. In addition, the authors did not explicitly discuss the level of trust and other social factors (ibid.). In this study, both the influence of applied technologies and influence of social capital as factors of maintenance of situation awareness are explored.

Endsley (1995, 58) hypothesised that 'the degree to which relevant information features of the environment are available to the operator either directly or through the system's

displays fundamentally affects a person's ability to achieve SA'. In SA requirements analysis and design guidelines, the focus is often on how to integrate and present properly the information already acquired (Endsley et al., 2003). The presentation of information is only one aspect of SA research, and both information availability and potential difficulties in obtaining information have been studied less. In the present study ease of accessibility of information relevant for the maintenance of situation awareness is analysed.

Social, organisational, and technological factors all shape the quality of – especially team level – situation awareness. Trust and empowerment among team members, ability and willingness to take responsibility, courage to seek a second opinion, and willingness to challenge the opinions of peers and managers were observed as elements of improved situation awareness (Brady & Golderhar, 2014). At the organisational level, standardisation of processes and procedures supporting organisational learning, development of a shared language, and distribution of experience and expertise have been associated with better situation awareness (ibid.). Also, the informal and tacit ways in which more experienced professionals sense deviations in, for example, a medical patient's state are important resources to share with peers (ibid.). Procedures that secure continuity in understanding of patient statuses and knowledge exchange during shift changes have been mentioned too (ibid.). Ease of use and active utilisation of electronic tools for documenting, displaying, and monitoring patient health information also proved central to performance in risk management (ibid.). It was found that the inconsistent use of health information in a set format and not following predetermined practices for its documentation across professional groups reduced the possibilities for maintaining high quality SA (ibid.). Maintaining situation awareness in complex work environments wherein operation continues 24/7 and the continuity of patient care needs to be ensured across shift changes was rooted in established communication and documentation practices. Social and organisational conditions were designed to support responsibility and mutual accountability. Electronic patient records served as an important SA device. Another central element was to ensure communication and coordination of temporal interdependencies for maintaining an accurate shared picture of patient states. The conventions employed in communication and information exchange were the central mechanisms and processes for realising SA (ibid.).

A central problem considered in studies of SA is the overabundance and overload of potentially relevant information, along with the concomitant need for filtering out irrelevant information. As noted above, situations wherein information necessary for assessment of the situation is lacking or scarce are less studied. Analyses of SA requirements also typically concentrate on dealing with a specific incident or event, rather than examining the whole work-duty repertoire for which actors in a certain work role have responsibility. In this study, the approach involved encouraging participants to comment on their entire task repertoire as context for SA requirements assessment. This study approaches SA from the standpoint of expressible information needs and the activities that actors perform when furthering their work goals. The focus of attention is on exploring what kinds of

observable and deliberate, conscious information interactions are required for developing, maintaining, and updating one's situation awareness.

There are arguments for and against the view that situation awareness is the same thing as a coordinative protocol in combination with certain coordinative artefacts. One kind of solution for team situation awareness problematics might involve specifying the informational elements related to the interdependence management as the core content and origin of team situation awareness. The position taken in this study is that the information content of team situation awareness sums to actors' understanding of the effects of interdependencies on each actor's individual-level and shared goals, and means of reaching them.

2.6   Experience knowledge management as a means of coordination

In this chapter, the concept of experience knowledge management is introduced. Further, it is compared to other conceptual constructs dealing with retention of the knowledge that the work community has generated during practical task-execution and that will be utilised later in the work community.

The concept of 'experience knowledge' was developed by Bergmann (2002) in the context of design of case-based reasoning systems. Bergmann focused on the details of how to capture and model experiences in a manner supporting their reuse. Experience knowledge is a critical and valuable enabler of efficient operation in complex technical problem-solving domains. In these domains, human experts under time pressure must be able to support diagnostics and rectify (often remote) technical failures in collaboration with local technicians. The central problem related to experience knowledge is how to enable its efficient capture, storage, retrieval, and reuse.

The concept of experience knowledge resembles that of organisational memory, which concentrates on the capture of memories in relation to decision-making. Walsh and Ungson (1991, 61) defined organisational memory as 'stored information from an organization's history that can be brought to bear on present decisions. This information is stored as a consequence of implementing decisions to which they refer, by individual recollections, and through shared interpretations'. In particular, decision-making in problematic situations over time forms information content that is central to organisational memory, answering questions about what kind of stimulus has generated an organisational response, with what kinds of consequences (ibid.).

Experience knowledge, in turn, is defined as specific knowledge situated in a particular problem-solving context (Bergmann, 2002). Experience knowledge differs from generalised organisational knowledge, which has a broader potential scope of application and is most often created via systematic exploration and induction from a large set of experiences and can be applied in a wide range of problematic situations. Experience knowledge is fundamentally representable and articulable because it refers to specific

problem situations and contexts. Capturing, storing, and sharing experience knowledge is more straightforward than with general knowledge: experience knowledge can be captured and expressed with shared situational vocabularies and via examples. The vocabularies and examples are domain-specific and need to be purposefully designed when systematic experience-knowledge capture is being developed (ibid.). Experience knowledge differs from tacit knowledge in that tacit knowledge has its roots in lived experiences and real situations yet cannot be easily expressed verbally or by other descriptive means. Experience knowledge is practical knowledge (cf. Schmidt, 2012) that can be expressed by the problem-solver to enable efficient reuse of the solution. Capture and storage of experience knowledge necessitates modelling the experiences in accordance with certain principles at the time of a problem's resolution. This is a classical problematic in expert-systems and case-based reasoning research (Minor, 2006).

Experience management as a conceptual approach is devoted to modelling and capturing specific, situational experiences in reusable, retrievable format. There are several issues influencing utilisation of individuals' and organisations' experiences of problem-solving situations. The literature on organisational memory explores the challenges of acquisition, retention, and retrieval of a variety of instances of past events, experiences, decisions, solved problems, and insights of organisation members. According to Walsh and Ungson (1991), there are at least five distinct areas to be dealt with in relation to information retention or storage in organisational memory: individuals, culture, transformations, structures, and ecology. All of these embody organisational memory. More recent research on organisational memory has analysed the growing importance of computer-supported retention mechanisms and challenges related to the practical use of organisational memories (Ackerman & Halverson, 2004).

The particular role of certain artefacts or documents in the retention and mobilisation of organisations' knowledge of past experiences has been explored in studies of boundary objects and transactive memory. Boundary objects serve as informational devices and mechanisms that respond to information needs of intersecting practitioner worlds in working life to represent a shared object of work, while still allowing a specific viewpoint on the object (Star & Griesemer, 1989). Transactive memory refers to organisations' and individuals' knowledge of 'who knows what' and the ability to utilise this distributed memory (Argote & Ren, 2012). One could suggest that organisational memory, boundary objects, and transactive memory all are concepts related to experience-knowledge management.

Next, empirical research on experience management and knowledge reuse is discussed. The review is limited to studies of technical support. Empirical studies of technical support centre work have analysed various means and practices applied to support experience management and reuse of knowledge of already solved problems. There has been extensive analysis of aircraft technical support (Lutters & Ackerman, 2007), support for cranes and tooling machines (Hölttä, 2013; Mannonen & Hölttä, 2013), and technical support

analysts' work executed by B-to-B customers of a vendor of call-centre knowledge-repository software (Gray & Durcikova, 2005). The analyses vary in their data and delineation of the unit of analysis. The case study of aircraft technical support employed extensive participant observation and involved detailed analysis of two technical support cases. The above-mentioned study of crane and tooling-machine support was based on contextual enquiry and simulations. The focus was on overall work practices, information reuse conditions and drivers in support work. The technical analysts were studied via a survey. The goal of the study was to understand motivations and practices in utilising various information sources and technologies that support knowledge reuse.

In the case of aircraft technical support, the process of information delivery was, for safety reasons, highly standardised. Three central types of documentary artefacts were utilised extensively. These documents served also as boundary objects in coordination of work between the client and experts in field support and at a global technicalsupport centre. These artefacts were the historical archive of approved problem resolutions, a structured record of all manufacturer–client communication, and a regulatory approval form for all resolutions. The analysis was centred on the activities performed at the global technical-support centre. It was found that the artefacts greatly facilitated knowledge reuse but were augmented with multiple situated, informal, and undocumented negotiations supporting interpretation and contextualisation of the artefacts. The artefacts did not capture the entirety of the information interaction surrounding the support case in question; they were created instead as snapshots of the case-resolution process (Lutters & Ackerman, 2007). The efficiency and performance effects of these practices were not evaluated in the study.

Knowledge-sourcing practices of technical analysts at call centres were unpacked by Gray and Durcikova (2005). Their study was aimed at understanding why analysts utilised such a great variety of information sources in their daily work: colleagues, official documentation provided by the company, and the knowledge base from technical-support cases. The researchers found that knowledge repositories were used as a source of 'recipes' for solving customers' problems but not for building a more in-depth understanding of the products to be supported. The practice of producing and utilising problem-case records was locally optimised to provide quick and effective help during handling of cases. Deeper contextualisation, learning across cases, and root-cause analysis were conducted through consulting colleagues and official company documents such as manuals (ibid.).

In crane and tooling-machine technical support too, a wide range of information resources was utilised in resolution of service requests. The researchers also observed considerable variation from person to person in habits of documenting problem cases. The official solution for management of customers' requests was not utilised to document solutions. Operational-efficiency pressures encouraged taking little time between closing one request and opening the next rather than documenting resolutions in detail. Some informants displayed a habit of writing elaborate personal notes on problem resolutions,

and, even though they seldom needed those notes themselves, this practice enabled their colleagues to consult them in very difficult cases (Mannonen & Hölttä, 2013).

The empirical, descriptive studies of knowledge reuse in technical support environments have touched the role of rather permanent information resources and their artefactual use as a means of coordination. However, their effectiveness as coordinative devices has not been elaborated so far. In the present study the concept of experience knowledge and its management are utilised as analytical tool when tracing the information interactions in geographically and temporally highly distributed service work contexts. Experience knowledge is approached as a shared resource of collaborators in distributed work. The emphasis in analysis is to scrutinize the role and function of experience knowledge as a coordinative resource in collaborative work.

2.7 Social capital and information interaction in work communities

As new ICTs influence interaction and communication in work communities, an understanding of the drivers of collaboration and communication becomes crucial. When interaction and communication are not fully predetermined and bound to certain modalities, moments, or channels and when there is a great deal of freedom in ways of organising the communication and collaboration practices, factors behind the interactions that materialise require scrutiny. Overall, why do people socialise, communicate, and exchange information and knowledge? Why this socialising is patterned in certain ways in certain communities? To unveil these phenomena, the concept of social capital was established, originally in sociology. The first classical treatments of social capital were provided by Bourdieu, Coleman, and Putnam.

Depending on the author applying the concept, social capital refers either to social relationships that provide access to benefits and resources or to the characteristics of the social relationships that enable access to benefits and resources in a certain social structure or relationship (Portes, 1998). Social capital is essentially a community resource. Coleman (1988) defined social capital as a social structure that serves as a resource for the members of a society in their pursuit of their interests. Social capital is a characteristic of the structure of the relationships and accessible to the participants in those relationships. Social capital as a resource for individuals can also aid in the pursuit of other resources of interest. In various types of communities, social capital has been observed providing intangible resources such as information, security, trust, and reciprocity. Social capital has been studied at the level of geographical communities, nations, occupations, firms, professional communities, and – increasingly – in the virtual sphere and virtual communities.

In the recent literature on computer-supported collaborative work, human–computer interaction (HCI), and knowledge management, interest in social capital has been driven by a need to understand the social interactions in various online communities and in relation to the challenges of sharing valuable knowledge (Widen-Wulff & Ginman, 2004;

Huysman & Wulf, 2006; Wasko & Faraj, 2005; Preece, 2004; Kosonen, 2008). There has been a need to explain why people engage in voluntary sharing of knowledge and how social capital can be observed in online communities. The concept of social capital has also been used for designing information systems aimed at supporting interaction and knowledge exchange in work communities (Huysman & Wulf, 2004) and to inform designs that are sensitive to dimensions of social capital.

The literature often divides social capital into three dimensions on the basis of the associated potential for beneficial interaction. These dimensions are opportunity, ability, and motivation (Kwon & Adler, 2014). Opportunity refers to the structural possibility to access and contact other actors. It is related to the actual configuration of the network of relationships and the actual structure of relationships within a community. Ability involves the knowledge and skills that enable successful participation and resource sharing. Finally, motivation refers to the willingness to share resources and mutuality. It encompasses shared norms, values, obligations, trust, and respect for membership in the community. These three dimensions closely mirror the definition by Nahapiet and Ghoshal (1998), who classified the dimensions of social capital into structural, cognitive, and relational. The structural dimension refers to network configuration, ties, and network organisation; the cognitive dimension has to do with shared language, codes, and narratives; and the relational dimension involves trust, norms, obligations, and identification (ibid.).

An individual's access to resources via social capital is not dependent on power relations or financial resources but comes about through membership in the community and being part of the social structure.

2.7.1   Social capital as a shaper of knowledge practices

Before the everyday utilisation of the Internet, repository-based knowledge management solutions were not very successful in fostering knowledge sharing among employees (e.g., Yamauchi et al., 2003). Therefore, research interests became directed toward a more detailed study of the patterns and means of knowledge sharing in real-world work settings. One influencing factor for explaining lack of knowledge sharing is the level of social capital within the community assumed to be pooling the members' knowledge. The role of social capital as a shaper of knowledge practices in various collaborative settings has been studied actively (see Huysman & Wulf, 2004) for the evaluation and design of knowledge management systems. As knowledge management systems (or, in fact, any tools that support the distribution of knowledge) can be utilised over the Internet in distributed work, understanding the role of social capital for knowledge sharing remains crucial.

Next, earlier empirical results on the relationships between social capital and knowledge practices in the work context are explored. Though a plethora of studies analyse single dimensions of social capital – e.g., the relational dimension in studies of trust, or the structural dimension in research into social networks and ties – studies considering

a comprehensive operationalisation of social capital are few. From the standpoint of the present study, empirical studies conducted in real-life settings in work communities and networks of practice in which the employees are informants in the data collection are especially interesting. Empirical analyses of the relationships between social capital and knowledge practices at company or institution level are scarce. There exist no previous empirical studies examining the relationship between social capital and coordinative practices in work settings.

2.7.2   Social capital as a factor in knowledge sharing

Some studies have found evidence of a positive influence of higher levels of social capital on the sharing of knowledge and expertise. The empirical studies have been conducted within a single company (Steinfield et al., 2009), with a sample of professionals from several companies (Chow & Chan, 2008; Widen-Wulff, 2007), and among communities of practice consisting of members of a certain profession (Chiu et al., 2006). These studies' empirical operationalisation of social capital has varied somewhat but includes at least some kind of operationalisation of the structural and relational dimensions of social capital.

Recently, alongside with the increase of social networking site use in work organisations, the quest to understand connection between social capital and knowledge sharing has risen (Ellison et al., 2015). A study (Steinfield et al., 2009) conducted among employees of a global IT company found that higher levels of social capital were associated with more active use of the company's internal social-network site. Those using the site more actively had closer ties to their personal network, a greater sense of corporate citizenship, greater willingness to contribute to the company, and global connections and better access to people and expertise. However, no claims were made as to the direction of the causal relationship between social capital and use of the social-network site (ibid.). In a study of managers from several firms, relations between social capital and knowledge sharing were detailed (Chow & Chan, 2008). It was found that contacts and accessibility among organisation members and shared goals, missions, and visions explained the level of willingness to share knowledge. Social trust, in contrast, was not related to greater willingness to share knowledge (ibid.). A study of a virtual community of practice of lawyers found that higher levels of structural social capital and cognitive social capital were associated with higher volumes of contribution to the community of practice. Surprisingly, the relational dimension of social capital did not play a role in the degree of contributing to the community of practice (Wasko & Faraj, 2005). In another study of a virtual community of practice, composed of IT professionals, all three dimensions of social capital were found to be factors enhancing knowledge-sharing (Chiu et al., 2006).

In design-oriented studies, the potential of social features of ICTs to enhance formation of social capital and further knowledge sharing in work has been explored (e.g., Ackerman & Halverson, 2003). Social capital has not been explicitly operationalised

and studied empirically as either a dependent or an independent variable in these studies, however. Nonetheless, design-oriented studies have shown the importance of evaluating collaboration technologies from the standpoint of their support for activities that are embedded in a social context. Technologies designed to support distributed collaboration can and indeed must provide affordances that fit the variation and level of social capital present in the user population and community contexts wherein they are applied.

Overall, empirical studies of social capital and knowledge sharing show that different dimensions of social capital do not have uniform impact on knowledge-based collaboration. However, the interaction between interdependence patterns at work and the level of spatio-temporal distribution have not been analysed explicitly in earlier studies. In the present study the role of social capital as potential shaper or driver of coordination and information interaction in distributed work is analysed. It is scrutinized if spatio-temporal distribution have an effect on social capital among collaborators when they do not share same location and co-presence in time.

2.8 Spatio-temporal factors in distributed work

As work becomes more distributed and virtual, the challenge and the effort needed to manage work tasks' interdependencies become greater. Virtual and distributed work in general has generated a plethora of empirical studies. The quest has been on developing conceptual frameworks and even taxonomies to detail success factors of virtual and distributed work (e.g. Andriessen & Vartiainen, 2005; Gilson et al., 2015; Hinds & Kiesler, 2002; Koroma et al., 2014; Olson & Olson, 2000; Olson & Olson, 2013; Vartiainen et al., 2007).

The challenge of distribution and virtuality manifests itself in various ways. DeSanctis et al. (1999) have maintained that the number, quality, symmetry, and duration of interdependence relationships at every level of the work activity – firm, work team, and individual worker – vary more in virtual work than in work settings where the collaborators are closer to each other spatially and temporally. Work relationships wherein the power relations between partners are symmetrical rather than asymmetrical are growing more commonplace. Also, the overall ambiguity and unpredictability of task interdependencies is rising. When the predictability of partners' knowledge, skills, and experiences is low, collaborators' understanding of the critical interdependencies between areas of expertise may be limited. The duration of interdependencies will be shorter. Relationships are started and terminated on the basis of the situated needs imposed by work goals, not on the basis of long-term contracts. ICTs both shape and embody the interdependencies and strategies for managing them in day-to-day work. Exchanges occurring in the relationships involve intangible, knowledge-based resources more often than tangible elements. This development makes social bonding not less important but even more vital.

On the team level, changes in the nature and dynamics of work task interdependencies as a result of distribution and virtuality of work may be reflected in the degree of visibility of interdependent relationships. Activities of each member must be made visible and observable by other means than those employed in a shared location and in face-to-face communication. Various forms of electronic communication enable greater visibility in distributed, virtual team settings, but distance may weaken cohesion and the sense of trust within the team and be experienced as a threat to privacy (ibid., 91–93).

At the level of the individual, distributed virtual work also requires additional effort in interdependencies management. One needs to monitor and control the emergence, maintenance, and termination of interdependent relationships. The repertoire of interdependencies requires flexibility and security of work activities. One must delicately coordinate the information exchanges that the various interdependencies require. Ways to accomplish this may be invisible even to those who manage the workers (ibid.).

Working in spatially dispersed way create barriers for work performance in general. In the review of studies analysing hindrances of working in multiple locations it was found that not all hindrances apply to all locations of mobile work equally. However, the most common hindrances multi-locational workers faced could be divided into physical, virtual and social issues. The hindrances of physical space are related to limited working spaces and interruptions. In virtual space, problems are related to limited connections and lack of IT support. In social space, hindrances are related to lack of social support, to the feeling of being external and to limited privacy. (Koroma et al., 2014.) However, spatio-temporal dispersion does not always hinder coordination of distributed work in the same ways. In the study of technical teams working in different geographical locations and at different times, it was found that temporal separation manifesting itself as large time-zone differences had a more negative impact on coordination and performance of distributed teams than did spatial dispersion on its own (Espinosa et al., 2012). It has also been posited that ability to manage discontinuities created by spatio-temporal dispersion may be managed more efficiently because of supporting social, cultural, and organisational continuities present in the work community (Watson-Manheim et al., 2007).

In the present study the level and nature of spatio-temporal dispersion that separates a work role holder from collaborators is observed as one potential shaper of the formation coordinative practices.

2.9   Technological affordances

Designing ICTs that are both usable and useful in human activity is the central goal for HCI research and interaction design. Here, the concept of affordances, which has roots in ecological psychology, is used to refer to properties of ICTs determining what kinds of actions are possible for the user when he or she is interacting with them. In simple terms, the possibilities for action are called affordances (Gibson, 1986). The associated school of

thought is interested in the user's ability to perceive, observe, and comprehend what the object affords. Originally, the concept of affordances was used with reference to human ability to interact successfully with physical objects, and it was, in essence, a concept describing perception of physical properties. Since the introduction of the concept, scholars have debated whether an affordance is a property of the object or environment, the observer (the human user), or the relationship between the object and the observer (Norman, 1999; Kaptelinin & Nardi, 2012; Gaver, 1991).

The debate surrounding the concept has pertained to the question of which human cognitive and cultural processes affordances are related to, or which processes are sensitive to affordances. Early works considered how affordances are related to sensory-level information processing and perception. Later, the role of higher cognitive processes other than perception involved in observing affordances came to be considered (e.g., Hartson, 2003; Kannengiesser & Gero, 2012). More recently, the role of cultural factors in sensitivity to affordances has been stressed (Kaptelinin & Nardi, 2012).

Gibson (1986) stated that whilst affordances exist in the physical environment as objective properties irrespective of the perceiver, which affordances are perceived by the observer depends on his or her specific needs and goals. The environment enables observation of affordances that is contingent on the observer's situational goal-directed interpretation. Affordances exist independently of the observer, and the human observes them more or less successfully and correctly (Gaver, 1991). Norman (1999) drew a distinction between real affordances and perceived affordances. He maintained that the former are objective properties of physical objects but that ICTs provide only visual feedback that advertises the actual affordances provided by physical properties of the device. In this sense, one can design only perceived affordances, which, when observed with the aid of cultural conventions and if functioning successfully, relate efficiently to and communicate the real affordances of the device (ibid.).

Hartson (2003) distinguished four types of affordances in interaction design: cognitive, physical, sensory, and functional. This typology specifies the ways in which affordances can assist users in their interaction with objects. A sensory affordance supports sensing something, such as physical features of an object. A physical affordance, in turn, refers to the physical features of an object and has to do with how that object physically assists in doing something. Thirdly, a cognitive affordance is a feature that helps one to know what something is. These three types refer to processes of sensing, perceiving, and knowing something in the world. A functional affordance refers to the potential of the object to help the user do something purposeful with the object. Functional affordances should be observed in parallel with and be supported by cognitive affordances. A functional affordance enables the user to comprehend a certain device as useful with respect to his or her task goals.

In line with Hartson's definition of a functional affordance, the concept of technological affordance and technological constraint has been used in information systems literature to

refer to the broader usefulness and actual use of a certain technology in an organisational context. Affordances and constraints are properties and potentials of relationships between people and technology. They are concepts referring to enabling actions such as 'sharing knowledge' and 'showing one's contacts'. Affordances and constraints as relational concepts are distinct from technological features and individuals' skills or attributes. This distinction is relevant in empirical analyses of the use of ICTs in organisations because specific technological features do not determine the use of a certain technology in a certain organisational context: '[W]hat one individual or organization with particular capabilities and purposes can or cannot do with technology may be very different from what a different individual and organization can do with the same technology' (Majchrzak & Markus, 2012, 2).

With the proliferation of collaborative and social technologies, social affordances or affordances of social technologies have attracted both theory-focused and empirical attention (Leonardi et al., 2013; Majchrzak et al., 2013).

It might be that certain affordances support communication that is too open in situations in which trust and accountability expectations and criteria of shared language/terminology are not met in the organisation. Some ICTs and their related use conventions can be deemed too open and threatening by certain participants. In such situations, the lack of social capital is the primary and most basic hindrance to efficient coordination and SA maintenance, and the technologies only mirror the barrier (e.g., Brady & Goldenhar, 2014).

Understanding technological affordances becomes crucial when new ICTs emerge and enter workplaces. The question literally is what new technologies can afford, if anything, when compared to existing technologies and practices of utilising them as part of work processes and practices. However, the affordance perspective, specifying the action potentials for the user's purposes, has been applied in communication research since long before the term 'ICTs' was commonplace, just without the phenomenon being given this name. Media synchronicity theory makes a classical distinction between affordances of synchronicity and asynchronicity (Dennis et al., 2008). In their classic study, Clark and Brennan (1999) presented a categorisation of media affordances and constraints: co-presence, visibility, audibility, co-temporality, simultaneity, sequentiality, reviewability, and revisability. These attributes can create barriers to communication, and new ICTs may provide features that enable overcoming these constraints. Mobile technologies, context-aware technologies (Gay, 2009), and social media (Leonardi et al., 2013; Treem & Leonardi, 2012) as technologies applied in working life have prompted analysis of their affordances for organisational use. A review of early research into the use of social media in various organisational contexts concluded that conventional computer-supported communication technologies have not provided affordances for visibility, editability, persistence, and association (Treem & Leonardi, 2012). Affordances created by social media in organisations include metavoicing, triggered attending, network-informed associating, and generative role-taking (Majchrzak

et al., 2013). In an empirical study of a hybridmedia platform prototype combining paper and tablet interfaces in medical work, affordances of mobility and portability, co-located access, shared overview, and mutual awareness were detected (Houben et al., 2015).

The role of ICTs in interdependence management can be approached from various angles. DeSanctis and colleagues (1999) proposed that ICTs can function in dependency management as a medium, as a trigger, as a result, and as a context. They can serve as a platform and channel for interdependence management and provide the right medium at the right time for the right task, enabling smooth and efficient operation among distributed entities. The choice of a specific medium for specific interdependence relationship management need is not trivial from the performance standpoint (DeSanctis et al., 1999). This creates the motivation for the study of affordances – the crucial question is how and why certain technologies should be selected to be the platforms for the maintenance of exchanges involved in certain kinds of interdependencies.

ICTs may serve as a context for independent emergence of virtual work and of dependency management. They may serve merely as a rich ecology for relationships' unfolding and operation. It is nearly impossible to characterise human relationships at work without considering the technologies that make them material. From this angle, the possibilities for purposefully designing the way in which interdependencies emerge and are managed are limited. The key in the management of interdependencies is to provide an enabling technology environment through which the interdependence ecosystem can live and grow (ibid.). This view is in accordance with the idea that strategies to manage interdependencies are not something that can be designed or modelled very well. Coordination technologies do not reflect any particular model of coordinative strategies.

The practical embedding of affordances of new ICTs had been theorised to be implemented in various organisational communication processes, among them knowledge-sharing, the one researched most actively (e.g., Majchrzak et al., 2013). What has not been elaborated upon in earlier research is the potential of new ICTs to support coordination functions and coordination mechanisms in distributed collaborative work. It is important to explore the kind of support that is provided by various ICTs for maintaining accountability, predictability, and a common understanding in distributed work (see Okhuysen & Bechky, 2009).

It is assumed in the present study that coordination mechanisms as part of coordinative practices can be implemented by applying various alternative technological affordances. Certain technologies, like instant messaging, can provide various affordances for coordinative practices. It is hypothesized that depending on the context and the level of coordination challenge, certain assemblies of applied technological affordances are more efficient in the service of coordinative practices than some other assemblies. In the context of distributed work, collaborators operate both in spatial and temporal separation, and even in the move. In this study in particularly technological affordances of asynchronity, mobility, reviewability, persistence and visibility are paid attention to as potential enhancers

of better coordination of distributed work. These affordances are provided by several new mobile and social media technologies like variety of Internet-enabled mobile devices, Internet of Things (IoT) -applications and various collaborative messaging solutions, but had not been available with older technologies and media like phone calls, fixed line internet connections, or text messages.

2.10 Evaluation of information interaction in distributed work

When implemented well, information interaction in shared work enables better management of the inherent interdependencies between work roles, activities, and resources. In collaborative work, the decisions one actor takes depend on and reflect information created and stored elsewhere. The actor needs to consider and integrate multiple observations made by others and consider the status of the relevant shared work object. At best, information is communicated and visible in sufficient time for the decision-maker. Effective management of interdependencies with the help of information interaction – that is, the quality of coordination – is shaped by many factors.

Location-based division of labour has clearly existed for centuries, but Internet-based technologies have brought hopes for better communication making work over a distance more efficient and more similar to co-located work. Models presenting factors affecting the success of distributed work have been proposed in tandem with the development of Internet-based ICTs that enable collaboration over a distance (e.g., Olson & Olson, 2013; Neale et al., 2004; Kraut et al., 2002; Hertzum & Simonsen, 2011). Models of coordination in distributed collaborative work have borrowed elements from the social sciences, psychology, management science, information science, and computer science. The variety of dependent variables and of independent variables in the models reflect the interdisciplinary, practical nature of the collaboration problem – there is great variety in the phenomena shaping the success and smoothness of collaboration.

One of the most comprehensive and empirically tested models of collaboration success in distributed work is by Olson and Olson (2013). The model features success of collaboration as a dependent variable and five factors as independent variables: the nature of the work; common ground; readiness for collaboration; management, planning, and decision making; and technology readiness. Olson and Olson's model does not explicitly consider coordination as a dependent variable. The present study extends and refines Olson and Olson's model by analysing interdependencies and their coordination practices as a core explainer of information interaction performance success in distributed work. Further, this study refines understanding of the impacts of the variety of actually applied technological affordances to coordination effectiveness.

Crowston (1997) proposed that a viable way to detect unknown and unmanaged interdependencies between tasks and inappropriate coordination mechanisms is to look for performance problems in a specific work task. This study observes performance successes

and problems experienced in the information interaction between co-workers executing distributed tasks.

In information systems literature, there is a long tradition of studying factors and building predictive models related to success in implementing new technologies in organisations and gaining added business value and other benefits from ICTs (e.g., DeLone & McLean, 2003; Venkatesh et al., 2003). In this tradition, information (as an independent variable) is evaluated mostly in terms of its quality, accuracy, and usefulness for individual users in the organisation. The value of ICTs for an organisation as equipment capital has also been measured quite routinely (for example, with metrics for total cost of ownership). The final impacts of, for instance, information quality on performance of the entire production processes or even for the performance success of single work role holders in their duties has not been given focus in the model building. Another weakness of current evaluation models is that they often try to observe impacts of new technologies in isolation. In users' work contexts implementations of new technologies never enjoy the luxury of starting from the scratch, but are integrated and appropriated into a context of existing practices and technologies (Franssila & Okkonen, 2013). That is why also the evaluation approaches should study performance impacts of new technologies in their complete utilization contexts, as part of the ecosystem of information systems resources for work.

Most of the research projects observing and evaluating current or emerging technologies and their embedding in real world work practices contain at least an implicit goal of performance development, user experience enhancement or better support for the work performance. Accordingly, in CSCW and HCI research, design implications and recommendations are often required and provided based on the research. However, often the performance enhancement goal and criteria for assessing the impact of the recommended design regarding the goal are left invisible or undefined – how and why the work performance or user experience gets better by applying the suggested design changes. Connection between recommended new design and its' projected impacts for the work performance could be clearer. More concrete projection of performance effects of recommended new design from the users' viewpoint could also help to avoid plainly digitalizing existing, but inefficient processes and practices. The present study approaches the goal of information interaction performance development and the need for criteria for evaluating performance effects of coordinative practices from the perspective of information waste.

The concept of information waste comes from lean management literature. Lean management is a widely applied approach to business performance development. Introduced by Womack and Jones (1996), it focuses on the utilisation of production resources and the optimisation of resource use. The word 'lean' refers to the idea of implementing more value-adding products with reduced use of resources. The resources needed in production are human resources, time, materials, and space. As there is common agreement that information is also a key resource in business processes, it should be included in the search

for lean production processes. In their classic text, Womack and Jones (ibid.) do mention information as a resource, but they do not cover it very comprehensively. Lean management is, in practice, applied mainly to the physical transformation processes in organisations.

A core concept in lean management and one that, in a sense, represents a highly tangible approach is waste (the Japanese *muda*). It refers to any activity that consumes resources but creates no value (ibid.). The seven categories of waste in the classic approach are defects, overproduction, stock, overprocessing, unnecessary movement of people, unnecessary transfer of materials, and waiting (ibid.). These categories were originally defined to apply to manufacturing of physical goods, but they can be equally well applied to other processes. Eliminating waste from the overall production process is key for creating higher value for the customer.

The phenomenon of waste related to the flow and management of information in the product-creation process has been elaborated upon very little in the research literature thus far. Studies exploring potential relationships between information waste and waste of time and materials are practically absent. This is surprising in view of the ongoing discussions in both practical and academic literature about the criticality of information for the success of business operations.

One of the most fleshed-out accounts of information waste was presented by Hicks (2007). Using empirical data from small and medium-sized enterprises, he identified four fundamental causes and four types of information waste. The term waste refers to all extra and not planned work efforts needed to make right information to be available in the right place and in the right format for collaborators to fulfil their work duties. The first basic cause of information waste is that information does not flow, because it was never created in the first place. The information-management process is 'broken', or a critical information-management process is unavailable for other reasons. The second cause is that information cannot flow, because there is a lack of understanding of what information should flow or because processes needed to get the information to flow are not activated or the shared processes needed for the flow are not compatible. The third cause of information waste is overproduction, excessive flow of information. This hampers the detection of necessary and relevant information from among the extraneous information. The fourth cause is inaccurate information that creates the need for additional corrective actions and feedback loops in the information processes (ibid.). The first of the corresponding four types of information waste is called 'failure demand', referring to the additional resources needed to acquire the missing (not created) information. The second type is called 'flow demand'. This refers to the resources needed to activate the information flow. The third waste type is called 'flow excess.' It refers to the resources needed to overcome the drawbacks of information overflow. The final type is what Hicks (2007) called 'flawed flow'. This term refers to the extra resources needed to repair incorrect information (ibid.).

The categories of information waste are useful for identifying waste drivers. While the root-cause typology they constitute is not new, it is relevant for understanding and

identifying causes for the generation of information waste. The ultimate utility of information waste classification in the analysis of coordination of distributed work and their impact on information interaction performance is in the conceptual tools it provides for observing non-value-creating work needed to repair disturbances in the management of interdependences between collaborators.

2.11 Theoretical framework, hypothesis to be examined and research questions

Based on the theoretical concepts reviewed in the earlier chapters, the theoretical framework of this study is formulated next. The aim is to provide an explanatory model for the formation of coordinative practices and their impact on information interaction performance with associated hypothesis to be tested in the empirical part of the study.

The division, alignment and distribution of work goals, activities, and resources – including information resources – are central challenges in the organisation of work in general. When work arrangements are not based on spatial and temporal co-presence, the challenge of coordinating shared work requires more attention. The categories of interdependencies elaborated upon in the literature provide a good starting point for tackling the challenge of coordinating distributed and mobile collaborative work. In light of the existing literature, *it is hypothesized that the interdependence portfolio within distributed activities and resources creating coordination needs and experienced in a certain work role are related to the coordinative practices applied in distributed work.*

The coordination in distributed and mobile work is accomplished via a variety of practical coordination mechanisms. According to the literature, coordination is accomplished on the basis of either explicit or implicit application of diverse coordinative mechanisms, many of them involving and augmented by communication and information sharing. It is not evident from the literature which coordination mechanisms and what kinds of means of information interaction as part of them are most efficient for managing specific kinds of coordination needs. *It is proposed that distributed and mobile work settings contain interdependences and create variety of coordination needs, which need to be managed if successful performance is to result. It is hypothesized that the suitability of the coordination mechanisms applied affects the successfulness of information interaction performance experienced in a single work role.*

It proposed that experience knowledge management and situation awareness serve as overall means of coordination in distributed work. They are enablers for successful collaborative work, and they require the management of information flow and interaction. In every work context and every work activity, they are key basic processes that require attention if the work tasks are to be performed smoothly and efficiently. They can be empirically

observed because the attendant processes take place in everyday activities, and their study is important since they are clearly connected to work performance.

The variety of coordination mechanisms is wide. However, it is not clear, why certain coordination mechanisms are applied or not in specific kinds of certain distributed work contexts. As earlier research suggests, patterns of relationships at work can be approached from the standpoint of social capital and degrees of spatio-temporal dispersion among collaborators. Social capital refers to the possibility of, capability of, and motivation for sharing resources within a relationship. *It is hypothesized in this study that the patterns of interdependencies at the level of tasks, goals, and resources in distributed work influence the level of social capital.* Furthermore, the possibilities for spatio-temporal co-presence vary in distributed and mobile work. *It is hypothesized that the spatio-temporal configuration actualised in shared work-execution is related to the amount of social capital among the collaborators.* In addition, while earlier research indicates that the level of social capital influences knowledge sharing, *it is hypothesized that the level of social capital among co-workers shapes the overall coordinative practices applied at work.* Finally, affordances provided by collaboration and communication technologies provide possibilities for action. *It is hypothesized that the way technological affordances are interpreted and applied among co-workers to support distributed work is related to coordinative practices applied in the collaboration.* Further, *it is hypothesized that the applied technological affordances are related to the level of social capital among collaborators.*

Based on theoretical perspectives on interdependencies, coordinative practices, social capital, technological affordances, spatio-temporality, and information interaction performance effects, an explanatory model for the formation of coordinative practices and information interaction performance effects is established and examined in the study. The model depicted in Figure 1 proposes that

1) Interdependence portfolio is the originator of coordination needs in a single work role.
2) Social capital, technological affordances, and spatio-temporality moderate the formation of coordinative practices of distributed work and
3) Characteristics of coordinative practices explain success in information interaction performance.
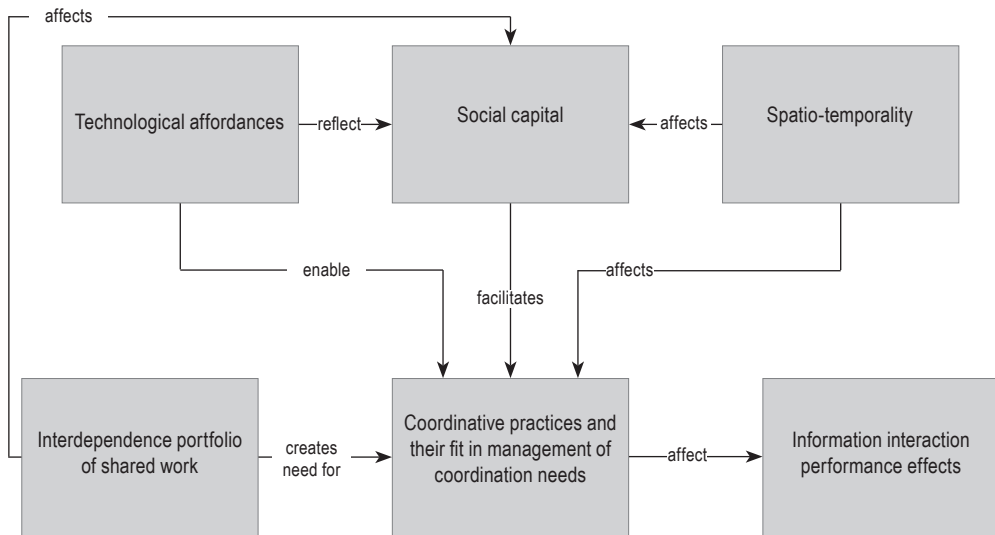
Figure 1. Explanatory framework for the formation of coordinative practices and information interaction performance in distributed work.

The empirical studies were designed to address the following research questions:

What kind of coordinative practices does distributed work require in four case contexts?

How do interdependencies, spatio-temporality, social capital, and technologies' affordances shape these practices?

How do coordinative practices influence information interaction performance in distributed work?

The multiple-case-study design applied in this research operationalised qualitative variation within the conceptual dimensions of the explanatory model and generated initial evidence of the adequacy of the model.

3 RESEARCH METHODS AND EMPIRICAL SETTINGS

In this chapter, the methods, research settings, data, and data analysis are described.

3.1 The case studies and comparative design

The research employs a multiple-case-study approach and is oriented towards theory-building (Yin, 2014; Eisenhardt, 1989; Ragin & Amoroso, 2011). This type of design was selected to enhance theoretical understanding of a relatively little-researched field – coordination and the related information interaction performance in real-world distributed work experienced in a single work role.

The goal of comparative, multiple-case-study is to unfold conditions which enable phenomena under study to emerge. The study seeks to explain how and why certain phenomenon of interest emerges or not. The pattern of factors and conditions present can be complex, and diverse combinations of conditions may create same end result. The process of qualitative, comparative research is based on constant interaction and iteration between conceptual frames and analysis of empirical evidence. The initial conceptual frames and hypotheses are revised based on gradually gathered data and analysis. The set of hypotheses will be sharpened during the analysis of case studies from the viewpoint of the revised theoretical framework. (Ragin & Amoroso, 2011.)

In the present study the conceptual exploration of coordination in distributed work was started on the basis of earlier empirical research. Earlier reserach allowed the forming of initial hypotheses about key factors and the relationships between them. Then the multiple case studies conducted provided gradually the data for further examination of initial hypotheses. In each case study context it was possible to observe variation related to dimensions defined in the explanatory framework presented Chapter 2.11 above. Thus, the empirical data led to a theory building enterprise, and consequently, the data was re-analysed from the viewpoint of the explanatory framework.

Data analysis, data collection and theory development overlap temporally in comparative, theory building oriented multiple case study (Eisenhardt, 1989). This was the case also in the present study. During the empirical phases of the study, data collection in case environments was completed both in sequence and parallel. This provided the opportunity to adjust data collection protocols and instruments from case to case on the

basis of the observations gained from the cases. In multiple case study, the data collection protocol and data collection instruments designed for a single case typically cannot serve as the data collection protocol for the entire project (Yin, 2014). The advantage of the multiple case study design is that opportunities and needs to collect new data supporting examination of a certain dimension of theory under development more deeply can emerge. The features and challenges of distributed work were observed during the case studies in a systematic manner although the data collection protocols naturally had to be adjusted to contextual conditions in each case study. (Eisenhardt, 1989.) The key theoretical concepts were operationalised into observation and diary guides and interview protocols in each case study.

Crowston and Osborn (2003) suggest that in order to find interdependencies and associated coordination mechanisms applied in their management, *information intensive activities* that rely on information created as an output or input in certain other activity in the value creation network can be understood as coordination mechanisms. In particular, certain features of distributed work activities could be observed. Flow of resources (physical, informational or other necessary resources) between activities and collaborators should be observed. In addition, utilization of potentially shared resources need to be detected. Finally, *any disturbances in the performance or critical activities that seem to serve coordination of activities should be observed as candidates of coordinative practices.* (Ibid.)

In the present study, the data collection protocols and instruments reflected both the thematic focus and the idiosyncrasies of each individual case. The thematic foci varied slightly across the case studies but still secured that the central phenomena were scrutinized. Some or all dimensions of the framework had unique manifestations in each case context. The dimensions with unique features in each case study's context were the following:

– The variety in the work roles, actors, and work communities that participated in the distributed work
– The observed coordinative practices, with the associated coordination mechanisms, applied in the distributed work
– The spatio-temporal distribution of the actors and of the objects of the shared work
– Interdependencies between actors, goals, activities, and resources
– Social capital among and between work communities reflected in the amount of co-presence, level mutual acquaintance among members of the community and symmetricity of mutual expectations regarding interaction at work
– Technologies' affordances actually utilised or with potential for utilisation in the coordination of the distributed work

The following work roles were examined in the case studies:

Case 1: Process operators on a multi-unit site of a chemical production company
Case 2: Technical support engineers at machine maintenance service companies
Case 3: Professionals at a telecommunications service company
Case 4: Security service personnel at a security services company

In the *process operator case study*, the participants worked on a single production site but were not co-located. There was variation in temporal co-presence of teams on each shift. Work activities and physical resources were variably interconnected and shared across units and across shifts. Interdependencies related to the work's execution and delivery of information between units were observed during the research. There was variation in how well operators knew their fellow operators within the unit and in other units. The work featured variety in the interdependencies between work activities and information resources within and between individual units. The ICTs applied varied in line with the operation situation at hand. Also, variation was observed in the application of practical means of coordination.

In the case involving *technical support engineers*, geographically distributed maintenance service support work was analysed. The participants in the study were product support engineers and special field support advisers providing support for field maintenance service technicians working worldwide in local offices of the companies and installing and repairing machines at clients' sites. The technical support engineers' physical work location was mainly fixed (the main site of the company), but the work locations of the field service technicians they supported were continuously changing. The delivery of support service also involved personnel from the design and manufacturing departments of the company. There were interdependencies between work tasks and information resources supporting the shared work. While the field service technicians and technical support engineers worked for the same company, they did not always know each other personally. Also, their expertise in the work varied considerably, and this fact was reflected in the social capital dimension. The technical support engineers were typically very experienced professionals who had previously served as field service technicians.

In the case of the *telecommunications service professionals*, the work of experts and managers in sales, production management, and internal services was analysed. These professionals interacted with colleagues in their own company and with clients and other business partners outside the company. Participants worked in the office, at other sites of the company, and at clients' and business partners' sites. They knew personally quite well colleagues in the own company. They worked while travelling and and also at home, and their were sometimes mobile, too. The participants used their work time doing both solitary and group work. Temporal availability of collaborators for synchronous interaction was restricted, and interaction and coordination needs arose somewhat unpredictably. Information types such as questions and notifications about work progress were accessed via mobile applications. There was a need for coordination of work between subordinates and their managers, between professionals and their colleagues, and between professionals and clients and business partners. Multiple types of work activity and information-resource interdependencies were present between collaborators. The volumes and functions of interactions were analysed and measured, and ICT choices for interaction were analysed. Coordinative practices and means of communication aiding in distributed work were explored. Affordances of mobile technologies were analysed.

In the s*ecurity service case*, guards and their foremen worked primarily alone and were mobile during the work. Their interaction with collaborators when on the move was analysed, as was the coordination of the distributed work. In the case study, information interaction involving guards working in the field, the security service's back-office staff, and clients was observed. The guards knew other guards and foremen in the same company somewhat well, but not the personnel of the client. However, the personal interaction with other guards was rather limited because of the mobile nature of work. Communication with clients was indirect and was channelled to the field through back-office staff. Coordinative information activities carried out between guards on successive shifts, the guards and the back office, and the back-office and clients were explored. ICT options for supporting information interaction were analysed, and future scenarios related to the performance impacts of coordinative practices were scrutinised.

The ICTs utilised varied considerably from case to case, as did the companies' document repositories. Documentation and coordination procedures of both a standard and *ad hoc* nature and the performance impacts of coordination were observed.

3.2   Data collection

The data collection in each case study was designed to reflect both the thematic focus of the case study and the overall research project. In each case, the first phase consisted of observation of work practices and qualitative semi-structured interviews. The observation based data provided basic information about the physical work settings of the participants and glimpses of the face-to-face interaction taking place when they were at work. In addition, the ICTs utilised in the participants' work duties were observed. Interview questions focused on the daily work practices and information interactions involved in task execution related to the work role profile of the participants. Work role profile is composed of all tasks, responsibilities, group memberships, and collaborative relations incorporated in the work role. The interview data were recorded and fully transcribed in each case study. Interview data were analysed qualitatively via fact based content analysis and critical-incident analysis. Interviews served also as a tool from which to design contextually grounded diary and survey instruments. In case 1, survey data were collected for explorative purposes, not as quantitative support for the examination of hypothesis. In cases 3 and 4, the collection of survey data was intended to provide quantitative support for the examination of the hypothesis presented. In case 3, diary data were collected and analysed as input to selection of empirically grounded propositions for inclusion in the survey, targeting a larger respondent sample. The empirical data collected in the case studies are summarised in Table 1.

Table 1. The empirical data

Case study	Number of informants interviewed	Number of observation sessions	Number of survey responses	Number of diary-keepers
Chemical processing plant	16	8	9	-
Technical maintenance service	8	-	-	-
Telecommunications services	6	-	115	8
Security service	7	2	35	-

The collection of data in each of the case contexts is described in detail in Sections 3.2.1–3.2.4.

3.2.1 Process operators at a multi-unit chemical production plant

The first study focused on process operators' work in a multi-unit chemical product plant. This case study was completed in co-operation with a global chemicals company operating in Finland. The company participated in a four-year (2006–2009) research project called 'INTACT – Industrial Interaction through Open Service Platforms'. The project was funded by Tekes – the Finnish Funding Agency for Innovation and participating companies. The goal of the project was to analyse the interactions, knowledge management practices, and resource flow bottlenecks in the work communities. Real-world distributed industrial work environments have been studied less in knowledge management research. The project also explored the affordances and potentials of new social and collaborative technologies (instant messaging, instant video calls, microblogging, and wikis) in supporting interaction in distributed work. The company's participation in the research project was based on a desire to enhance interaction and mutuality within the plant community, to increase the reliability of the plant's production process overall, and to learn about the potentials of new social technologies. The empirical data in this case study were collected in 2007–2008.

The plant produced chemical products for B-to-B markets and operated continuously on a 24/7 basis. The plant comprised four production sites, which were geographically distributed within an area of three square kilometres. More than 300 people worked in the plant area. Three of the sites produced mainly raw materials (chemical ingredients) needed for the end products produced at the fourth site and energy resources (electricity and water vapour) for creation of these products. The production processes of each site were operated and controlled by dedicated process operation and technical support staff. Each production site had a separate operation control room. Every site had five operator teams, with two to five members. Their work was in three shifts – the day, evening, and night shift. Tasks were related to the monitoring, operation, inspection, and technical maintenance of the production process. Practical operation work was executed via a computerised process automation system. Its user interface presented the layout of the production

process as a schematic diagram, accompanied by measurement, alarm, and notification data. Information about technical maintenance tasks and their progress was accessible from a maintenance management information system. In addition, a plant-wide intranet was available. For information security and reliability reasons, the process automation system and other information systems were operated from dedicated computer stations. Monitoring work took place in the control room. Inspection and technical maintenance were carried out in the physical vicinity of the production equipment. In a typical day, one or two operators were in the control room while other operators were mobile on the production premises.

Because of the exploratory nature of the research and the goal of understanding team-level interaction and practical knowledge management, the empirical data were collected by means of participant observation, semi-structured thematic interviews, and a survey. Access to control rooms and contact with site teams were provided by production managers of each of the four sites of the plant. Participant observation and interviews were conducted at each site. At every site, 2–3 teams were observed and interviewed. The observation and interviews were conducted jointly by the author and other researchers[1] participating in the research project. The observations and interviews were carried out in control rooms. Observation lasted 1–3 hours per shift team in each control room. Attention was directed to the interaction and communication of operators inside and outside the control room and to use of the control room's information systems and sources. Operators were interviewed during the observation, with the interviewers sitting with the operator working in the control room. Operators were asked about their current work activities, typical work activities executed in the course of their shift, exceptional and challenging tasks in the work, site-internal interactions and interaction between sites, ICT use, critical incidents occurring in the work, and development needs experienced with respect to information management and interaction at work. The interviews lasted from one to two hours.

In addition, a Web-based survey was undertaken for further exploring the nature and volume of interaction within the work, the level of acquaintance (on the dimensions of social capital), and the quality of information access and use in the everyday work. The survey form was made available via the plant-wide intranet. The number of responses was very low ($n = 9$), but the sample did include at least two responses from each site. After administering of the survey, the shifts reported that they had condensed the opinions of their shift members into a single survey response to better reflect the viewpoints of the shift in general. In light of this, it was concluded that the response rate on unit level was 40–60%.

Methodologically, the focus in the first empirical setting was on understanding the variety of interdependencies at work and the drivers and shapers of interaction and of technology and information use at work.

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[1] Toni Koskinen, Petri Mannonen and Marko Nieminen from Aalto University.

3.2.2 Technical support engineers at machine maintenance service companies

The second empirical study focused on the work of technical support engineers at two global companies in the machine manufacturing and maintenance service business. The companies provided installation, preventive maintenance, corrective maintenance, and modernisation services for the machines the respective company had built and delivered for customers. The participating unit at Company A was the central technical support centre. At Company B, the participating unit was the local (national) maintenance service unit. The two companies participated in a research project titled 'Adaptation and Integration of Electronic Knowledge Management into the Work Practices in Installation and Maintenance Service Work' in 2006–2008. The project was funded by the Finnish Work Environment Fund and participating companies. The data were collected in 2007. The goal for the project was to explore the everyday information use and knowledge management in the practical work of field service technicians and technical support staff, detect development needs, and envision possible enhanced experience knowledge management practices and tools. The motivation for both companies' participation in the research project stemmed from the observation that field maintenance technicians' information support during the work on client sites was unsatisfactory. In addition, new mobile and social technologies appeared promising as potential enablers of more efficient and timely access to the information needed in the field. The project was designed to explore the potential of these technologies.

The empirical data were collected via semi-structured thematic interviews. Four technical-support engineers were interviewed at each of the companies. The technical support engineers had many years' experience of field maintenance service, and they had served as installation and service technicians and/or engineers before joining the technical support staff. They knew the work conditions of the field maintenance service staff well and also were familiar with the company's products, on account of their extensive experience. They worked at the technical support centres of their respective units. The technical support centres served the field maintenance technicians and installation engineers working in the field. The engineers were recruited for interviews by the human resources development managers. The interviews were held on the technical support service back-office premises, with each lasting one to two hours. The interviews were conducted by the author or jointly with another researcher[2].

The focus in this empirical case was on exploring the respondents' experiences of information access and use, along with the significance of information quality for work performance. The activities related to information resource interdependence management were central in this case.

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[2] Marika Pehkonen from University of Tampere.

3.2.3 Professionals at a telecommunications service company

The third empirical study focused on the work of the sales staff, product experts, and managers at a global company providing telecommunications services (network operator's services and numerous other services related to mobile Internet solutions). The company initiated and funded the research project MURIKKA – Service Productivity Measurement Research. The goal was to explore the use and potential work performance impacts of a mobile email service that had been in pilot use for a year. The company wanted to gather evidence about the effects of this mobile email service on work performance.

The empirical data were collected in three phases in 2008. The first stage involved exploratory semi-structured themed interviews with six users of the mobile email service. They represented the management, marketing and sales staff, experts, product management personnel, and service production workers. Interviewees were recruited by the business development manager of the company. The interviews were carried out in the company's meeting room by the author together with other researchers[3]. In the next phase, based on activities recurrently mentioned in interviews, a diary-form research instrument was developed. Eight employees were invited to keep a structured diary for five working days, to pinpoint the nature, volume, and variety of the communication tasks they executed with mobile email. The invitation was delivered by the manager of user experience development at the company. In the third phase, a Web-based survey examining user experiences and performance impacts of mobile email was targeted at all employees who had used the mobile email service in a pilot. Potential respondents were recruited by email by the business development manager. The response rate was 59%, with 115 responses received in total. As an incentive to participate in the survey, respondents were entered in a prize draw for a navigation application for cars. The focus of this case study was on observing the role of the technological affordances applied and performance effects of communication based coordination of distributed work of telecommunication business professionals within one company.

3.2.4 Guards with a security service company

The fourth empirical setting for data collection was a guarding business providing security and facilities management services. The initiative for the company's participation in the research project came from a telecommunications service company that had participated in the 'INTACT – Industrial Interaction through Open Service Platforms' -project. The telecommunications service company was piloting a service with the security service company that involved a new kind of guarding service application utilising near field communication (NFC) technology. Both companies were interested in the performance impacts, usability, and feasibility of this new type of mobile, location aware technology.

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[3]   Maiju Vuolle and Heli Wigelius from Tampere University of Technology.

The companies wanted to explore the potential of NFC technology in security service work. Two units operating in a metropolitan area took part in the study. These units had both guarding personnel who had used the piloted NFC service and personnel who had not used it. The empirical data were collected in 2009.

Empirical data were collected first by means of small-scale observation and semi-structured themed interviews with guards and their foremen. Guards were selected and invited for interviews by the development manager of the security company. Six participants were interviewed to generate an understanding of the nature of guarding work, to shed light on the information interaction involved in the work, and to collect user experiences of the piloted NFC service. The interviews were conducted in the control rooms of the security service, where it was also possible to observe the utilisation of appliances and the NFC phone-based service being piloted. The main work of the guards was done on the premises to be guarded. Based on the interview results, a Web-based survey was designed to explore both the information interaction impacts and potential future uses of NFC in such guarding services. Survey invitations were delivered to 50 guards and their foremen, and 35 responses were received.

The motivation for collecting the data was a desire to understand the information needs of security service personnel and explore the affordances of NFC-supported information interaction. The emphasis in this case study was on understanding short- and longer-term situation awareness maintenance as a means of coordination between service personnel in the field, security service back-office personnel, and clients.

3.3   Data analysis

The analysis of interview- and observation-based data was executed from the perspective of the individual work role holder, who was a member of several work-related communities and subgroups based on his or her work role. In fact-based analysis, occurrences of themes related to each research interview question were coded and tabulated, with associated direct quotations. After that, coded excerpts were categorised to provide accounts of collaborators of each participant, the relationships each participant had with collaborators, frequency of collaborations, the place and time of collaborations, technologies applied in the information interactions with collaborators, types of information managed collaboratively, and descriptions of successes and failures, along with performance effects experienced in the information interaction related to the collaboration. After this, descriptions of successes and failures (critical incidents) were compared between participants, for assessment of how the nature of interdependencies between collaborators, social relationships with collaboration partners, the place and time of collaboration, and the technologies applied varied between critical incidents. From these comparisons, generalised event descriptions were prepared, reflecting the coordinative practices applied. Survey data were analysed with SPSS statistical analysis software. Descriptive statistics were calculated, and distribution

characteristics for the variables were analysed. When the sample size permitted statistical testing, it was carried out.

Subsequently, from each case study, the evidence it provided with respect to each conceptual dimension and initial hypotheses considering relationships between dimensions of the explanatory framework was collected. During the analysis, the understanding about the nature of relationships between dimensions was sharpened. Based on familiarity with and analysis of single cases, the initial hypotheses considering the relationships between dimensions of the framework were subjected to final cross-case analysis. Then, the cross-case evidence related to each conceptual dimension and relationships between dimensions was summarised and tabulated (see tables 23, 25 and 26). The summaries reflect the qualitative variation along each dimension and relationships between dimensions across the cases.

To provide a condensed representation of the cross-case qualitative variation on each conceptual dimension of the framework, a qualitative score expressing the variation in the values on each conceptual dimension was developed. The qualitative scores for each conceptual dimension was constructed and calculated as follows:

- *The interdependence portfolio complexity score*: expresses the level of the coordination challenge experienced in a work role. This score is generated on the basis of qualitative assessment of the type variation, number, asymmetry in understanding, and ambiguity of the interdependencies present in the interdependence portfolio of a work role. Each component of the score can have a value from the 0–2, and the overall score value as a sum on component values can vary between 0–8. The overall score value variation has been reclassified into a range of 0–2. The higher the component value, the higher the challenge the component creates to coordination. The greater the type variation, number, ambiguity, and the level of asymmetry of understanding of interdependencies, the higher the complexity score.

- *The coordinative practice modification score*: expresses how much coordination modifiers expressed in the explanatory framework may enhance or hinder coordinative practices. This score provides an overall indicator about the combined impact of spatio-temporal co-presence level, the level of social capital in the interdependence relationship, and the appropriateness of the applied technological affordances as part of coordination mechanisms as modifiers of coordination practices. The modification score can vary between 0–6. For example, the score is low if social capital is low within relationships requiring coordination, if collaborators work contexts are spatio-temporally extremely very dispersed, and if technological affordances of asynchrony, mobility, reviewability, persistence and visibility are not utilized in the coordination mechanisms. The overall score value variation has been reclassified into a range of 0–2. The higher the modification score, the more modifiers provide enhancing context for coordination practices applied.

- *The coordinative practice fit score*: expresses how well coordination practices applied in the management of interdependences the work role contains fulfil the coordination needs. This score is determined on the basis of qualitative assessment

of the appropriateness and scope of coordination mechanisms present in the coordinative practices applied in the interdependence relationships of a work role in comparison to the level of coordination-related challenges and needs indicated by the interdependence portfolio complexity score. The score can vary between 0–2. Appropriateness and scope of coordination mechanisms were analysed from the viewpoints of effectiveness and fluency of the mechanisms and the frequency of occurrence of coordination need. For example, the score may be low, if there are often and in a similar fashion recurring coordination need that is not managed with any systematic coordination mechanisms, if recurring coordination needs are mainly responded in an ad hoc manner, if the information content processed during coordination would be valuable later but is left undocumented, and if the applied technologies in the coordination are based on person-to-person communication when more varied both formal and many-to-many communication technology solutions would be more efficient. The score is high, if the complexity of interdependence portfolio is high, recurring interdependences are managed systematically, and there are both formal and informal communication media applied in the coordination. The higher the score, the better the fit between the level of coordination challenge and the applied coordinative practices.

- *The information interaction performance score*: is generated on the basis of qualitative assessments of the information-waste activity level experienced in a work role in the information interaction of the shared work activity. The values of the score can vary between 0–2. The higher the score, the lower the performance losses and the fewer the disturbances related to information interaction.

After constructing the qualitative scores, a comparative analysis of case evidence was made (see about the method Ragin & Amoroso, 2011, 146–154). The qualitative scores of each dimension were collected case by case into the table. The table representation supported comparative analysis of which combinations of scores from each case represented conditions that enabled a phenomena under scrutiny to take place or to get a certain value. Based on the comparative evaluation of value combinations of these scores derived from each case, original hypotheses expressed in Section 2.10 were refined and assessed. Finally, conclusions about the level of support evidenced by multiple cases for the proposed framework is presented in Chapter 5.

4   FINDINGS

This chapter presents key findings from the four case studies of coordinative practices in distributed work. Firstly, the within-case findings providing results for each dissertation research questions from the case studies are presented. After this, the results of each case study are discussed from the systematic cross-case comparison standpoint of how they provide evidence for the explanatory framework proposed and tested in the dissertation study.

4.1   Article 1: The Formation of Coordinative Knowledge Practices in Distributed Work: Towards an Explanatory Model

The context of the first sub-study was process operation work in geographically distributed, continuous chemical production operations. Various sub-communities on the multi-unit, distributed production site were studied: shift crews working in the same unit but in different time frames, shift crews working in different units but at the same time, and shift crews working in different units and also not simultaneously. The case study explored coordinative knowledge practices in distributed work within these variable communities from the viewpoint of single process operators' work role holder. Analysis examined the information interactions as coordinative practices involved in a variety of task situations, alongside what kinds of challenges were observed in the interactions. The goal for this sub-study was to explore and understand the details of information interactions, and the role of community characteristics and collaboration technologies in interaction between various kinds of sub-communities in process control work. The research objectives, research questions, and a summary of the findings of the case, and their contribution to dissertation research questions are presented in Table 2.

Table 2. Research objectives, questions and findings of the first sub-study (Case 1) and its contributions to the dissertation research questions

		Contribution to the dissertation research questions		
		RQ 1	RQ 2	RQ 3
Research objectives of the Case 1	Understanding information interactions within various work communities at a chemical plant	x		
	Understanding information interaction needs, enablers, and barriers related to coordination		x	x
	Understanding types of interdependencies, social capital, spatio-temporality, and technological affordances as shapers of information interaction		x	
Research questions of the Case 1	What are the characteristics and challenges of information interaction related to coordination in distributed collaborative work?	x		
	What coordination needs and outcomes does information interaction serve?		x	x
	How are coordinative practices shaped by work coupling, social capital, spatio-temporality, and technological affordances?		x	
Findings of the Case 1	Three coordination needs of distributed collaborative work: extending attention of collaborators, maintaining continuity, and synchronising bonded activities	x		
	Barriers to, and enablers of, efficient information interaction in coordination of distributed work		x	x
	Types of interdependencies, social capital, spatio- temporality, and affordances as explanatory shapers of coordination practices		x	x
	Coordinative practices as drivers of collaborative work performance success			x

The findings illustrate the coordination requirements arising from management of the work domain and goal interdependencies and how they were met through diverse information interaction means. These diverse information interaction means and coordinative functions they served were basis for detection of coordinative practices in the case.

Based on the initial analysis of empirical observations during the first case study, an explanatory model for the analysis and evaluation of coordinative knowledge practices was introduced and empirically tested. As a contribution to dissertation RQ2, the model proposes conceptual dimensions that together can explain the formation of coordinative knowledge practices in distributed work. The model was designed for enabling a better understanding of performance drivers of information interaction in distributed work and to inform decisions about the ways in which ICTs could support coordination.

The explanatory model is composed of the following elements. Firstly, it proposes that coordinative knowledge practices emerge because distributed work involves work

coupling (i.e., interlocking between elements) that necessitates coordination. The nature and intensity of the coupling are shaped by the interdependence patterns within the goals, activities, and resources involved in the work. Interdependencies in the context of distributed work demand coordination mostly via ICTs. In addition, work coupling is the primary context of formation of social capital in the work community.

Hence, while the need to coordinate interdependencies is the main reason for the emergence of coordinative practices, these practices and their success are shaped by social capital possessed by the work community. Affordances of various collaboration technologies and spatio-temporal characteristics of work settings also affect the efficiency of coordinative practices. In addition, spatio-temporal characteristics of work settings influence the formation of social capital within communities of collaborators. Finally, concrete outcomes and performance of work tasks are influenced by coordinative practices.

The explanatory model tested in the first case study and presented in the article 1 differs from earlier models of collaborative work (e.g., Olson & Olson, 2014) in its emphasis on coordinative knowledge practices and work outputs as dependent variables. In addition, a greater emphasis is placed on detailed analysis of interdependencies. The model depicts three dimensions of interdependencies and incorporates an understanding of which elements of work display practical interdependencies. Furthermore, with the concept of social capital, the proposed explanatory model brings together independent factors related to the level of sense of community and motivation to collaborate.

With the aid of the model, a set of coordinative practices was distinguished in the body of empirical data. To provide results to dissertation RQ1 and RQ2, from the survey data and analysis of activity episodes identified in observations and interviews, three recurring coordinative practices were observed: extending attention, maintaining continuity, and synchronising bonded activities.

Extending attention is a practice wherein the span of deliberative attention and awareness of distributed collaborators was proactively widened. The existence of this practice reflected the need to manage unexpected flow and sharing interdependencies requiring more intensive mutual adjusting of dispersed operations than in a normal operation situation. Coordinative function of this practice was to align activities between units, but also notify other units about interdependences and support monitoring. In practice, this meant paying attention to factors that normally did not influence activities in the work unit. The practical interaction was shaped also by social capital of the collaborating actors. When normal operation did not require deep understanding of all fundamental resource interdependencies between physically dispersed units and the frequency of interaction was not very high, the level of social capital amongst the spatially distant members of collaborating units was not very high. The selection of collaboration technologies reflected the level of acquaintance between the collaborators. Only one-to-one synchronous communication channels such as phone calls were utilised between collaborators. One-to-

many, highly visible media modes of communication (e.g., group instant messaging) were not applied in these practices.

Maintaining continuity is a coordinative knowledge practice enabling shared understanding and awareness of the status of a shared work object. This practice was carried out between successive shifts in units operating and working with the same part of the overall production process. Coordinative function of this practice was alignment of successive activities within a single unit and also between different units when completion of shared activity needed to be followed up and completed by a successive shift. Flow dependency was often exhibited between activities on account of the need to continue the operation after the shift change, and the number of flow dependencies was high. Interdependence levels were high because of the need for temporal continuity. The predictability of emerging interdependencies was moderate. The level of social capital among collaborators sharing the same physical work context but with a time offset was relatively high. The use of communication and documentation tools in the coordination work was rather inconsistent. The choice and use of tools varied, and the content communicated varied too, even though the coordination need was encountered regularly. The variation in the selection of communication media occasionally created obstacles to the continuity of coordination of the activities carried out in the previous shift.

Synchronising bonded activities is a coordinative knowledge practice employed in managing distributed decision-making and task-execution that requires real-time, orchestrated, and synchronised activities from the collaborating parties. Coordinative function of this practice was ordering and timing of interdependent activities between units and allocation of shared resource utilisation in exceptional process situation. This practice is applied typically in disturbance situations wherein a critical resource that is shared between collaborating units is scarce and needs to be managed differently than in normal operating conditions. Because this kind of disturbance situation is atypical but is related to the fundamental interdependence between operation units, unconventional means of coordination and communication were needed in the case studied. It was observed that efficient, text-based many-to-many communication methods were not applied in these time-critical situations. Instead, ineffective one-to-one synchronous communication channels such as voice communication by phone were applied.

As a result for the dissertation research question 1, the characteristics of the coordinative practices were further analysed (see Table 3). It was found out, that the nature and variety of coordination mechanisms applied was related to the sub-community which was involved in a certain coordination situation. With the community within own unit both formal and informal coordination mechanism were applied, and discursive and non-discursive mechanism were utilised. Within the community which crossed different units, mainly informal and discursive mechanisms were applied. In particular with collaborators with other units rather reactive coordinative practices were applied, while with the community within one unit more proactive coordinative practices were applied.

Table 3. Findings in Case 1 relevant to dissertation RQ1

Coordinative practices applied	Variety in the mechanisms applied as part of coordinative practices within various sub-communities and experienced in the operator work roles within them: • Within shift crews working in the same unit but with a time offset, a wide variety of applied mechanisms – routines, roles, representations, *ad hoc* communication, and spatial proximity • Within shift crews working in different units with and without a time offset: only *ad hoc* communication and a low level of mutual expectations

As result for dissertation RQ2 and RQ3, the findings of the first case study demonstrated that the coordination challenges experienced by operators who were working in different units were related to the intensity of work coupling. It reflected the variation in the nature of interdependencies between tasks, work objects, and resources of the shared work in different kinds of work situations. Based on these observations, the interdependence portfolio complexity score[1] in the process operator work role was given value 2 (high).

The set of coordinative practices distinguished was further elucidated by considering work coupling intensity, social capital, technological affordances, and spatio-temporal factors. It was possible to unpack the foundation and constraints of the coordinative practices' formation on the basis of dimensions of the explanatory model. The findings from the first case study in relation to the RQ2 are presented in Table 4. Score measures related to the interdependence complexity and modification of coordinative practices are also given in Table 4.

Table 4. Findings in case 1 relevant to dissertation RQ2.

Dimension of explanatory framework	Findings related to the dimension
Nature of interdependence portfolio of shared work	Complex patterns of interdependencies between collaborators, based on differences in the operation situation: • Variety of interdependence types (flow and sharing) in the relationships (2) • Variation in the number of interdependencies (1) • Various levels of ambiguity of interdependencies (1) • Asymmetric understanding of interdependencies among collaborators (2)
Sum of sub-scores: 6. Reclassified into interdependence portfolio complexity score: 2.	
Social capital among collaborators	Variation in collaborators' level and dimensions of social capital, by subgroup: • Within shift crews working in a single unit, high social capital on all dimensions • Lower social capital on all dimensions within shift crews working in different units whether there was or wasn't a time offset
	Influence score as a modifier of coordinative practice: 1

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[1]   See description of scores and their value ranges in section 3.3.

Technological affordances applied in collaboration	Variation in the utilisation of technologies within different sub-communities at the multi-unit production site: • Use of mobile phones, walkie-talkies, electronic diaries, physical diaries, the process automation system, and face-to-face conversation in the interaction within a unit • Use of mobile phones and walkie-talkies in the interaction between different units • No use of instant messaging, videoconferencing, electronic discussion forums, or the intranet
	Influence score as a modifier of coordinative practice: 1
Spatio-temporality among collaborators	Variation by sub-community in the level of spatio-temporal distribution: • Low spatial but high temporal distribution within shifts crews in a single unit • High spatial but low temporal distribution within shift crews working in different units in the same time frame • High spatial and temporal distribution within shift crews working in different units in different time frames
	Influence score as a modifier of coordinative practice: 1
Sum of sub-scores: 3. Reclassified into coordinative practice modification score: 1 (moderate)	

The information interaction challenges and barriers that were observed in the coordination of distributed work were related to unsatisfactory understanding, awareness, and management of interdependencies. Compared to the coordination challenge and need the interdependence portfolio posed to the operator work role, the efficiency and fit of the applied coordinative practices was only moderate. The *coordinative practice fit score expressing the appropriateness and scope of practices was 1 (moderate)*. The actual coordinative practices applied reflected the moderating effects of social capital, spatio-temporal distribution and applied technological affordances.

In order to contribute to dissertation RQ3 dealing with performance effects of coordination, information interaction challenges and barriers observed, and coordinative practices applied were further analysed with the help of concept of information wastes (see Table 5). Nature of coordinative practices applied was related to and reflected the performance losses in the shared work. Performance losses occurred because a coordinative practice of extending attention was needed to make necessary information available to and acknowledged by then team working in different unit. Extra effort was needed to inform different unit about resource interdependences. This represents a category of *failure demand* in the classification of information waste activities (Hicks, 2007). Performance losses were associated also to the coordinative practices of maintaining continuity and synchronizing bonded activities. The practices reflected performance losses related to extra efforts needed to make sure that information related to interdependences between teams and units flow accurately and in time. This represents a category of *flow demand* as information waste activity (Hicks, 2007).

Table 5. Findings in case 1 relevant to dissertation RQ3.

Coordinative information interaction performance effects	*Disturbances and performance losses when coordination of ambiguous interdependencies failed between units and between shifts.* Performance losses generated when the coordinative practices required unplanned, extra activities to make necessary information available and to flow between collaborators. *Effective coordination between shifts in same unit enabled disturbance-free awareness of the status of shared work.*
Information interaction performance score: 1 (moderate)	

The case provided evidence about variation of coordinative practices (dissertation RQ1), about shapers of coordinative practices (dissertation RQ2) and about performance effects of various coordinative practices (dissertation RQ3). The results of the case 1 are summarized in Table 6 providing scores[2] which condense the findings related to the conceptual dimensions of explanatory framework depicted in Figure 1 (see Section 2.11 above).

Table 6. Summary on evidence from Case 1 concerning explanatory framework

Interdependence portfolio complexity score	Coordinative practice modification score	Coordinative practice fit score	Information interaction performance score
2 (high)	1 (moderate)	1 (moderate)	1 (moderate)

From the results of the first case study, it can be concluded that the interdependence pattern present in connection with a single work role was complex in this case. A process operator was a member of various sub-communities in the shared work context, and variable interdependences between activities within one community and between communities created a complex portfolio of interdependences to be managed. The level of social capital, the technological affordances applied, and the level of spatio-temporal dispersion within various relationships in the process operator work role together created conditions that only moderately supported coordination and management of interdependencies. The coordinative practices employed did not fully reflect the complexity of the coordination needs. This created certain inefficiencies in the information interaction performance of process operators, and finally resulted in performance breakdowns and losses in shared work.

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[2]   See description of scores and their value ranges in section 3.3.

4.2 Article 2: The Role of Knowledge Intermediaries in the Management of Experience Knowledge

The case study reported on in Article 2 analyses support engineers' work at technical support centres. Special attention was devoted to analysing activities surrounding the management of experience knowledge in distributed work as a shared resource. These interactions and duties related to experience knowledge management illustrated the need to coordinate work executed in the field and back-office of the companies, and in particular shared knowledge resources utilised in distributed activities. The support engineers, working in the back offices of the companies and serving field technicians and installation supervisors working around the globe on clients' premises represent knowledge intermediaries in the knowledge management of the globally operating company's service businesses. The support engineers helped remote technicians in difficult service cases by phone and email. They operated as collectors of expertise and experience knowledge. Their work tasks included search, compilation, sharing, and application of what was already known in the company about problems with machines. They supported maintenance personnel who worked in the field in varied contexts on clients' premises. The duration of contacts and collaboration with field-maintenance technicians was related to the problem-case resolution. The collaboration episodes were short but intensive. The support requests varied in degrees of difficulty and urgency. In addition, support engineers collaborated with other support engineers, R&D personnel, and production staff working on the same site of the company when delivering support to the field.

The research objectives and questions and a summary of findings of the case, and their contribution to the dissertation research questions are presented in Table 7.

Table 7. Research objectives, questions and findings of the second sub-study (Case 2) and its contributions to the dissertation research questions.

| | | Contribution to the dissertation research questions | | |
		RQ 1	RQ 2	RQ 3
Research objectives of the Case 2	Understanding practical knowledge management activities in technical support work	x	x	x
	Understanding needs for knowledge management development that are experienced by technical support service staff		x	x
	Creating scenarios for enhanced knowledge management practices in technical support work			x
Research questions of the Case 2	What are the characteristics of information interaction in the work of knowledge intermediaries?	x	x	x
	What are the information interaction challenges and demands related to the sharing and reuse of experience knowledge?		x	x
Findings of the Case 2	Challenging information interaction episodes in knowledge intermediation: problem space assembly and narrowing, compilation of hidden and forgotten experience knowledge, and information maintenance related to new products and components	x	x	x
	Information interaction difficulties related to accessing, evaluating, and compiling experience knowledge from various sources			x
	The nature of performance losses in information interaction: additional searching for information, missing information, errors in information, undocumented information, and repeated generation of information			x

Challenging information interaction episodes in knowledge intermediaries' work were observed and classified into recurring typical types. It was found that information interaction in the support engineers' work and challenges related to the management of experience knowledge can be grouped into three classes: 1) *problem-space assembly and narrowing in response to urgent support requests*, 2) *compilation of the hidden experience-based knowledge*, and 3) *acquisition and updating of knowledge about new components and products*. These three classes of recurring information interaction episodes provided evidence and contribution to the all three dissertation research questions. They are coordinative practices which manifested the challenging management of critical shared resource in service work – experience knowledge.

The first type of coordinative practice, *problem-space assembly and narrowing in response to urgent support requests*, involved difficulties and delays in finding a fit between existing experience knowledge and solutions to the urgent problematic situation in the field. The support request handling practice in both companies at the time of the study did not include guidelines for requesters to collect basic information about the machine and about

problem symptoms that is necessary for commencing problem solving before sending the request. The episodes of this type illustrated difficulty in managing flow dependency on information resources between the help requester in the field and the technical support workers in the recurring work activity of providing support to the field. Only after collection of basic information about problem context and associated machine types was it possible to start the problem resolution phase. The lack of conventions and supporting documentation artefacts led to extended problemresolution turnaround times and generated an additional cognitive burden for the support personnel.

The second type of coordinative practice, *compilation of the hidden experience-based knowledge*, entailed difficulties with being aware of, finding, and activating experience knowledge that was left undocumented and often forgotten. Solutions to problems encountered earlier with a certain machine type and across variable client contexts were critical information resources, which should flow between successive support-request cases associated with the machine type in question. The technical support engineers did not have a common method of documenting the solutions they delivered to the field. Sometimes, left to their own devices, they forgot the details of past solutions. Accordingly, the circulation of experience knowledge among technical support staff was uncertain. Some service requests were resolved directly between field personnel and R&D staff or production units without the participation of the support personnel. Information about the solutions and design changes did not reach the support unit and was unavailable for later use. Even though there was an agreement that all support requests were to be delivered via the support unit, some requests still were handled without any information being submitted to the support unit. Sometimes, the support personnel discovered only after a time delay that certain types of problems had been faced earlier and solved. The absence of a shared convention for documentation of solutions created extra work, 'reinventing the wheel', and breakdowns in the flow and sharing of experience knowledge.

The third coordinative practice, *acquisition and updating of knowledge about new components and products*, involved difficulties in managing valuable experience knowledge related to new machine products, new features of machines, and the installation of new machines in the field. Support engineers received information about new products with considerable delay. New problems typically occurred during the first weeks of use and first installations, and solutions to these had to be generated. Here too, the solutions were often created in the field and by the R&D, production, and technical support units. Frequently, the critical experience knowledge related to the problems and their solutions was not documented and there was no follow-up to gauge the success of the proposed solutions. Knowledge of the solutions' success did not reach the R&D, production, and technical-support units, since problem cases faced by an individual support engineer were not circulated. Information on the success of past solutions was not available to be evaluated and considered in the design of new resolutions. Fit dependency related to utilisation of information resources generated in earlier problem cases was not managed successfully.

The above episode illustrates that there was need to manage shared knowledge resources of distributed work better. Alignment and timing of information delivery from information creators to information utilizers was not specified and information flow was prone to errors. Overall, based on the analysis of critical episodes of coordination, it can be concluded that a majority of coordination functions were not fulfilled with sufficient coordinative practice. In addition, possibilities to monitor and get notifications about important information updates were weak. The contribution of the second case study to dissertation R1 is summarized in Table 8.

Table 8. Findings in Case 2 relevant to dissertation RQ1

Coordinative practices applied	◆ Plenty of *ad hoc* communication in recurring task activities involving a need for documentation ◆ Lack of conventions and documentation artefacts to respond to recurring information interdependence management needs during handling of support requests and across support cases ◆ Weak routines, roles, and representations, with no close-proximity support for coordination

The critical episodes observed highlight disturbances in the coordination of interdependencies among various collaborators in distributed technical maintenance work processes and recurring information needs in the delivery of technical support. These interdependencies were related to the unsatisfactory management of shared information and lack of recognition of experience knowledge as a critical shared resource in the field-maintenance work. Both flow and fit interdependencies were encountered in relation to unsystematic management of informational resources required for successful task-execution.

The coordinative practices applied to managing information-resource inter-dependencies were somewhat weak because of the looseness of conventions in the documentation and communication among field, production, R&D, and technical support staff, and because the documentation was not always reliable. Coordination mechanisms at protocol and artefact levels did not enable efficient performance of technical support. Compared to the coordination challenge and need the interdependence portfolio posed to the support engineer's work role, the efficiency and fit of the applied coordinative practices was low. The *coordinative practice fit score*[3] *expressing the appropriateness and scope of practices was 0 (low)*. The actual coordinative practices applied reflected the moderating effects of social capital, spatio-temporal distribution and applied technological affordances.

Technologies applied to support coordination of interdependent activities were mainly phone calls and emails, supporting informal and ad hoc communication. One-to-many information delivery, notification and monitoring (e.g. case repository) were applied inconsistently or not at all from case to case. The repertoire of technological affordances

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[3]   See description of scores and their value ranges in section 3.3.

applied in the collaboration was very limited. ICTs enabling more efficient and reliable documentation, indexing, and search of product and experience knowledge were recommended.

Spatio-temporal distributedness between collaborators was high. There was no shared spatial context for work – all collaborators worked on a distance from each other. The generation and application of knowledge resources which collaborators utilised in their work activities was temporally very distributed. There was need to be aware, find and apply knowledge that was generated weeks or months earlier. Working in different time zones created time pressures to support service delivery.

Spatio-temporal context created barriers for social capital development between collaborators. The differences in professional expertise background of the collaborators in the community which support engineers collaborated moderated the level of social capital supporting the maintenance of relationships. Support engineers and field technicians shared similar work experience and professional background – most of the support engineers had worked earlier as field technicians. Work experience background and expertise profiles of support engineers differed from R&D and production professionals' profiles. This created certain social and cognitive distance between these professional groups.

The findings from the second case study contributing to the RQ 2 are summarized in Table 9.

Table 9. Findings in case 2 relevant to dissertation RQ2.

Dimension of explanatory framework	Findings related to the dimension
Nature of interdependence portfolio of shared work	• A low number of activity interdependencies per collaborator dyad (1) • A high level of ambiguity of interdependencies between collaborators and resources (2) • Moderate type variation of interdependence: flow and fit interdependencies related to the information resources present in relationships (1) • Asymmetric understanding of interdependencies between collaborators (2)
Sum of sub-scores: 6. Reclassified into interdependence portfolio complexity score: 2.	
Social capital among collaborators	Variation among collaborators in the level of social capital on its various dimensions: • A moderate level in the cognitive dimension (with differences in expertise and experience background among field technicians, support engineers, R&D staff, and production staff) • Low structural capital between staff working in the back office and otherwise on the company site and the field staff (barriers to communication because of distance and time-zone differences) • Individual variation in relational capital (sometimes only occasional collaboration and contact between a certain field service technician and support engineers)
Influence score as a modifier of coordinative practice: 0	

Technological affordances applied in collaboration	• Active use of email and phone calls in one-to-one collaboration • Limited means of communicating, documenting, and delivering information via one-to-many channels between professional groups • Limited means of observing updates in shared information • Idiosyncratic use of the electronic case repository and personal paper notes
	Influence score as a modifier of coordinative practice: 0
Spatio-temporality among collaborators	High spatial and temporal distribution among all collaborators
	Influence score as a modifier of coordinative practice: 0
Sum of sub-scores: 0. Reclassified into coordinative practice modification score: 0 (low)	

For support to be delivered to the field efficiently and quickly, the flow of problem-space information, experience knowledge, and information on new products should be more systematically arranged. This would enable gathering of information and insights about situation-specific solutions to inform resolving of the next problematic situation that arises in the field. Time and effort costs arise in relation to the laborious detection and compilation of relevant knowledge from around the enterprise. The contribution of the second case study to dissertation RQ3 is summarized in the Table 10.

Table 10. Findings in Case 2 relevant to dissertation RQ3.

Coordinative information interaction performance effects	*Disturbances in information need fulfilment, a need for additional effort to collect information, and performance losses when there was failure in coordination of flow and fit interdependencies related to information resources*
Information interaction performance score: 0 (low)	

The case provided evidence about nature and scope of coordinative practices (dissertation RQ1), about shapers of coordinative practices (dissertation RQ2) and about information interaction performance effects of coordinative practices (dissertation RQ3). The results of the case 2 are summarized in Table 6 providing scores which condense the findings related to the conceptual dimensions of explanatory framework depicted in Figure 1 (see Section 2.11 above).

Table 11. Summary on evidence from Case 2 concerning explanatory framework

Interdependence portfolio complexity score	Coordinative practice modification score	Coordinative practice fit score	Information interaction performance score
2 (high)	0 (low)	0 (low)	0 (low)

The second case study revealed the critical role experience knowledge serves as a shared resource of maintenance service work. In general it can be stated, that experience knowledge

as a content of knowledge repository (be it artefactual or not) is a coordination mechanism. The second case study revealed complex interdependence patterns present in a single work role. The level of social capital, the technological affordances applied, and the level of spatio-temporal dispersion within various relationships in the work role of technical support engineers jointly created conditions that did not support coordination and management of interdependencies. The coordinative practices employed were not congruent with the complexity of the coordination needs. This resulted in several inefficiencies in the technical-support engineers' information interaction performance. Overall, the second case study highlighted to requirements which intensive spatio-temporal distribution in the execution of interdependent activities creates to coordination.

4.3   Article 3: Mobile Email As a Business and Personal Performance Driver in Everyday Knowledge Work – a Multi-method Case Study

The case study presented in Article 3 focused on marketing and management professionals and experts in a global telecommunications enterprise and how mobile email application affected their work performance, coordination of work, and situation awareness, all as subjectively assessed by the informants. Mobile email's utilisation and its business and work process performance aspects had not previously been studied empirically. The goal was to explore, by means of multiple data collection methods, the nature of the everyday communication activities among the professionals in the case organisation and to understand the role of mobile email as a potential performance driver in distributed knowledge work. The content of the communication tasks and the goals for them were observed, as were the volume and distribution of tasks, the tools utilised in those tasks, and the performance effects experienced. The detailed observation of communication activities enabled the analysis of coordinative practices and their drivers among collaborators. The analysis was concentrated on the coordination experiences in a single professionals' work role. The research objectives, research questions, and a summary of the findings of the third case study and its contribution to the dissertation research questions are presented in Table 12.

Table 12. Research objectives, questions and findings of the third sub-study (Case 3) and its contributions to the dissertation research questions.

| | | Contribution to the dissertation research questions | | |
		RQ 1	RQ 2	RQ 3
Research objectives of the Case 3	Understanding communication needs and activities of mobile workers when they work outside the office	x	x	
	Understanding communication-oriented work practices when workers are on the move	x	x	
	Understanding effects of mobile email use on personal performance of work			x
Research questions of the Case 3	What are the nature and volume of the communication tasks involved in the day-to-day work of knowledge workers?	x		
	How is a mobile email application utilised in communication-focused work tasks?		x	
	What are the performance impacts of mobile email use?			x
	Are there differences in communication patterns and impacts between professional groups connected with the amount of work related travel?		x	
Findings of the Case 3	Variety of communication tasks in the work: everyday communication with clients and business partners, communication with colleagues within the enterprise, administrative management tasks, and communication tied to personal issues	x	x	
	A higher volume of internal than external communication. More intensive application of mobile email internally than externally; managers as mobile email's most active users. Mobile email as most useful in mobilising internal information resources and in coordination of work.		x	x
	Reasons for using mobile email instead of other mobile communication channels: variety of use modes, speed, discrete and polite nature, and fit of task to technology			x

In the third case study, information interaction for coordinative purposes in work activities of telecommunications professionals was analysed. As a result contributing to dissertation RQ1, information interaction can be divided into four categories. There were tasks related to communication with clients and business partners outside of the case enterprise, communication with company-internal colleagues, communication related to the managerial and administrative tasks within the case enterprise, and communication related to personal issues. The task recurring most often in the data was varied communication with company-internal colleagues, with communication with external contacts taking place less often. Managers were the most active and frequent users of mobile email, and

the range of tasks for which they applied mobile email was wider than for those in other professional positions.

Mobile email was applied more intensively in internal communication. This clearly indicates the importance of mobile email as a tool for managing coordination of work in the internal work community. Mobile email was assessed to be especially useful in activities that required quick mobilisation of information resources within the enterprise and coordinating activities. In the interaction with external collaborators, desktop email and phone calls were utilized more often. Collaboration with external collaborators was considered to require more formal communication.

Findings from the third case study reveal that coordinative practices applied reflected shared understanding of division of responsibilities among internal colleagues. Coordinative practices operationalized understanding of goal and activity interdependencies among internal collaborators. Applied communication technologies and particularly the utilization of mobile email supported the specified division of authority, responsibilities and activities by providing quick and easy-to-use device to deliver information resources between collaborators and to notify both manually and automatically about important issues. The contributions of the third case study to dissertation RQ1 are summarized in Table 13.

Table 13. Findings in Case 3 relevant to dissertation RQ1

Coordinative practices applied	• Clear authority and responsibility division among collaborators. • Lots of *ad hoc* communication with internal colleagues by mobile phone, mobile email, and SMS, while use of mobile email was more limited in external communication • A moderate amount of routines and proximity with internal collaborators in coordination • With external collaborators, more formal coordination via desktop email and phone calls

As a result contributing to dissertation RQ 2, the third case study revealed that coordination of interdependencies among goals, internal collaborators, and information resources entails task activities in which mobile email as a technology enables efficient performance, at least when assessed on a personal level. When interdependence patterns in the work activities were examined, managers were discovered to operate often in a position from which, with their decision-making and goal-harmonisation rights, they represent a shared resource for subordinates. Managerial approval of various activities of subordinates was a typical task executed by mobile email. Managers need to coordinate their role as authority, representing sharing dependencies and at the same time make it possible for their subordinates to coordinate and manage flow dependency within their respective chains of activities. Managers need to maintain accurate situation-awareness with respect to parallel goals of business activities. They also must coordinate overall efforts of teams, assemble harmonised triggers for action for their subordinates, and

compile bodies of information that enable subordinates' activities to proceed. Managers often act as decision-making and information-resource hubs for subordinates, and mobile email can serve as an efficient tool for enhancing communication intensive coordination and situation awareness maintenance tasks. When this secondary meta-work is efficiently and flexibly supported, the overall performance of distributed work can be enhanced. Compared to the coordination challenge and need the interdependence portfolio posed to the telecommunication professionals' work role, the efficiency and fit of the applied coordinative practices was high. The *coordinative practice fit score*[4] *expressing the appropriateness and scope of practices was 2 (high)*. The actual coordinative practices applied reflected the moderating effects of social capital, spatio-temporal distribution and applied technological affordances.

Affordances of mobile technologies provide variety of possibilities for their application in coordination of knowledge work. Mobile email was utilised in the case company as a technology providing brief notifications and discrete ways of maintaining situation-awareness in circumstances wherein it was socially acceptable to observe incoming messages peripherally only. In addition, mobile email as a medium most often used for brief communication, question and answer exchanges, and brief approval interactions reflected the level of social capital residing in company-internal colleagues. When there was ample relational and cognitive social capital in the internal work community, informality and expectations of rapid response in communication were appropriately supported by mobile email.

The work of telecommunications professionals and managers contained mobility, involving work executed in the own office, in the client's premises and other traveling. The amount of spatio-temporal distribution was rather high among the internal collaborators. This context affected means for coordination.

The findings from the third case study in relation to dissertation RQ 2 are summarized in Table 14.

Table 14. Findings in case 3 relevant to dissertation RQ2.

Dimension of explanatory framework	Findings related to the dimension
Nature of interdependence portfolio of shared work	◆ High type variation in interdependencies: presence of flow, fit, and sharing interdependencies in relationships (2) ◆ A large number of interdependencies (2) ◆ Moderate ambiguity of interdependencies between collaborators and resources (1) ◆ Symmetric understanding about interdependencies between collaborators (0)
Sum of sub-scores: 5. Reclassified into interdependence portfolio complexity score: 1	

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[4]   See description of scores and their value ranges in section 3.3.

Social capital among collaborators	High social capital on all dimensions among internal colleagues and a moderate level between external collaborators
	Influence score as a modifier of coordinative practice: 2
Technological affordances applied in collaboration	Active use of mobile email, mobile calendar applications, SMS, and phone calls with internal collaborators.
	Desktop email and phone calls utilised with external colleagues.
	Influence score as a modifier of coordinative practice: 2
Spatio-temporality among collaborators	Moderate spatial and temporal distribution between internal collaborators, with internal collaborators sharing a primary physical workplace and working-time scheme (conventional daytime work); with external collaborators, no sharing of a physical workplace but use of a similar working-time scheme (again, conventional daytime work)
	Influence score as a modifier of coordinative practice: 1
Sum of sub-scores: 5. Reclassified into coordinative practice modification score: 2 (high)	

The performance effects of mobile email's utilisation were shaped by professional role and the variety of tasks wherein mobile email was applied. The more varied ways in which mobile email was used, the greater the personal and business-performance benefits the users experienced. Those utilising mobile email intensively reported more often than non-intensive utilizers that their work satisfaction and personal productivity had improved, decision-making was quicker, and they were able to produce more output in their work. However, at the same time they reported more often experiencing work related stress. Also, overall, response times in decision-making and information delivery and distribution were enhanced. These case findings contributing to dissertation RQ3 are summarized in Table 15.

Table 15. Findings in Case 3 relevant to dissertation RQ3.

Coordinative information interaction performance effects	*Performance gains (absence of non-value adding activities related to information management) when coordination of the various interdependencies succeeded because of well-known interdependences and appropriate technologies supporting coordinative practices*
Information interaction performance score: 2 (high)	

The third case study provided evidence about nature and scope of coordinative practices (dissertation RQ1), about shapers of coordinative practices (dissertation RQ2) and about information interaction performance effects of coordinative practices (dissertation RQ3). The results of the case 3 are summarized in Table 6 providing scores which condense the findings related to the conceptual dimensions of explanatory framework depicted in Figure 1 (see Section 2.11 above).

Table 16. Summary on evidence from Case 3 concerning explanatory framework

Interdependence portfolio complexity score	Coordinative practice modification score	Coordinative practice fit score	Information interaction performance score
1 (moderate)	2 (high)	2 (high)	2 (high)

The results of the third case study revealed an example of a context of distributed work, where the complexity of an interdependence pattern in a single work role was moderate. The level of social capital, the technological affordances applied, and the level of spatio-temporal dispersion within various relationships in the work of telecommunications service business professional together created conditions that enabled and supported coordination and management of interdependencies very well. The coordinative practices employed were suitable, given the moderate complexity of coordination needs. This resulted in efficiency in the information interaction performance of the telecommunications service professionals and in satisfaction with that performance.

4.4 Article 4: Enhancing Information Interaction As a Means for Situation Awareness Maintenance in Mobile Field Work

The fourth case-study article continued the analysis of information interaction challenges faced in distributed, mobile field work. The empirical context of the case study was security services that provided both local and circuit guarding for office building facilities. Local guarding entailed monitoring the security of certain buildings continuously, while circuit guarding involved patrol rounds covering multiple building locations. The case study explored and evaluated information interaction challenges and maintenance of situation awareness in guarding work in the field. The case study revealed that maintaining situation awareness was a means to enable coordination both within the security service (back-office and field) and between security service and clients. The coordination need was related to the flow of situation information considering changing activities affecting security situation in the premises to be guarded. The research objectives, research questions, and a summary of the findings of the fourth case study and their contribution the dissertation research questions are presented in Table 17.

Table 17. Research objectives, questions and findings of the fourth sub-study (Case 4) and its contributions to the dissertation research questions

| | | Contribution to the dissertation research questions | | |
		RQ 1	RQ 2	RQ 3
Research objectives of the Case 3	Exploring and analysing the day-to-day work practices and information interaction of guarding personnel	x		
	Evaluating information interaction in maintenance of situation awareness from the standpoint of identifying information waste		x	x
	Assessing future potential of NFC services to support information interaction in guarding work			x
Research questions of the Case 3	What kind of information interaction the information journeys of conventional working days in the security service work contain?	x		
	What kinds of information requirements, resources, barriers and challenges exist in the current information interaction related to the maintenance of situation awareness?		x	
	What kind of information waste categories do the barriers and challenges present		x	x
	What kinds of future features and functions of NFC technology could support maintenance of situation awareness and elimination of information waste?	x		
Findings of the Case 3	Information interaction activities related to creating understanding of the situation on the premises, documenting and reporting exceptional incidents, and managing information exchange upon shift change	x		
	The security service personnel's satisfaction with short-term situation awareness maintenance as lower than that with longer term maintenance of situation awareness. Means to maintain accurate and timely awareness of exceptional and temporary changes were not fully satisfactory		x	
	Security service personnel experience information interaction challenges related to two types of information waste: they need to pay extra attention to detecting, finding, and remembering relevant information from various operative sources (excessive flow), and there are sometimes disturbances in the flow of task critical information from clients to the security service (an issue of flow demand)			x
	The quality and efficiency of information interaction in mobile security service work can be enhanced by enabling sporadic short-term updates of information to flow in a micro location-aware way		x	x

Situation awareness is central in dynamic work contexts that may involve risks for the worker. The fourth case study analysed the information interaction of guards patrolling in the field, in various client premises. Another goal was to assess the potential of new mobile information technologies in this connection.

The work activities of security service personnel were studied in a situation wherein a new mobile application for supporting guarding work was being piloted. The application was based on near field communication technology (one of the Internet of Things technologies), which enables location- and context-sensitive information interaction within buildings. The service was composed of an application used with an NFC-enabled mobile phone and NFC tags to be touched in the buildings. This service supported reporting upon and monitoring the guard's progress on the patrol circuit and the patrol work's execution, and it provided a means of quickly reporting the checking of the premises.

Situation awareness means perceiving the status, attributes, and dynamics of relevant elements in the work environment (Endsley & Jones, 2012). The means and processes of acquiring information about these were evaluated in the case study. Analysis revealed that information necessary for maintaining situation awareness has to do with perceiving information on both relevant short-term elements and events and longer-term elements and events in the environment.

Information interaction activities related to maintenance of short- and long-term situation awareness elicited in the interviews were operationalised as survey items. Data from the survey revealed that the responding security-service personnel had difficulties in maintaining short-term SA more often than they faced problems with longer-term SA. Weaknesses in short-term situation-awareness maintenance were linked to uncertain information flow related to temporary, day-to-day exceptions and changes affecting clients' premises. Personnel working in circuit guarding were less satisfied with the delivery of this information (and with how well it reached the security service from the clients). Guards were more satisfied with the information support related to maintenance of longer-term awareness, but they expressed some dissatisfaction with the means of creating an overview of events in recent history in certain buildings – for example, when returning to work after holidays. As coordinative practices, applied means to maintain situation awareness did not supported perfectly temporal alignment and continuity of guarding activities. Conventions and routines to review recent events in client premises for a longer period were not established. In addition, notifications from the client about security relevant events taking place at their premises was not very strong routine. The findings of the fourth case study regarding RQ1 are summarized in Table 18.

Table 18. Findings in Case 4 relevant to dissertation RQ1

Coordinative practices applied	◆ Reliance on communication and notification via email and face-to-face discussions in internal coordination ◆ Lack of strong routines in coordination with external collaborators ◆ No proximity support for coordination between guards in the move, premises clients and security service back-office

While the coordination of concurrent activities was not a central performance bottleneck in this particular context of mobile work, information resources' interdependencies and their efficient coordination did constitute a core performance issue. Clear flow dependencies between client, back office, and field were discovered in the level of situation information, and disturbances and errors in the coordination and communication were detectable as a source of information waste. The root cause of these coordination inefficiencies might be related to the asymmetric knowledge of the dependencies between information-consumers and other actors. Compared to the coordination challenge and need the interdependence portfolio posed to the security service guards' work role, the efficiency and fit of the applied coordinative practices was moderate. The *coordinative practice fit score*[5] *expressing the appropriateness and scope of practices was 1 (moderate)*. The actual coordinative practices applied reflected the moderating effects of social capital, spatio-temporal distribution and applied technological affordances.

The clients and individual guards completing guarding circuits in the premises had practically no direct contacts or communication channels to exchange information while guards were on the move. All information from client to security service was delivered via back-office. When assessing the level of social capital between security service stakeholders, there was both relational distance and structural difficulties to maintain coordination between guards and clients utilizing the premises. The spatio-temporal distributedness was also very high between collaborators.

Technological affordances supporting coordination when on the move in the guarding circuit were very limited. When assessing the future potential of NFC functionality, respondents evaluated features supporting delivery of information on exceptional circumstances, increasing of guards' security, and easier and more automatic exception-reporting from the field as useful. Overall, functions supporting more location-aware, accurate, automatic, and timely access to and delivery of changing human-generated information about the premises were viewed as enhancing field-service performance.

The study revealed that information resources flowing to and from the field for purposes of maintaining more coherent situation awareness could easily be enhanced via Internet of Things technologies. Touch-based mobile technologies of this nature would be clearly accepted among security-service personnel. Information accessible via activation of NFC tags should provide a new coordination mechanism that is low-effort but efficient.

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[5] See description of scores and their value ranges in section 3.3.

The findings from the fourth case study in relation to the explanatory framework and RQ2 are presented in Table 19.

Table 19. Findings in case 4 relevant to dissertation RQ2.

Dimension of explanatory framework	Findings related to the dimension
Nature of interdependence portfolio of shared work	◆ Moderate type variation of interdependencies; evidence of flow and sharing interdependencies in relationships (1) ◆ A low number of interdependencies (0) ◆ Moderate ambiguity of interdependencies and resources (1) ◆ Asymmetric understanding of interdependencies between collaborators (2)
Sum of sub-scores: 4. Reclassified into interdependence portfolio complexity score: 1	
Social capital among collaborators	A high level of social capital on all dimensions between internal colleagues but very low levels of social capital between external collaborators (clients)
	Influence score as a modifier of coordinative practice: 1
Technological affordances applied in collaboration	◆ delivery of shift reports via (non-mobile) email, use of phone calls, paper-based case reporting, various security information systems with only back-office access, and limited face-to-face discussion; ◆ no use of mobile email or location-based Internet applications
	Influence score as a modifier of coordinative practice: 0
Spatio-temporality among collaborators	High spatial and temporal distribution with both internal and external collaborators, possibilities to co-presence very limited.
	Influence score as a modifier of coordinative practice: 0
Sum of sub-scores: 1. Reclassified into coordinative practice modification score: 0 (low)	

The ease and reliability of obtaining information in order to maintain situation awareness when the worker was in the field were assessed in terms of the categories of information waste suggested by Hicks (2007). Of these types of information waste, flow excess and flow demand were detected in the analysis. As stated earlier, flow excess involves information waste related to additional effort needed to detect, find, and remember critical information from various sources, and flow demand is a category that refers to disturbances in a critical information flow. Summary of the results obtained from the fourth case study relevant to dissertation RQ3 are presented in Table 20.

Table 20. Findings in Case 4 relevant to dissertation RQ3.

Coordinative information interaction performance effects	*Disturbances and performance losses when coordination of ambiguous interdependencies failed*
Information interaction performance score: 1 (moderate)	

The fourth case provided evidence about nature and scope of coordinative practices (dissertation RQ1), about shapers of coordinative practices (dissertation RQ2) and about information interaction performance effects of coordinative practices (dissertation RQ3).

The results of the case 4 are summarized in Table 6 providing scores which condense the findings related to the conceptual dimensions of explanatory framework depicted in Figure 1 (see Section 2.11 above).

Table 21. Summary on evidence from case 4 concerning explanatory framework

Interdependence portfolio complexity score	Coordinative practice modification score	Coordinative practice fit score	Information interaction performance score
1 (moderate)	0 (low)	1 (moderate)	1 (moderate)

In the fourth case study an interdependence complexity to be managed a single work role was moderate. However, the level of social capital, the technological affordances utilised, and the level of spatio-temporal dispersion within various relationships in the security service work role created conditions that only moderately supported coordination and management of interdependencies. The coordinative practices applied were not in congruence with the complexity of coordination needs. This resulted in several inefficiencies in the information interaction performance of the security services personnel.

5   SUMMARY OF THE FINDINGS

This research addressed the issue of coordination, a classical and timely practical motivation for CSCW research. Collaboration, whether co-located or distributed, needs coordination. The need to coordinate collaborative work is present in every distributed work setting, and it must be addressed by work secondary to the core, primary work activities. Distributed and mobile work contains variable interdependence patterns to be managed through the secondary, meta-level work. Relative to a work setting that enables co-location and co-presence, a distributed work setting restricts the variety of coordination means available. In addition, when the core resources of distributed work are mostly invisible, immaterial information resources, coordination gets even more difficult. The challenge of coordinating interdependencies manifests itself as information interaction performance disturbances and successes.

Schmidt (2011b) stressed that the analytical effort should be devoted to analysing how coordinative practices evolve; which resources, requirements, and constraints shape them; what kinds of problems are experienced in the coordination; and how various technologies support specific coordinative practices. It should be possible to model coordination strategies, techniques, and practices in generic terms. Otherwise, the selection of information technologies for specific coordinative purposes may be inappropriate. This study proposed and examined a generic model for analysing and explaining the factors shaping the formation of coordinative practices as experienced in a single work role.

In distributed work, a variety of ICTs may support the communication and information management which is a prerequisite to coordination of action. Schmidt (2011b) proposed that current understanding of coordinative practices in real work environments is rather limited, as is that of technologies that should be supporting them. He states that fundamental categories and techniques of coordinative practices must be empirically observed in actual work environments via ethnographic methods if we are to gain conceptual foundations for development of coordination technologies. This study has provided rich empirical account of coordinative practices applied in four real-world work contexts, and coordination means present in those practices. The multi-dimensional analysis of formation of coordinative practices, integration of results of analysis into a conceptual framework, and the empirical test of conceptual framework provides an explanation why coordinative practices have their varied characteristics and varied effects on information interaction performance in distributed work.

This chapter presents the answers to the research questions for the study.

5.1 RQ1: Variety of coordinative practices in distributed work

As defined in section 2.3, coordinative practices are communicative and information interaction activities which serve coordinative functions and implement the set of coordination mechanisms applied in a certain context of distributed work. The four case studies demonstrated that distributed work is very much information work: representations of information, which capture and indicate the status of both physical and non-physical objects of work activities, are a key resource inseparable from the work. Information about the status of the relevant work object and on recently completed work and work to be done in the near future is needed for both individual-centred and collective reasons. It was found that the need for coordinative practices in distributed work arises from diverse interdependencies. They create coordination needs. Distributed collaborative work involves several kinds of interdependencies between actors and their tasks. Understanding and managing interdependencies at various levels (those of goals, methods and procedures, and resources) is crucial for successful performance of distributed work.

In the four case studies, it was found that coordinative practices encompassed the following elements:

- Extending the collaborators' attention
- Maintaining continuity of task completion
- Synchronising bonded activities among dispersed collaborators
- Maintaining situation awareness in relation to the shared work context
- Assembling and narrowing problem spaces in remote collaboration
- Compiling the hidden, latent or forgotten experience knowledge related to shared work objects
- Obtaining new knowledge surrounding shared work objects and updating the current knowledge
- Enabling task and resource flow within internal value creation process

Next, each of these practices is briefly summarized.

Extending the collaborators' attention as coordinative practice in distributed process control work was needed to secure smooth shared operation. Because different units were dependent on shared resources also in exceptional situations, the coordinative practice was needed. The exceptional situation required tighter coordination than normal operation conditions. There was a greater need to allocate resources and time critical activities. Resource and process dependencies that were the sources for the coordination need were all the time present, but did not require in normal situation any deliberate mutual indications between collaborators. The abnormal change in the status of shared resource required extra monitoring and notification among collaborators. Coordinative practice enabled critical notification of collaborators about changed status of shared processes and common resources, in the conditions of tight time frames for execution of coordinated activities. Deliberate coordinative practices notifying collaborators was needed when abnormal

situation occurred, even though the dependencies between sub-processes controlled by single units were well known. Information interaction performance obstacles in coordinative practice were related to the lack of conventions in the monitoring technology utilisation to detect abnormal conditions in interdependent processes and in the utilisation of shared resources. The technology (process automation system) providing information to monitor interdependent processes was present, but the convention to monitor certain parameters was absent.

Synchronizing bonded activities was a coordinative practice found in the process control work context. Because of the strongly interrelated nature of physical chemical production process certain exceptional process situations required very tightly coordinated and sequenced, concerted activities from different production units. Coordinative practice ensured organization and allocation of shared raw materials of production without production losses. Synchronizing required extra effort to control and inform distributed activities. The dependences between sub-processes were well-known, but exceptional process situation required more intensive, parallel and simultaneous of communication and notification between collaborators. Moderate performance losses occurred, because the communication media options utilised were not sufficient considering the need to inform many collaborators simultaneously and immediately, while executing activity allocation and delivering status change and timing plans at the same time in the controlling subunit.

Maintaining continuity of task completion was a coordinative practice observed both in process control case and security service case. The coordinative practice existed because the responsibility of task finalization was handed from one work shift to the next, and relevant information about the status of common work object and activity processes left uncompleted needed to be exchanged. Coordinative practice served also need to allocate responsibility about task completion and ensure that next responsible actor completing or continuing the activity understood the state of the activity process properly. Coordinative practice ensured that operation continued smoothly after the shift change. Information interaction performance obstacles of the current coordination mechanisms applied in the coordinative practice were related to inconsistent written reporting and considerable amount of status information delivered only informally in spoken encounters. Moreover, also the salience of status information which was still relevant when shift change occurred was not sufficiently supported with applied technologies. These features of practice created information flow disturbances.

Maintaining situation awareness in relation to the shared work context was a coordinative practice crucial in the security service work which contained monitoring and protecting security in the office premises. The practice manifested in the guards' need to maintain awareness about relevant status changes in the premises they were monitoring. This awareness was crucial in order to avoid flawed interpretation of security situation in the clients' premises. Means to maintain accurate situation overview was partly dependent on the information delivered from clients about exceptions in the premises (like exceptional

timing of premise use) into the back-office information system of the security service. The information flow from clients to security service was sometimes incomplete, and guards completing their circuit did not had accurate situation information or means to update the situation information with current devices. Disturbances in the information flow were partly due to the unclear responsibility allocation between client and security service considering status change notifications. Coordination disturbances also reflected the criticality of status information about the premises as shared resource enabling efficient security surveillance.

Assembling and narrowing problem spaces in remote collaboration was a coordinative practice observed in the technical support work context. The practice contained rather laborious, recurring and remote information collection regarding the problem to be solved in the field. Information that was collected in every support case was related to the nature and status of object of work – the machine or process in a failure mode. The practice reflected unclear division of labour between the support requester and support provider. Support requesters were not aware of the criticality of problem situation details as central shared resource making problem resolution possible. However, the practice was needed to secure consistent and suitable solution to the problem at hand. The performance losses the current practice created were related to the absence of conventions and representation formats for reporting problem situations from the field.

Compiling the hidden, latent or forgotten experience knowledge related to shared work objects was a coordinative practice taking place in the technical support work context. The practice had emerged as response to the organizational failure to establish conventions and routines for problem case solution documentation. The support engineers needed to manually search, memorize or encounter by change earlier solutions for the problem at hand. The earlier solutions served as a critical resource for new problem situation resolutions, and enabled securing consistency between solutions provided in a similar problem from case to case. The practice reflected obscurity in the allocation of duties related to the documentation of already solved problem cases. The status and lifecycle information about problem situations related to the certain machine type or client environment was difficult to obtain. Lack of documentation routines created recurring extra work when compiling critical experience knowledge.

Obtaining new knowledge surrounding shared work objects and updating the current knowledge was a coordinative practice applied in the technical support work context. The practice related to the need maintain status knowledge about totally new shared objects of work (machine types) in the field and about success of solutions made to solve problems occurring to new machine types in the field. The practice supported consistency between solutions devised to similar, new machine types in the field, and enabled mobilisation of new machine knowledge as resource for technical support work. Performance losses occurred, because knowledge dissemination concerning new machine type installations was not a

convention and there were no established routines to ensure new machine information reached technical support personnel in time.

Enabling task- and resource flow within internal value creation process was a coordinative practice observed most saliently in telecommunication professionals' work context. The work of professionals contained lots of communication and information exchanges with internal colleagues, with limited possibilities for spatial and temporal co-presence, some of the collaborators being on the move considerable share of their working time. Information requests and links to resources in operative information systems needed in task execution of individual professionals were flexibly communicated via mobile email which enabled both composing, sending and receiving messages and approvals in variety of work situations. Performance was efficient, flexible and fluent because of good and asynchronous access to information relevant for the activity at hand for the collaborator. Status information about shared objects of work were delivered efficiently and interdependencies between work activities of individual professionals was supported adequately.

Coordinative practices observed in the cases can be contrasted and compared from the viewpoint of coordination function they supported in distributed work. In the earlier literature discussed in Chapter 2, the following categories of functions coordination serves in distributed work were distinguished. Coordination enables

- aligning of goals and responsibilities in the shared value creation
- decomposition of activities between actors
- organization of resource utilization between activities
- securing consistency and assembly of various parts and contributions from activities to fit together
- ordering, sequencing and timing of interdependent activities
- expressing and acknowledging status of the common object of work, shared resources and activity processes.

These categories of coordination functions were utilized as analytical lenses when comparing coordination practices found from the cases. Coordinative practices observed in the cases often supported several elementary coordination functions. Next attention is directed into which coordination functions were most often the reason for the emergence and existence of observed coordinative practices. Coordinative functions that the observed coordinative practices fulfilled in the case contexts are tabulated in the Table 22.

Based on the comparison, following answers to RQ1 can be given. When comparing the coordinative practices found from the cases, it can be concluded that certain coordinative functions require more often explicit attention than others in the accounts of collaborators. First, majority of coordinative practices occurring in the contemporary distributed work are related to activities enabling better access to and utilisation of shared informational resources of work. Second, expressing and acknowledging status of common objects of work, shared resources and activity processes generated variety of coordinative practices in each settings. Other coordination functions were fulfilled too, but above two functions

Table 22. Comparison on coordinative practices based on their coordinative function

Coordinative practice	Functions of coordination coordinative practice serves					
	Aligning of goals and responsibilities in the shared value creation	Decomposition of activities between actors	Organization of resource utilization between activities	Securing consistency and assembly of various parts and contributions from activities to fit together	Ordering, sequencing and timing of interdependent activities	Expressing and acknowledging status of the common object of work, shared resources and activity processes
Extending the collaborators' attention			x		x	x
Maintaining continuity of task completion	x			x	x	x
Synchronising bonded activities among dispersed collaborators			x		x	x
Assembling and narrowing problem spaces in remote collaboration		x	x	x		x
Compiling the hidden/latent and forgotten experience knowledge related to shared work objects		x	x	x		x
Obtaining new knowledge surrounding shared work objects and updating the old knowledge			x	x		x
Enabling task- and resource flow within value creation process				x	x	x
Maintaining situation awareness in relation to the shared work context		x	x			x

characterized more or less majority of coordinative practices observed. This is in line with results from studies of coordinative practices observed in underline control rooms (Heath & Luff, 1992; Heath et al., 2002) and air traffic control (Berndtsson & Normark, 1999).

Most often the applied coordinative practices served the function of expressing and acknowledging the status of shared work object and shared resources. However, the mechanisms applied in the practices were often time-consuming, inflexible because of requiring synchronic communication, and relied on person-based communication leaving critical information undocumented for further shared use. Salient were the obstacles related to the inefficient mechanisms in the maintenance of accuracy and timeliness of information regarding the status of shared work objects and resources.

There was a temporal element that shaped and motivated coordinative practices: the collaborators' need to maintain awareness about past activities within the work environment and shared resources of work and to synchronise activities that need to be performed in parallel or in a certain order. In the continuous process operation work temporal coordination of interdependent activities was crucial. The role of information interaction supporting coordination was evident also in the case study involving technical field support. Incomplete procedures for documenting and communicating status changes in the shared object of work generated much extra work and considerable performance losses in the form of information waste such as rectifying broken information flow and expending extra effort in searching for undocumented information. In the case study of guards' work, difficulties in finding, documenting, and communicating relevant changes in the status of the shared work object constituted the information-related challenges that hindered performance. Finally, in the case study examining mobile email, ability to utilise affordances of mobile media to manage one's work load were found to be crucial for personal productivity.

Dependencies between goals, work methods and procedures, and – especially – the knowledge resources are the elements of work situations that need to observed at both individual and collective level. This secondary work of observation manifest as overt activities of maintaining situation awareness. Situation awareness was enabled by several types of coordinative means and mechanisms. A very important category of coordinative enablers consists of the practices and conventions applied to make sure that informational artefacts accurately reflect the status of the remote or less familiar objects of work they represent. It was found out that very often informational artefacts which contain and mobilise the experience knowledge residing in the work community are critical for successful coordination. Another important issue is that coordination is needed to enable continuity of SA. Situation awareness and the management of experience knowledge together form the information resource that must be managed if the interdependencies in the work domain are to be coordinated successfully.

5.2 RQ2: Interdependencies, spatio-temporality, social capital, and technologies' affordances as shapers of coordinative practices

It was hypothesized in this study, that the nature of the interdependence portfolio present in shared work generates the coordination challenge faced in a certain work role. The number of interdependencies, the scope of interdependencies variation (flow, fit, and sharing), ambiguity among the interdependencies, and the level of mutual understanding of interdependencies affect the coordination challenge and requirements for coordinative practices. Interdependencies between work roles, methods, resources, and activities may be regular or irregular, temporally quick or slow, and more or less well-known among the actors – sometimes even appearing as a surprise. It was assumed that the more complex the interdependence portfolio in shared work, the broader and situation-based the set of coordinative practices that need to be applied to enable successful coordination. For recurring and predictable interdependencies, coordination mechanisms of a formal and a plan-, role-, and artefact-based type are suitable. For more unpredictable and infrequently arising coordination needs, more *ad hoc*, mutual, and situated informal communication based coordination mechanisms are suitable. Information enabling smooth coordination of interdependencies must be communicated, disseminated, and documented in various ways, which depend on criticality, the nature of the constraints, and temporal characteristics.

Further, it was hypothesized in this study, that the level of social capital, the nature of actually applied technological affordances and the extent of spatio-temporal distribution among collaborators modify the applied coordinative practices and their fit into the coordination needs. The case results considering the combined impact of these modificators[1] alongside with the interdependence complexity are summarized in Table 23.

Table 23. Cross-case comparison of the factors shaping coordinative practices

Dimension of the explanatory framework		Score in the Case 1	Score in the Case 2	Score in the Case 3	Score in the Case 4
Coordinative practice modificators	Social capital	1	0	2	1
	Technological affordances	1	0	2	0
	Spatio-temporal dispersion	1	0	1	0
Interdependence portfolio complexity		2	2	1	1
Coordinative practice fit score		1	0	2	1

Based on the evidence considering the impact of modificators and interdependence portfolio complexity, following findings related to the RQ2 are presented. The high level of coordination challenge – the high level of complexity of interdependence portfolio characterising a work role – per se does not make successful coordination impossible.

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[1] See calculation details of modificator scores in chapter 3.3.

High spatio-temporal dispersion among collaborators does not make good coordination impossible either. However, in order to enable the best possible fit of coordinative practice to associated coordination challenge, higher social capital among collaborators and higher variety of actually applied technological affordances in the coordination enhance the fit, regardless of the overall level of interdependence portfolio complexity.

Based on the multiple case evidence, the original hypotheses of the comparative case study design were sharpened into the following refined hypotheses, which were examined based on the complete case evidence (Table 24).

Table 24. Refined hypotheses

Original hypotheses	Refined hypotheses
Spatio-temporal dispersion affects coordinative practices	The stronger the spatio-temporal dispersion among collaborators, the lower the fit of the coordinative practices
Social capital among collaborators affect coordinative practices	The stronger the social capital among collaborators, the higher the fit of the coordinative practices
Technological affordances enable coordinative practices	The wider the variety of technological affordances applied in the collaborative coordination, the higher the fit of the coordinative practices
Interdependence portfolio within shared work affect social capital among collaborators	The greater the complexity of the interdependence portfolio among collaborators, the greater the social capital among collaborators.
Spatio-temporal dispersion affects social capital among collaborators	The greater the spatio-temporal dispersion among collaborators, the lower the social capital among collaborators.
Technological affordances applied reflect social capital	The wider the variety of technological affordances applied in the collaborative coordination, the greater the social capital among collaborators.
Interdependence portfolio created need for coordinative practices	The greater the interdependence portfolio complexity, the lower the fit of coordinative practices.
Coordinative practices and their fit with the coordination needs affect information interaction performance	The better the fit of the applied coordinative practices to the level of coordination challenge, the better the information interaction performance.

Next, results of the analysis of the cross-case evidence for comparative examination of refined hypotheses is presented. The level of support for each of the refined hypotheses in each of the cases is provided, and assessment of the level of overall cross-case evidence is presented in the last column of the Table 25.

Table 25. Examination of hypotheses based on cross-case evidence

Refined hypotheses	Case 1	Case 2	Case 3	Case 4	Level of support for refined hypothesis across cases
The stronger the spatio-temporal dispersion among collaborators, the lower the fit of the coordinative practices	+	+	-	-	low
The stronger the social capital among collaborators, the higher the fit of the coordinative practices	+	+	+	+	high
The wider the variety of technological affordances applied in the collaborative coordination, the higher the fit of the coordinative practices	+	+	+	-	moderate
The greater the complexity of the interdependence portfolio among collaborators, the greater the social capital among collaborators.	-	-	-	+	low
The greater the spatio-temporal dispersion among collaborators, the lower the social capital among collaborators.	+	+	-	-	low
The wider the variety of technological affordances applied in the collaborative coordination, the greater the social capital among collaborators.	+	+	+	-	moderate
The greater the interdependence portfolio complexity, the lower the fit of coordinative practices.	+	+	-	-	low
The better the fit of the applied coordinative practices to the level of coordination challenge, the better the information interaction performance.	+	+	+	+	high

The following findings providing results to RQ2 were obtained from the cross-case evidence analysis. Considering relations between interdependence portfolio complexity, the level of spatio-temporal dispersion and variety of technological affordances applied in the coordination, the following conclusion can be made. The level of interdependence portfolio complexity experienced in the work role is not associated with the level of social capital experienced. Moderate level of social capital was possible to be present in a collaborative context both with high and moderate interdependence portfolio complexity. High spatio-temporal dispersion was not associated unanimously to lower social capital. Further, the wider the variety of actually applied technological affordances was associated in most cases with higher social capital. No statements about potential causality explaining the direction of impact can be made between these variables based on this analysis. However, it can be tentatively suggested, that higher social capital facilitates more nuanced and comprehensive

utilization of different kinds of technological affordances with respect to the nature of the coordination challenges. On the other hand, nuanced and appropriated use of technological affordance may reflect in itself higher social capital among collaborators. This more nuanced use of technological affordances may also suppress the potentially hindering effect of higher spatio-temporal dispersion between collaborators.

Based on the findings, the original explanatory framework proposed in the theoretical part of this study for the formation coordinative practices and information interaction performance in distributed work can be modified into a simpler model (Figure 2).
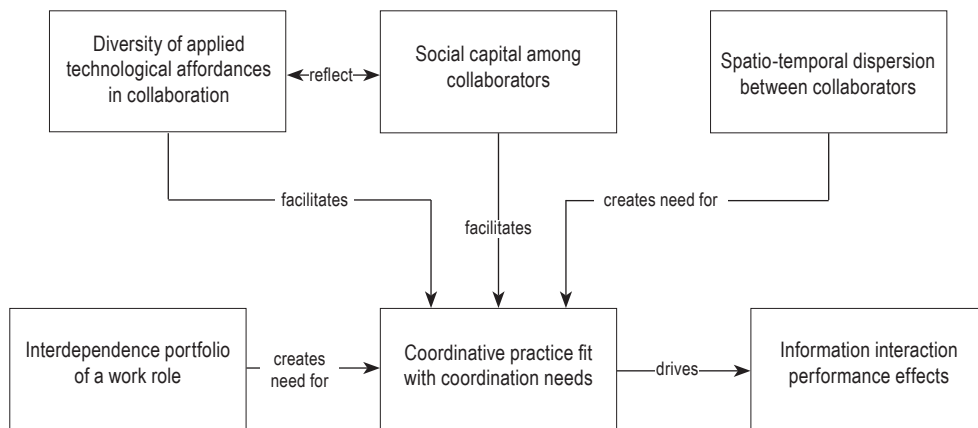
Figure 2. Revised explanatory framework for the formation of coordinative practices and information interaction performance in distributed work.

In order to simplify interpretation of combined influence of coordinative practice modifiers on coordinative practices, the aggregate coordination modification scores were calculated in each case[2]. The score can vary between three values: low, moderate or high. The score indicates the level of supporting or hindering influence coordinative practice modifiers (social capital, the level of spatio-temporal distributedness and variety of technological affordances) as a combination have on the coordinative practice fit. In the Table 26 case evidence considering the main dimensions of the explanatory framework is tabulated.

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[2]   See calculation details in Chapter 3.3.

Table 26. Summary of cross-case evidence for the explanatory framework

Explanatory dimension score	Case 1	Case 2	Case 3	Case 4
Interdependence portfolio complexity score	high	high	moderate	moderate
Coordinative practice modification score	moderate	low	high	low
Coordinative practice fit score	moderate	low	high	moderate
Information interaction performance score	moderate	low	high	moderate

Cross-case evidence indicates that the main explainer of information interaction performance success is the level the coordinative practice fit. The better the fit of actually applied coordinative practices to the coordination challenge the interdependence portfolio complexity poses, the more successful is the information interaction performance experienced in the work role. When there is a greater fit between the level of coordination challenge and the actually applied coordinative practice to manage it, the information interaction performance succeeds better regardless of the level of interdependence portfolio complexity. In other words, a complex set of interdependences does not directly hinder performance success. If coordinative practices applied reflect the level of coordination challenge, the information interaction performance can be successful. If the coordination challenges are in equal level in two distributed work contexts, in the context were enhancing coordination modifiers as aggregate provide more support than in other, the coordinative practices fit better and information interaction performance is more successful.

5.3 RQ3: Coordinative practices' influence on information interaction performance in distributed work

The set of coordinative practices found in the study reflected the challenges faced in the distributed work. Coordinative practices mainly fixed disturbances having their root cause in poorly understood and managed interdependencies between actors, activities and shared resources of work. Further, most of the practices reflected coordination mechanisms which were generating unnecessary load or hindrance for individual task execution. Coordination mechanism applied were often informal, discursive and reactive, even though the coordination need they fulfilled was recurring or based on stable relationships between activities. Clearly the distributed nature of work required coordination, but the means of coordination were not always optimal and generated performance losses for actors.

In CSCW, there are various ways to observe coordination activity in distributed co-operation. Certain approaches emphasise informal ways to maintain an overview of shared activity, while others highlight the importance of more formal resources. High quality of both formal and informal means is necessary. However, quality should be assessed with respect to both the short and the longer term. For instance, informal communication may serve several short-term needs demanding urgency while impairing effectiveness in the

long run (e.g., repairing the shared information base for the work may necessitate several activities that entail information waste).

The coordinative practices were discovered in this study through analysis of information interaction challenges, disturbances, and successes experienced in the distributed work-execution (compare Crowston, 1997). The observed and applied coordinative practices did not always exhibit an ideal fit between coordination needs and possible coordination mechanisms. Rather, they often highlighted ways in which collaborators jointly worked around incomplete and asymmetric understanding of interdependencies. These workarounds created time and effort costs in information interaction performance. Inappropriate coordinative practices generated performance losses in the form of information waste activities.

Information interaction performance losses experienced in a certain work role are not always necessarily related to coordinative practices. However, the case studies revealed that only seldom was the trouble with information interaction related to difficulties in managing personal information repositories or information collected by individual workers for their own personal purposes. The information resources whose accessing and utilisation entailed additional effort were created by other actors in the value-creation chain. These information resources were most often experience knowledge cumulated during execution of shared, but distributed work. The difficulty in accessing and obtaining this information was related to inadequate knowledge about information-resource interdependencies existing between activities and work roles. The collaborators were not always aware of their role as information providers for other actors in the shared-work process and value-creation chain.

The study highlighted that efforts to maintain situation awareness in multi-environment distributed work are plagued by difficulties in obtaining information. This challenge has not been considered much in situation awareness research, wherein either the physical environment examined has been rather stable or the information input receivable has been somewhat fixed (as with sensors aboard an aircraft or in a power plant). Obstacles to obtaining relevant information pose an important threat to formation of appropriate situation awareness. There is a clear need for conceptual tools to enable characterisation of the difficulties that workers face when attempting to make situation assessments.

To be able to solve problems efficiently, one must have access to a knowledge base of problems, previous cases and solutions already encountered. These can help in several ways to frame the problems and can save time and costs in problem-solving efforts.

The findings show the centrality and explanatory power of interdependencies for an understanding of information interaction performance in distributed work. The need to manage interdependencies at multiple levels is reflected in the necessity of maintaining situation awareness as a coordinative practice. For facilitation of information interaction, attention should be paid to the quality and means of formation of these resources, along with their accessibility and access interfaces. In addition, the choice of technologies (with specific affordances) and communication media should reflect the needs associated

with maintaining sensitive situation awareness in rapidly and also suddenly changing work situations. Intermediary factors related to social capital and the overall array of technological affordances available shape the means. At the practical level, there is a need for concepts that could aid in pinpointing ways in which practices can be changed for better coordination. Categories of information waste form a suitable lens for this purpose.

6   CONCLUSIONS

In striving to understand work, this study has attempted to understand the structure and logic of interaction with the common field of work. Work can involve various complexities and interdependencies that need to be managed. There may be structural complexity, the intensity of interdependencies can vary, and complexity may arise because of apperceptive challenges generated by the work. Structural complexity stems from the interdependence inherent to the common field of work: the number of interdependencies between elements of the work, the variety of elements, the intensity of the interaction, the heterogeneity of relationships, and the various possible states of the elements. Intensity of interdependence is related to rate, response time, and rise time of state changes and to the frequency of interaction between elements. Finally, there may be apperceptive challenges related to unreliability of observations and to problems with the quality or availability of information (Schmidt, 2011b). Schmidt (ibid., 49) wrote:

> How can the coordination requirements of cooperative work arrangements be accomplished more easily, rapidly, flexibly, comprehensively, etc. with information technology? [...] [A]s a research area devoted to exploring and meeting the support requirements of real world cooperative work arrangements, CSCW requires that technologists extend out from a strict technical focus and investigate how their artifacts are, or could be, used and appropriated in actual settings.

Interdependencies in work can be between actors' goals, task-execution, materials and information resources. These are essential interdependencies that create the production structure of distributed work. The study verified the importance of managing interdependencies. It can be stated that determining the interdependence portfolio influencing the activities linked to a given work role forms a key part of proper work design for that role. The portfolio should capture at least the most recurrent and predictable interdependencies.

This study showed, that a new work method design problem but one with clear practical relevance arises as today's workplaces become filled with diverse technologies and work communities struggle in attempts to figure out what is the best, most cost efficient, and most productive way to apply various technologies. Assembling a reasonable ensemble of technologies is far from a straightforward design issue. In light of this situation, a solid conceptual understanding of the coordination requirements of distributed collaborative work is needed.

This study was carried out to explain root causes for information interaction successes and disturbances experienced in distributed and mobile work. It was shown that successes and disturbances are related to the coordinative practices applied in the work between co-workers. In coordination theory, it is proposed that redesigning the work by changing its coordination mechanisms is a possible and viable solution. The study reported here contributes to coordination theory through the proposal of an explanatory framework for the analysis of factors that influence the actual selection of coordination mechanisms in real-world work environments and for assessing the appropriateness of specific coordination mechanisms.

One theoretical goal for the study was to consider the variety of technology choices in coordination of distributed work in various case environments. Which communication media would support coordination efficiently? What is the role of informational artefacts and (often medium-choice-bounded) communication conventions in the coordination? How do the choices of media for use in coordination affect overall performance and user experience? Can the lack of understanding of dependencies and an absence of conventions in the coordination hamper performance of distributed work? Most domain-specific ICTs provide digital representation of the shared objects of work and enable shared, co-operative manipulation of the state of those objects. These applications often provide sufficient support for direct manipulation of the state by individual actors but not for the coordination and communication of the collaborative activities.

Collaboration requires techniques and mechanisms for integrating the efforts of interdependent collaborators to enable smooth and efficient shared action. Interdependencies at the levels of goals, constraints, tasks, and resources create the need for coordination. This effort is not related to the goals of the overall task or the sub-tasks; it is a general category of secondary but necessary interaction work needed for integration of the collaborators' work. This kind of secondary work can be found in any distributed collaborative work setting. It can be stated at least provisionally at this point that a poor understanding of dependencies (manifested as shallow or inappropriate utilisation of what are termed coordinative artefacts) impairs the performance and quality of distributed work. If the work' dependency portfolio is not known well, the process of coordination cannot be very efficient.

In the course of the study, the dimensions shaping information interaction in distributed work were uncovered. It was found that the combination of these various dimensions shapes practices and affects performance. Each dimension exhibits variation, which should be taken into account when organisations attempt to optimise their use of information. The study highlights the importance of maintaining experience knowledge, situation awareness, and coordinative practices as means for effective information interaction.

The study sheds light on coordinative practices, with a special focus on the information interaction challenges. This approach differs from that usually employed in coordination studies, wherein the main focus is on describing emergent everyday coordinative practices.

In contrast, in this study coordinative practices and the associated information interaction were examined as a factor in the performance and efficiency of distributed work. The study shows the relevance of coordinative practices for work design. Barriers to coordination are encountered in information interaction and manifest themselves as performance consequences.

Task-critical information needed in certain phases of service production is often created by other participants in the distributed production network, and information serves as input to the respective part of the production process that the relevant actor is in charge of. The challenges and barriers in information interaction are most often related to difficulties in getting access to the information that is needed for completion of the actor's work tasks, with reasonable time and effort costs. The information one needs may be left undocumented, sometimes the information cannot be found, or it may be difficult to access or filter from irrelevant information. When relevant information is not available, task-completion relies on incomplete or faulty information and overall performance may be impaired.

Availability of information sources without time constraints is key for eliminating effects of spatial barriers in distributed work. When information is the most important resource for the work, geographical distance between collaborators *per se* does not have a serious effect on performance, as long as the information interaction is efficient. Rather, one needs proximity to information and ease of access. Shared information forms the primary work environment in such work. This can be termed the information-work environment. In such a context, one cannot conclude that spatial distance is always a hindrance to work performance (cf. Watson-Manheim et al., 2012).

In the production of physical products, a bill of materials or product structure lists the set of raw materials and components needed in the manufacturing of the product. In the realm of non-material, information- and knowledge-based products such as service provision or expert work, an analogous product structure can be distinguished. The product structure for a service product covers the information that is needed for accomplishing a service or expert task. This bill of information resources is not exhaustive – for example, it does not list the knowledge that an actor utilises from his or her own memory. Instead, the bill captures the essential, core information about the client, context, and task environment that is needed in each service case and that needs to be explicitly sourced in one way or another. In distributed and mobile work, this bill of essential information for accomplishing a service task can be given a concrete form through observation of the information interaction that occurs in the course of task-completion.

Information and interactions with it as an immaterial factor in production (Kendall & Scott, 1990), alongside with the application of information in the various phases of goods and services production processes, have not been addressed extensively in the work-design literature. Though interest in application of new ICTs in work processes has not waned, conceptualisation has been lacking. Coordination theory and associated efforts

to reconsider the coordinative practices in distributed work serve as tools for better management of information as a central means and resource of value creation. Better performance in distributed work is about having the right information, in the right format, in the right place, at the right time for the purposes of task-execution.

6.1   The contribution of the study

In this study coordinative practices manifested in information interaction as a performance driver in distributed work were analysed. The study contributes to coordination theory by providing a framework to explain shapers and drivers of coordinative practices in distributed work and their development. It enables explaining why certain coordination mechanisms are applied and others not and ascertaining how the mechanisms applied affect performance. As a further contribution to coordination theory, this study has shown how the maintenance of situation awareness and management of experience knowledge are evidenced in the selection of coordination mechanisms. In addition, the conceptualisation of interdependence portfolio complexity aids in approaching interdependencies in a holistic manner and concretising the coordination needs in specific cases.

The explanatory framework for the formation of coordinative practices in distributed work provides theoretical tool to analyse and explain the successes and failures of information interaction performance in distributed work. It sharpens the model provided by Olson and Olson (2013) by concentrating on coordination as a core driver of collaboration success. In addition, the framework this study provided takes the viewpoint and experiences of a work role holders as starting point, while Olson and Olson (2013) and other treatments of coordination problem (e.g. Costa et al., 2011) analyse the phenomenon in the level of a single project.

The research contributes also to interdisciplinary studies of distributed work by providing insights into how important and resource-intensive element coordination is as secondary work or meta-work in contemporary working life. Consideration of coordination as a feature of work that merits specific attention and appropriate means of analysis represents an original approach to studying contemporary work.

In addition, the study provides practitioners of work design and work-process development conceptual tools that help in analysing information interaction in distributed work and uncovering the root causes of performance disturbances and successes. Conceptual tools of this sort assist practitioners in observing coordinative practices (and factors shaping these practices) and in unlocking potential for enhancement of current practices.

The originality of the study stems from its emphasis on complete work roles and the performance drivers of information interaction related to a complete work role profile. In HCI and CSCW research, this kind of holistic viewpoint is atypical; most often, the research is centred on analysing and designing certain technology or a certain task to be supported by technology (Franssila & Okkonen, 2013). The CSCW literature seldom

takes the overall performance of the collaborating actors in an information environment featuring a multitude of tools, applications, and repositories as a target of scrutiny. More often, CSCW research is motivated and directed toward either designing a single ICT solution for a certain task or describing current interaction practices. The CSCW research performed for development of a single ICT solution often observes only a specific subset of the collaborative tasks and does so from the task-flow viewpoint to inform ICT development. However, the most appropriate context to consider for the ICT solution is that of the complete work profile of a collaborator. This is where the ICT solution should fit. Enhancing a single task type with a certain technology may fail to enhance overall performance of work role in question. In addition, the intellectual motivation behind many CSCW studies is a desire to understand why a certain collaboration technology gets adopted while another does not. The second stream of CSCW research mentioned above studies real-world practices and tends to remain descriptive and not oriented to development of practices or to enhancing performance. This study takes a socio-technological perspective and is oriented to performance development, to the design for performance. When performing his or her work duties in value-creation networks, a collaborator is making use of a plethora of ICTs, information sources, and social conventions. This study contributes to the 'toolbox' of analytical means of evaluating the performance of one's 'shop' in the value-creation network. Enhancing practices in distributed work can encompass both technological elements and elements related to changes in social conventions such as rules, norms, and role expectations in the coordination of interdependencies.

In information studies, the perspective adopted for evaluation of performance in relation to information interaction has been that of either the efficiency of individual sub-processes of information interaction (e.g., seeking information and retrieving it from various information repositories) or task-based information interaction (see Järvelin et al., 2015). In contrast, how information interaction provides support for overall work performance has not been considered in any depth in earlier studies. Finally, application of the concept of information waste serves as a novel and potentially fruitful way to analyse information interaction performance success.

6.2   Limitations

The goal of this study was to distinguish the coordinative practices taking place in various distributed work settings, and establish and test a theoretical framework explaining formation of coordinative practices and its effects on information interaction performance. The four case contexts provided moderate amount and variation of empirical data to test hypotheses considering various relationships in the framework. The empirical data collected did not provide evidence about every logically possible unique combination of values of dimensions of the explanatory framework. This can be considered as limitation

of the study. However, even bigger number of case contexts cannot guarantee that every possible combination can be empirically found.

It is possible that not all of the coordinative practices applied in four case contexts were identified based on the empirical data collected. The data collection was mainly based on accounts, reports and impressions of study participants. More prolonged non-disturbing observation could have provided more comprehensive data to detect additional coordinative practices. However, a limited number of case contexts was possible to be included into the study because of resource constraints. Another limitation of the study is that the investigation involved observing interdependencies mainly as revealed by disturbances and explicit successes in information interaction in the case environments. This approach may limit the possibilities for development of coordinative practices. In addition, all work encompasses elements of tacit knowledge which does not manifest itself directly in information interaction and cannot be expressed in terms of conscious information needs. The analysis of information interaction on the basis of workers' accounts captures only the conscious aspects of information needs.

In general, relations between shapers of coordinative practices may, in at least some cases, be much more complex than assumed in the explanatory framework. Another aspect which has not been considered are the longitudinal temporal aspects of collaboration, rhythms as a feature in coordinative practices. These are important areas for future research.

Methods for identifying interdependence portfolio characterizing the coordination needs in a certain work role were mainly based on the qualitative accounts of the work role holders and field observations. However, depending on the unit of observation, interdependence portfolio could be observed empirically with other means. If the coordination is observed in a single project level, the empirical means to detect coordination needs can be based on more objective technical data. In the studies of coordination within a single software development project the coordination needs have been determined by analyzing objective, logical interdependences within the structure of the software code under construction created for individual contributors (Costa et al., 2013). The actual coordinative actions taken by collaborators could be identified by tracking the interactions collaborators have with shared object of work from variety of activity logs. Comments to a certain source code file, or chat messages containing certain identifier are considered as indicators of coordinative actions. (See e.g., Cataldo et al., 2006.) Another more objective way to observe actual coordinative actions would be digital tracing and analyzing all electronic communication taking place between distributed collaborators for a certain time interval. Digital tracing could be augmented with video observations and wearable socio-metric sensor-based data (see e.g., Daggett et al., 2017).

In a comparative multi-case study aiming at theory development, there is always room for challenging the interpretations made about constructs and relationships found between constructs under study. The evidence collected for proposing relationships is based on qualitative, interpretative analysis, not on statistical testing (Eisenhardt 1989;

Ragin & Amoroso, 2011). In this study, criteria for assessing the coordination fit of the applied coordinative practices were based on interpretation of effectiveness and fluency of coordination mechanisms applied and frequency of occurrence of coordination need. The criteria reflected operational values of standardization of recurring coordination tasks and short cycle times of coordination need resolution from the viewpoint of work role holder under study. Coordination fit could be assessed with other criteria, too. Applying an ad hoc coordination mechanisms instead of formal one can consume less time and cognitive effort from one collaborators while creating extra load for other collaborators. Coordination effort can be observed and assessed differently even by collaborators in the same dyad. A limitation of the study was, that efficiency of coordination was not assessed from the viewpoints of all collaborating partners in shared work in each case. The analysis was restricted to the viewpoints of participants in a single company in each case study.

Performance of information interaction related to coordination observed from the viewpoint of single work role does not necessarily always reflect effects on complete value creation chain the role is member of. What is optimal from the viewpoint of one role may be suboptimal from the viewpoint of overall value chain. Performance effects were observed in this study based on subjective assessments and accounts of study participants, but they could be assessed with other means too. For example, in technical support centre context and security service context performance could have been analysed by tracing the overall life-cycle of a sample of service requests and by measuring information interaction activities they contained quantitatively. With this technique, various lead and response time and transaction measures could have been computed as more detailed indicators of performance.

The experience of information interaction performance related to coordination can be affected be other intervening factors than those included in the explanatory framework of this study. In particular the influence of interface usability of devices and applications supporting coordination may affect the willingness to apply certain technology as part of coordinative practices. The influence of usability experiences was not controlled in this study.

6.3   Practical contributions

Coordinative practices can be observed and evaluated for purposes of practical development of distributed work processes. In practice, it is possible to observe information interaction and deduce what kind of qualitative status is given to each factor on a given dimension of information interaction performance in a given work community.

As proposed by Crowston (2003), interdependencies and the coordination mechanisms needed for their management can be identified via observation of coordination problems in shared work. One way to discover these problems is to identify information interaction disturbances, barriers, and successes experienced at single work role level. Observations

from this study indicate that the practical information interaction supporting coordination of distributed work can be evaluated via the following chain of processes:

1. Identify the task goals, activities, and work products relevant to a single work role.
2. Discern which collaborators are communicated and interacted with in that role.
3. Distinguish the material and informational resources that are needed in that specific work role.
4. Determine who produces each of the resources.
5. Distinguish which material and information resources are delivered as output of the work role.
6. Ascertain who utilises each of these resources.
7. Discover which work activities need to be performed in smooth conjunction with the activities linked to the work role being examined.
8. Observe how resource interdependencies are managed.
9. Observe whether disturbances exist in the flow of information resources between work roles in the course of completing activities and reaching goals. Disturbances can materialise as difficulties in
    a. Determining whether information has been created or not,
    b. Finding information,
    c. Accessing information,
    d. Accessing information in time or at the right time,
    e. Filtering the relevant information,
    f. Collecting information efficiently,
    g. Integrating the information, and
    h. Delivering the relevant information.
10. Consider the impact of social capital on disturbances.
11. Consider the impact that technology choices in the current practices of interdependence management have on disturbances.
12. Consider the impact of the level of spatio-temporal dispersion on disturbances.
13. Distinguish any new needs to manage interdependencies.
14. Identify potential modifications needed to the current coordinative practices.
15. Introduce new coordinative practices to fulfil unmet coordination needs.

One core information resource creating interdependence between actors and activities is the status of a shared work object (such as that of a product or service delivered to a client, of the task environment, or of a shared resource). Another information resource that creates interdependence is the activity and status-change history of the shared work object. While the creation of status information often takes place in particular locations, delivery of this information and access to it should not be bounded by the location of the information creator. This information can also be referred to as experience-based

knowledge (or experience knowledge), because it is created during the life of the shared object and is based on interactions with it. Experience knowledge, without being consciously managed, readily remains undocumented and difficult to access. Information resources of this sort are produced and consumed in different phases of the work process in which distributed actors take part. Information on shared work objects and context forms a solid basis for maintaining situation awareness. Situation awareness is an overall enabler of interdependencies' efficient management. Maintaining situation awareness entails fulfilment of information needs related to the relevant interdependencies affecting the performance of the actor.

6.4   Future research

Future research should subject the drivers of coordinative practices in distributed work to additional empirical observation. However, operationalisation of practices is by no means straightforward. The body of work on operationalisation and typologies of coordinative practices is not complete, and practices take various forms and vary according to the environment. That said, general, information related goals for enabling situation awareness and utilisation of experience knowledge are present in every work context. Coordinative practices are means of maintaining solid work toward these goals. The nature of these practices could be more reliably observed if considered in terms of the dimensions of interdependencies and coordination mechanisms. Efficiency of these practices is shaped by social capital and technological affordances. The practices serve as important enablers of co-operation and smooth coordination, and the effects can be observed in the performance process and via output measurements.

Further research is needed to collect further evidence to test the explanatory framework and propositions laid out in this study. In particular, more in-depth understanding of the efficiency of various coordination mechanisms and ICTs applied in management of highly complex interdependence portfolios is needed. In addition, the cognitive ergonomics and subjective cognitive costs associated with coordinative practices as applied could be assessed in detail.

Observing one's personal digital communication activities and analysing the traces they leave is growing easier all the time. This enables more objective and cost-efficient modelling of interdependencies between collaborators and information resources at work, and more comprehensive modelling of collaboration activities.

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8 APPENDICES

8.1 Data collection in sub-study 1

8.1.1 Interview and observation guide

Background of the informant
1. What is your background at this workplace?
2. What is your current work position?
3. Have you previously worked in other positions at this workplace?
4. Can you tell me, briefly, what is happening in the part of the process you work with?

Task content and work environment
5. What kinds of tasks does your work include?
   a. Describe your activities in monitoring
   b. Describe your activities in shutdown and start-up
   c. Describe your activities related to product change
   d. Describe the actions you take in situations of disturbance
   e. Describe your activities in test trials
   f. Describe your maintenance activities
6. Describe in brief how your typical work shift proceeds
   a. What happens when you arrive at work?
   b. With whom do you communicate, and which communication devices and applications do you utilise?
   c. What kinds of issues do you discuss?
   de. What kinds of information do you review, how, and what is its origin?
   e. How do you make an overall assessment of the state of the process you are controlling and of the process technology's condition?
7. How, if at all, do your work days differ from each other?
8. Are there differences between morning, day, and night shifts?
9. Are the staff working on a given shift always the same?
10. What is central to the execution of your work tasks?
11. How much do you work in the control room versus the production area?
12. In what kinds of situations do you move about in the production area?

Interaction within the unit
13. Whom do you encounter face to face during the work shift, and where?
14. With whom do you typically communicate by phone, walkie-talkie, and email?

15. How are responsibilities distributed within your shift and among those in your unit?
16. How much interaction and coordination is required between work activities of different people on your shift?
    a. For what kinds of issues is interaction and coordination required?
    b. How it is practically accomplished?
17. How much interaction and coordination is required between shifts working in your unit?
    a. What kinds of issues are involved?
    b. How it is accomplished in practice?
18. What kinds of formal interaction and work-coordination meetings do you have within the unit?
    a. Are there shift change meetings? What is their purpose?
    b. Are there morning meetings? What is their purpose?
    c. Are there other formal meetings for these purposes?
19. If any, what kind of informal interaction and coordination of work is carried out?
20. Are there subcontractors working regularly in your unit with whom you work?
    a. What are their role and work tasks?
    b. How do you interact and coordinate your activities with them?
21. Do you discuss other than work issues during work shifts – such as hobbies and non-work events?
22. How would you describe the quality of the collaboration within your unit?
23. Which issues related to your work responsibilities are of relevance and would be useful to know about...
    a. Within your own unit?
    b. In the broader work community on the site?
24. Name the most important collaborators with whom you exchange information, knowledge, and insights within the unit

Interaction with other units and with external collaborators
25. Is there interaction and collaboration with other units and with external parties?
    a. Name the most important collaborators external to your unit
    b. What kinds of issues do you deal with, and why?
    c. How often do you interact with these parties?
    d. How regularly do you interact with them?
    e. How do you interact in practical terms, and by what means?
26. How much and in what way is the production process in your unit dependent on production processes in other units?
    a. What information do you need from other units?
    b. What information do you deliver to other units?
    c. How is the information exchanged in practice?
    d. How often does information exchange take place?
    e. How regularly does information exchange occur?
27. Is this interaction and collaboration satisfying?
    a. Are the interdependencies between units common knowledge?
    b. Is all of the relevant information exchanged?
    c. Are relevant status changes in other units reported appropriately to your unit, and vice versa?
    d. Are there development needs related to inter-unit collaboration?

28. Are there currently external actors you should interact and communicate with, or with whom this would be beneficial but is not possible at the moment?

29. Is there communication with external actors that is not directly related to work?

Knowledge management, information systems, and interaction devices

30. Name the information applications and information resources/records that are most important for your tasks
    a. What makes these the most important ones?
    b. In what kinds of situations do you utilise them?

31. What kinds of information do you deliver to:
    a. Colleagues within your unit?
    b. External colleagues, in other units and beyond the production site?

32. Is the information exchange between collaborators satisfactory?

33. What is your personal opinion about information exchange in general?

34. Do you have appropriate access to the information you need in your tasks?

35. Are there agreements, rules, or conventions addressing what kinds of workrelated events and information should be documented in certain systems and records?
    a. Is there redundancy of information content between systems (the same information being in multiple systems)?
    b. Is the information content complete and reliable?
    c. Is all of the relevant information recorded in systems?

36. Are these agreements etc. followed?

37. Are the applications and records created and utilised in a consistent and comprehensive way?

38. Are there any (other) problems related to the utilisation of information systems in your work?

Problem-solving and decision-making at work

39. Describe a typical problematic situation faced in your work

40. How do you proceed in the problem-solving situations you face in your work?
    a. How and where do you seek help?
    b. Is it easy or difficult to find the right source of help?
    c. Can you utilise records from earlier problem cases to aid in your solution-finding?
        i. Are case records of this sort available?
        ii. If so, how do you utilise them?
    d. What do you do if you face problems that are totally new to you?

41. Are problems solved within the unit or, instead, with the aid of colleagues from other units or external expertise?

42. When a problem is solved, how is the solution documented?

The social community and social networking

43. What kinds of interaction and collaboration exist between operators and personnel doing comparable work at different units?

44. What do you think about that kind of interaction?

45. Is expertise personal to individuals or evenly distributed among the staff?

46. How much do you know about processes external to your unit?

47. What kinds of social media do you utilise in your leisure time?
48. Could these media be utilised also at work?
    a. If so, how?
    b. What do you think about scenarios of utilising social media in this work [researcher describes scenarios]?

8.1.2 Web-based survey about communication and awareness in distributed process operation

Background
1. In which unit do you work?
    a. Unit A
    b. Unit B
    c. Unit C
    d. Unit D
2. Do you work mainly in...
    a. Process operations?
    b. Maintenance?
3. How long have you worked at this site?
    a. Under 2 years
    b. 2–5 years
    c. 5–10 years
    d. Over 10 years

Respond to the following statements, choosing the option that best describes your opinion on each statement: 1 = totally disagree, 2 = disagree, 3 = not sure, 4 = agree, 5 = completely agree
4. I know well how activities in our unit affect processes in other units.
5. Staff in other units know well how activities in their unit influence processes in our unit.
6. I am very familiar with the distribution of process-operation and maintenance duties among the staff of other units.
7. Amongst the various units at our site, we 'speak the same language'.
8. I can easily get information I need from other units.
9. I deliver information about our unit to other units on issues that are important and of interest to them.
10. I know well the most critical variables in our part of the process that influence the quality of the end product.

Indicate how often you discuss or exchange observations and thoughts about issues related to operating the process and machinery with the following collaborators: 1 = daily, 2 = weekly, 3 = monthly, 4 = less often
11. Production staff on your shift within your own unit
12. Production staff from other shifts within your unit

13. Production staff of other units
14. Experts and the team leader within your unit

Where do you **document** best practice, problem-solving tips, and other critical observations related to process-operation?
15. Physical memos in the control room
16. An interactive electronic logbook
17. A maintenance-issue system
18. The intranet

Where do you discuss best practice, problem-solving tips, and other critical observations related to processoperation?
19. At morning and shift-change meetings
20 In an interactive electronic logbook
21. On the intranet
22. In training sessions
23. In email

Assess whether you personally know the following collaborators very well: 1 = don't know them at all ... 5 = know them extremely well
24. Production staff from other shifts within your unit
25. Production staff in other units
26. Experts and team leaders from other units

Respond to the following statements about sense of community at work: 1 = totally disagree ... 5 = completely agree
27. I can trust my colleagues.
28. We have a great 'we' spirit in our unit.
29. We have a great 'we' spirit site-wide.
30. With whatever work issues I face, I can contact the staff working in the other units during work shifts.
31. Every unit on our site is concerned about the productivity of our shared production chain and the operation of our site.

Respond to the following statements on development of competence: 1 = totally disagree ... 5 = completely agree
32. I can get help, tips, and support from my colleagues when needed.
33. I can get help, tips, and support from information systems when needed.
34. My competence is respected in my work community.
35. I feel that I have opportunities to develop my competence.
36. I know which kinds of projects and development challenges experts and team leaders work with.
37. I know how I can communicate and document observations about problems and development opportunities related to the operation of our unit.

38. I feel that I can influence the operation of our unit through my development ideas.

39. I feel that I can influence the operation of our site with my development ideas.

8.2 Data collection in sub-study 2

8.2.1 Interview and observation guide

Interview with technical support service personnel

1. Describe your main work duties
2. How are your tasks organised at the level of the work day and week?
3. Describe your typical work day
   a. What kinds of work activities does the day involve?
   b. In what kinds of location do you work?
   c. Whom do you meet with in the course of the work day/shift?
   d. With whom do you communicate during the work day?
   e. Which communication media do you apply?
4. Describe a technical support case and the knowledge management and use involved
   a. What kinds of phases are there in handling an individual support case?
      i. How does the case arise?
      ii. What is the trigger for the case to be opened?
      iii. Who contacts you, and how?
   b. What kinds of information do you need to collect in order to start to construct a support solution?
      i. How do you collect this information?
      ii. Where does it originate?
      iii. Who provides this information?
      iv. Where you can find it?
      v. Which communication media do you utilise?
      vi. Which information repositories do you utilise?
      vii. Which documents do you collect?
      viii. How would you describe the quality and performance of the collection process?
   c. What kinds of information do you need to collect and apply when constructing the support solution?
      i. How do you collect this information?
      ii. Where does it originate?
      iii. Who provides this information?
      iv. Where can you find it?
      v. Which communication media do you utilise?
      vi. Which information repositories do you utilise?
      vii. What kinds of documents do you collect?
      viii. How would you describe the quality and performance of the collection process?

      d.   What kinds of information do you generate and deliver during and after processing of the support case?
- i. Are there guidelines addressing what kind of information needs to be generated and delivered?
- ii. Where do you deliver this information?
- iii. Who receives this information?
- iv. What communication media and documentation devices do you utilise?
- v. Who has access to the information you generate?
- vi. Who can modify or annotate the information you deliver?

      e.   What kinds of information do you utilise and manage between support cases?

      f.   What kinds of information is sought from you between support cases?

5. Is relevant information on support cases documented and exchanged?
   - a. If not, in what respect and why are there deficiencies? What kind of information is left undocumented and undelivered?

6. How would you describe the following aspects of your work community's information and knowledge management from the standpoint of the efficiency and smoothness of your personal work performance?
   - a. Availability of information and knowledge when needed
   - b. Access to information and knowledge in various situations
   - c. Usability of the information and knowledge
   - d. Quality of the information and knowledge
     - i. Timeliness
     - ii. Completeness
     - iii. Accuracy
   - e. Utility of the information and knowledge
   - f. The search and filtering functions of repositories
   - g. Conventions and commitments related to sharing information and h. knowledge
   - h. Information and knowledge sharing culture
   - i. Technical reliability of the devices and application systems

8.3   Data collection in sub-study 3

8.3.1   Interview guide

Interview with managers, sales professionals, and other experts

1. Describe your work tasks and your overall work profile
2. What kind of mobility does your work entail?
3. How much (in hours/day) do you work outside the office?
4. On whom are you dependent in execution of your work?
5. Who are the parties dependent on you in their work-execution?
6. What kinds of searches for and collection of information does your work include?
7. What kind of creation and generation of information does your work involve?

8. What kinds of communication and information-management needs exist in your tasks when you are mobile/out of the office?

9. Are there specific information needs related to your work tasks?

10. Describe how you utilise mobile email and mobile calendar functions (the MOP service) in your work

11. How long have you been utilising mobile email and mobile calendar functions (the MOP service) in your work?

12. What is most important for you in the use of the service?

13. How much time do you spend using the service per day?

14. With what device(s) do you use the service?

15. Do you use the service also when you're not mobile?

16. What kinds of benefits have you gained from using the service?

17. What kinds of hindrances have you experienced due to using the service?

18. Would you abandon use of the service? Why or why not?

8.3.2 Telecoms professionals' mobile communication and task diaries

Daily diary of mobile email, mobile calendar, and SMS use

Instructions for use of the daily diary: Keep your mobile phone voice-call log, email messages, and calendar entries you processed/saved for the diary-keeping dates.

How many times today have you performed the following tasks with email and calendar applications on your mobile phone? Mark the number of instances of completion of each task, followed by a symbol indicating the application feature you utilised: M = mobile email, C = mobile calendar, V = voice call, S = short message

	Day 1	Day 2	Day 3	Day 4	Day 5
Background information (total number of messages processed on a desktop computer and on a mobile handheld device)					
Number of email messages sent on this day					
Number of email messages received on this day					
Number of short messages sent on this day					
Number of short messages received on this day					
Number of reservations in your calendar for the day					
Tasks related to the sales or customer interface: total / number of times the task was performed via a mobile handheld device					
I proposed a meeting for a client.					
I proposed a meeting for a business partner / supplier.					
I approved a meeting time proposed by a client.					
I approved a meeting time proposed by a business partner / supplier.					
I contacted a client to ask how things are going.					

I asked a client for details (e.g., related to the planning of a bid).					
I asked for details from a client related to problemsolving (e.g., problems related to invoicing or an error).					
I asked a business partner / supplier for details.					
I received client questions related to our products or services.					
I answered client questions related to our products or services.					
Tasks related to internal collaboration within your organisation executed via a mobile handheld device					
I proposed a meeting to an internal colleague/ manager/ subordinate.					
I approved a meeting time proposed by an internal colleague/ manager/subordinate.					
I requested information from members of our own organisation.					
I received questions from an internal colleague/ manager/ subordinate.					
I answered questions from an internal colleague/ manager/ subordinate.					
I received drafts of important documents.					
I approved documents or requests I received (e.g., a bid, a contract, a presentations, or bills).					
I read announcements about important updates from the intranet or other operative information systems that I had requested be emailed.					
Tasks related to management and administration executed via a mobile handheld device					
I approved subordinates' requests (by answering 'OK' etc.).					
I received announcements about the need to approve a request from enterprise information systems (SAP etc.).					
I sent a request/item for approval to the foreman.					
I asked my subordinates how things are going.					
I sent progress details to the foreman.					
I sent messages to my team.					
I received messages addressed to our team.					
Other tasks executed via a mobile handheld device					
I managed my or my family's issues.					
I performed other tasks (please describe).					

8.3.3 Survey on mobile tasks and performance impact used with telecoms professionals

Where do you use mobile email?

How many hours have you worked outside the office within the last five working days?

How often have you used mobile email during the last five days in the following places?

- At home
- At your work desk in the office
- In meeting rooms and other places away from your desk, still in your own workplace
- On a different site of the organisation
- On clients' or business partners' premises
–- On public transport
- Abroad
- In a hotel
- At transport stations, cafés, restaurants, etc.

Utilisation of mobile email for various work tasks

Assess how often you use mobile email to perform the following tasks? (scale: 1 = occasionally, 2 = a couple of times a week, 3 = weekly, 4 = daily, 5 = several times per day)

- I propose a meeting for a client.
- I propose a meeting for a business partner / supplier or equivalent.
- I approve a meeting time proposed by a client.
- I approve a meeting time proposed by a business partner / supplier.
- I ask a client for details (e.g., related to the planning of a bid).
- I ask for details from a client in relation to problem-solving (e.g., with problems related to invoicing or an error).
- I reply to client questions related to our services or products.
- I propose a meeting to an internal colleague/manager/subordinate.
- I approve a meeting time proposed by an internal colleague/manager/subordinate.
- I request information from members of our organisation.
- I receive questions from an internal colleague/manager/subordinate.
- I answer questions from an internal colleague/manager/subordinate.
- I receive drafts of important documents.
- I approve documents or requests I receive (e.g., a bid, contract, presentations, or bill).
- I approve subordinates' requests (by answering 'OK' etc.).
- I receive announcements about the need to approve a request from enterprise information systems (e.g., SAP).
- I receive messages addressed to our team.
- I manage my or my family's issues.

Effects on performance

Assess the following statements on a scale of 1–7 (1 = I totally disagree ... 7 = I completely agree, or 'I can't respond')

Because of utilising the mobile email application...

– My work satisfaction has improved.
– My work has become smoother.
   My work has become more efficient.
   I'm now able to perform tasks requiring quick reaction/response immediately.
   I've been able to avoid excessive travel (e.g., to the office).
   I've been able to utilise idle time (e.g., waiting time) for work.
   My productivity has improved.
   Decision-making related to my work has become quicker.
   Planning and foresight of my work tasks has become easier.
   My time management has improved.
   I've been able to maintain a better situation overview.
   Communication and knowledge-sharing have improved.
   The amount of work-related stress has increased.
   The amount of free time has increased.
   I've been able to increase my work output.

8.4 Data collection in sub-study 4

8.4.1 Interview and observation guide used with security service personnel

Work profile and work environment

1. What is your job title at the moment?
2. How long have you had this job/position at this company?
3. How long have you worked in the security service sector?
4. Describe your typical work shift – what kinds of phases and events does it feature?
5. Are there certain recurring activities that need to be performed periodically?
6. What kinds of exceptional or abnormal work situations or tasks might your work shift involve?
7. In what kinds of physical locations do you work during your shift?
8. Is there variation between work days in the work events that occur during your shift?
9. What activities do you perform when working in a certain physical location and when moving to the next location?
10. Are there certain recurring activities related to the beginning of the work shift and the end of the work shift?

11. With whom do you interact/collaborate during your work shift – always, occasionally, or situation-specifically?
    a. Whom do you contact?
    b. Who contacts you?
12. In relation to what kinds of issues do you deal with the following collaborators during your shift?
    a. Colleagues internal to your company
    b. Clients
    c. Other service providers and their personnel
    d. Some other collaborators
13. Which information and communication technologies and documentation do you utilise in these interactions and duties?

Monitoring and measurement of performance

14. How is your work performance evaluated and measured?
    a. What kinds of key performance indicators are applied?

Information interaction related to the work

15. What kinds of reporting and documentation activities are part of your work day/ shift?
    a. Daily
    b. Occasional
16. How many locations do you inspect during a single work shift?
17. Are there differences in reporting and documentation requirements between inspected locations?
18. Where do you perform reporting and documentation duties?
19. Which tools do you utilise in reporting and documentation?
20. When during your shift do you carry out the reporting and documentation?
21. What kinds of information and guidance do you need in your work in the following situations, for example?
    a. When you are travelling to the inspection location
    b. When you are at the inspection location
    c. When you are moving about at the inspection location
    d. When you leave the inspection location
22. At the moment, how do you access the information and guidance you referred to?
23. Are the information and guidance needs similar or different when you work at inspection locations that you already know as opposed to inspection locations where you have not worked before?
24. At the moment, is there certain relevant information related to your work that is difficult to get either before or during your inspection rounds when needed?
25. Is there certain relevant information related to your work that is currently impossible to obtain either before or during your inspection rounds when needed?
26. Is there certain information that you should be able to deliver during the inspection rounds quickly and with precise location data attached but that is currently impossible to provide?
27. Is there error potential in the information management during the inspection circuit?

28. How is information that you deliver from the inspection rounds utilised and/or further managed...
    a. Within you own company?
    b. By the client?
29. How could information-related interaction, communication, and information management be enhanced overall in security service work?

8.4.2 Survey for security service personnel

Background questions
1. Do you work...
    a. In local guarding duties?
    b. On multi-location guarding rounds?
2. Which unit do you work in?
3. Does your work profile include...
    a. Practical guarding duties (inspection)?
    b. Foreman's duties?
4. Do you work...
    a. Full-time?
    b. Part-time?
5. How long have you worked in the security services sector?
6. How often do you work in inspection locations that are totally new to you?
7. Have you utilised an NFC-enabled mobile phone in your work within the last year?

Please respond to the following statements, considering information related interaction, communication, and information management in security service work (scale: 1 = totally disagree ... 7 = completely agree)
8. In most cases, clients notify the security service in time about exceptions and changes in the situation on their premises.
9. Information pertaining to exceptions and changes on clients' premises that clients have reported reaches the guards properly when they are performing their patrol duties in the field.
10. Information about the duration and exact location of exceptional situations reaches guards appropriately when they are on their patrol route in the field.
11. It's easy to obtain a comprehensive overview of the events and issues handled in the previous work shift when I arrive at work.
12. It's easy to gain a comprehensive overview of the events and issues handled in the previous days/weeks when I arrive for my first work shift after being on holiday.
13. Finding exception reports related to a certain event in the physical report archives is easy and quick when, for example, a client asks for detailed information about the event.
14. It's easy to memorise the patrol route and remember the issues to be checked (guarding specifications and instructions) for each set of premises.
15. It's easy to remember how to use the various devices and applications (alarm systems, locks, gates, etc.) on each set of premises.

Please respond to the following scenarios, considering the potential usefulness of future NFC-enabled functions in security service field work (scale: 1 = totally useless ... 7 = extremely useful)

16. The possibility of tracking the exact location of a guard within a building with the aid of a log of check-tag readings if he or she cannot be contacted by phone (e.g., in emergency or other highrisk situations)

17. The possibility of filling in and sending a simple exception report by phone directly from the premises (such that the information identifying the exact location and the client is automatically added to the report form upon touching of the check tag)

18. The possibility of attaching photos to the exception report filled in and sent via the phone

19. When the patrol route is completed, an application on the phone verifying whether all the check tags were read successfully

20. Announcements about temporary exceptions and special arrangements on the client's premises (which the shift foreman has entered in the back-end system)

21. Guarding specifications and instructions related to certain premises

22. Exception details that a security system (such as an alarm system) has automatically directed to the back-end system

9 ORIGINAL PUBLICATIONS

The formation of coordinative knowledge practices in distributed work: towards an explanatory model

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Abstract

Purpose The paper proposes a model aiming at the explanation of the formation of coordinative knowledge practices in distributed work. Findings from a pilot study aiming at the preliminary testing of the model are presented and discussed.

Design/methodology/approach The explanatory model was developed by combining concepts and findings developed in studies of social capital, knowledge sharing and computer supported cooperative work. The empirical data were gathered in 2007-2008 in a multi-unit Finnish chemical company production site. The methods used were structured observation of work processes, semistructured interviews and a web-based questionnaire.

Originality/value The model developed provides a novel perspective for the study of knowledge practices in the context of distributed group work. The model proposes that varying degrees in work coupling intensity, social capital, spatio-temporality and affordances of collaborative technologies explain the emergence coordinative knowledge practices. The study shows how coordinative knowledge practices can be studied empirically. The empirical study resulted in a typology of coordinative knowledge practices.

Practical implications The findings can be utilized in the analysis and assessment of coordinative knowledge practices between distributed work groups in multi-unit organizations. The findings can also be used in the development of solutions for knowledge sharing and communication in distributed work organizations and communities.

Keywords – coordination, distributed work, collaborative work, work coupling, social capital, knowledge sharing, knowledge practices

Paper type – Academic Research Paper

Introduction

A fundamental problem in all distributed collaborative work task performance is how to ensure that the information required for the completion of the work task moves from one work site or work group to another in a smooth and timely fashion. There exists a number of diverse electronic collaboration and communication tools. Collaboration technologies with social media features are increasingly applied in both everyday life and work-related settings. Work organisations struggle to find efficient ways to reorganise their work practices to fully utilise the potentials of both conventional and new collaboration technologies. When work is conducted in organizations having units across different locations and sites, the number of interdependencies between actors tend to grow and intensify the need for coordination.

In the literature, there have been attempts to comprehensively distinguish factors influencing collaboration and to explain the adoption of various collaboration technologies as resource for the collaboration (e.g., Sonnenwald, 2006). Based on several years of investigation of group collaboration, Olson and Olson distinguished several sociotechnical success factors influencing the effectiveness of collaborative work executed in distributed teams. The creation of common ground between workers, coupling of work, collaboration readiness and technological readiness were the main factors explaining the success of distributed work. (Olson and Olson, 2000.) Neale and colleagues proposed a framework for understanding remote group work. Their model, called awareness evaluation framework, identifies of the core processes in computer supported collaborative work as communication, collaboration and coordination. These processes are shaped by contextual factors, joint awareness and common ground. In their model, light-weight interaction, information sharing, coordination, collaboration and cooperation are understood as qualitatively distinctive levels of work coupling (Neale *et al.*, 2004).

These earlier models identified degrees of work coupling as an important explanatory concept, however, understandings and definitions of the concept vary. In addition, the understanding of the socio-psychological basis of collaboration readiness has been limited. Collaboration readiness has mainly been explained by the existence of explicit incentives to collaboration (Olson and Olson, 2000). There are significant gaps in research in the overall understanding of the context-dependent functional relevance of collaboration in the overall work goal achievement (Voss *et al.*, 2009). What is left unexplained is how and why collaboration per se happens, and how and why certain collaboration technologies are appropriated for collaboration or not.

The main goal of the paper is to propose a conceptual framework to explain the formation of coordinative knowledge practices in distributed group work. The formation of such practices refers to relatively established ways of acquiring,

communicating and combining knowledge to perform work tasks in groups. The processed knowledge can be explicit, that is, recorded in documents, or tacit, that is, embedded in routine and relatively established ways of performing work tasks. This study differs from earlier studies by its focus on coordination as the central sub-process in collaboration.

The paper first introduces the explanatory model for the formation of coordinative knowledge practices. We proceed to specifying the empirical research setting, followed by the reporting of empirical findings. The final section presents the conclusions of the study.

Explaining the formation of coordinative knowledge practices

There are several research perspectives on the study of knowledge practices on the level of collaboration. These issues can be the conceptualized, for example, by drawing on the concepts of *community of practices* and *situated learning* (Brown and Duguid, 2000; Lave and Wenger, 1991; Wenger *et al.*, 2002). Research streams focusing on the above issues also include *situated action* (Suchman, 1987) and *lean information management* (Hicks, 2007). The above approaches are particularly relevant in the study of knowledge sharing practices accomplished in work communities.

Studies focusing on work-related knowledge practices have typically explored the ways in which professionals such as scientists, engineers and managers identify information sources of various types, assess their relevance by diverse criteria, choose the most promising ones and finally access them by contacting an expert or searching a web site (Case, 2007, pp. 250-284). These studies have also paid attention to a number of contextual factors of information seeking such as task complexity (Byström, 1999; Courtright, 2007). Bruce and associates (2003) explored collaborative information retrieval behaviour of two design teams in a software company. Hansen (2011) examined collaborative information retrieval and seeking within the patent domain, while Reddy and Spence (2008) investigated information seeking within a multidisciplinary patient care team. Earlier studies on knowledge sharing have focused on diverse contexts such as academic communities (Talja, 2002), battlefied training simulations (Sonnenwald, 2006) and virtual communities (Chiu *et al*., 2006; Kosonen, 2008).

The present article provides a novel perspective on the study of knowledge practices by exploring the features of coordinative knowledge practices. We demonstrate that the formation of such practices can be explained by three key factors: *work coupling, social capital, spatio-temporality and affordances of collaborative technologies*. The article contributes to a more detailed understanding of the interplay between work coupling and collaboration readiness which earlier have been studied separately and with the help of concepts such as common ground, co-operation habits and motivational incentives. These are here understood as instances and different dimensions of *social capital*. The characteristics of collaboration technologies as shapers of group work practices are conceptualised as *affordances of collaboration technologies*. The key concepts are explained in a more in-depth manner in the next section.

Work coupling refers to the existence and nature of dependencies in the execution of a shared work. These interdependencies influence the way shared work activities are organised and accomplished in practice. The nature of work coupling is characterised in the literature by several factors. (Rasmussen *et al*., 1994; Neale *et*

al., 2004; Olson and Olson, 2000). First, the *number of dependencies* between the components of work executed by work group members affects the nature of work coupling (Olson and Olson, 2000). Components of work can be any resources needed to accomplish the shared goal of the work activity. Second, the *complexity or ambiguity of dependencies* in shared work influences the level of work coupling (Olson and Olson, 2000). Ambiguity refers to the amount of unpredictability and irregularity of dependencies. Third, the *type of the resource dependency and its variation* in common work shape the work coupling. Typical types of resource dependencies which need to be managed in group work are flow dependency, sharing dependency and fit dependency. In flow dependency one activity produces resources needed in another activity. Sharing dependency arise when multiple activities need to share certain resource. In fit dependency multiple activities produce resources that need to fit together in final product. (Malone, 2004.) The variation of dependency types present in the shared work affects work coupling. We introduce the concept of *work coupling intensity* that reflects these three factors of work coupling. Work coupling intensity is typically *high* when there are multiple dependencies between the components of work, when various types of dependencies are present, or when their emergence is unpredictable. Work coupling intensity is *low* when the amount of dependencies is low, when only a single dependency type is present, and when the dependencies are regular and predictable. In any work activity, these three factors can be differently manifested and affect the overall level of intensity in work coupling.

With the advent of social media, the concept of *social capital* has re-emerged as important in studies of social interaction taking place in work contexts. The fundamental tenet of the concept is that social networks and relationships constitute a valuable resource in the conduct of social and economic affairs (Coleman, 1988). Nahapiet and Ghoshal (1998) identified three major dimensions of social capital: cognitive, structural and relational.

The *structural dimension* refers to the general pattern of connections between actors, i.e, actors' possibilities of reaching and contacting each other as resources for information and action. The key determinant of the structural dimension is mutual acquaintance. The connections between social actors or units can be characterized by analyzing network ties, network configurations and the organization of networks. The *cognitive dimension* refers to enabling cognitive resources which actors master with their co-actors like shared language, narratives, representation styles, codes and systems of meanings. This corresponds to the concept of common ground used in some other frameworks (Olson and Olson, 2001; Clark, 1996). The key issue in the cognitive dimension is actors' tacit agreement on the meaning of symbols that are at use in common activities. Finally, the *relational dimension* refers to trust, shared norms and obligations between actors and to actors' identification with the social unit they are members of. The key issue is to have, in addition to shared language and symbols, tacit agreement of desired patterns of behavior.

Social capital stands for opportunity structures that enable or restrict information sharing. However, an actor´s decision to seek or share information also tends to be dependent on the specific methods and tools available for these purposes. Therefore, the concepts of work dependency and social capital have to be complemented by the construct of *affordance*. The term "affordance" refers to features in socio-technical environments that enable or restrict the performance of activities (Gibson, 1986; Hartson, 2003). The concept of affordance enables the study of works tasks, social networks, and tools and technologies, as interdependent.

The affordances of a specific technology are not inbuilt or given. The same technologies have different affordances in different work settings and in relation to different activities. Affordances of collaboration technologies can be conceptualized in several ways. One useful typology is provided by Clark and Brennan (1991). They assess the restrictiveness of a certain technology by analyzing if they can provide affordances of copresence, visibility, audibility, cotemporality, simultaneity, sequentiality, reviewability and revisability (Clark and Brennan, 1991).

When studying distributed work and identifying constitutive factors that shape the practices to accomplish it, *spatio-temporality* - spatial dispersion and temporal presence - needs to be considered. The level of physical proximity and possibility to work in the same time or in different time are primary contextual constraints for the formation of work practices.

Coordinative knowledge practices can be generally defined as relatively established ways of acquiring, communicating and combining existing work-related knowledge and solutions in the shared work process. Knowledge sharing is the key constituent of coordinative knowledge practices. *Knowledge sharing* takes place when actors or units communicate their existing knowledge to others. Knowledge sharing requires the existence of structural, cognitive and relational social capital.

The relationships between the main components of the explanatory model, i.e. work coupling, social capital, affordances of the collaborative technologies and collaborative knowledge practices are specified in Figure 1.
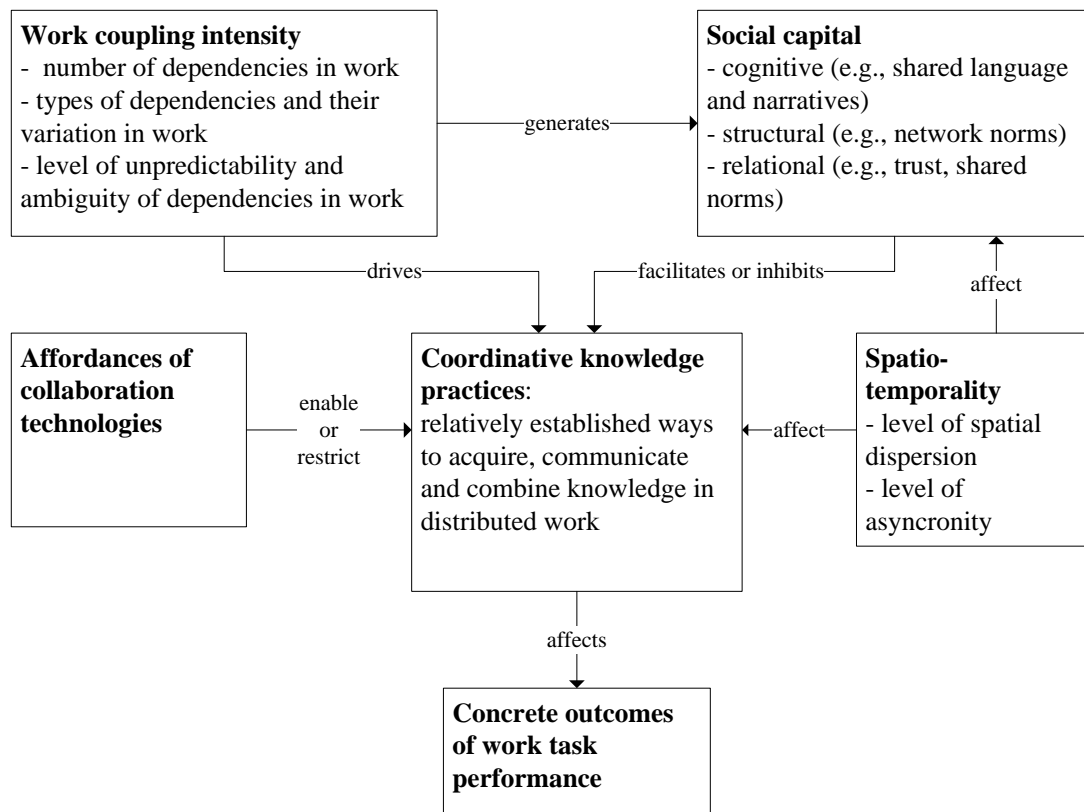
Figure 1. An explanatory model of the formation of coordinative knowledge practices

Figure 1 suggests that the types and degree of work coupling, the degrees of social capital, spatio-temporality and affordances of collaboration technologies, jointly

underlie the formation of coordinative knowledge practices. Work coupling is the key factor because the amount and nature of dependencies between work activities poses requirements for the storage, sharing and re-use of knowledge in collaborative work settings.

The structural dimension of social capital concerns questions about the existing relations and ties between actors and units having the need to share and use knowledge. In analytic terms, it refers to the identification of the actors involved in a joint work process. The cognitive dimension corresponds to the analysis of 'what' knowledge is sought and shared. The relational dimension refers to questions 'why' and 'when' people seek, use and share knowledge. For example, the adherence to intra-group norms may restrict knowledge sharing within an organization. The affordances of technologies relate to the question of 'how' knowledge is shared (Huysman and Wulf, 2006). It mandates the exploration of the variation in the affordances of collaborative technologies across different sites and situations.

Empirical research setting

The explanatory model formed the background for empirical study. The purpose of the empirical study was to observe coordinative knowledge practices in a real-life setting. The study focused on the following aims:

- testing the possibilities to empirically study and identify the dimensions of work coupling, social capital, spatio-temporality and affordances of the collaboration technologies
- characterizing coordinative knowledge practices
- analysing how above dimensions influence the formation of coordinative knowledge practices.

Due to the explorative nature of the study, no attempt will be made to test the causal relationships between the above components at this point. The empirical data for our study were collected in a Finnish chemicals processing company site having four production units. Chemicals processing is executed as continuous production, which is operated uninterrupted 24/7. The data were gathered at the site in each of the four units during 2007-2008. The overall number of employees working daily in the site was about 300. A varying number of employees worked for subcontractor companies (in all more than 150), within the production site. The continuous physical production processes of the four production units were interconnected. Three units produced raw materials and other physical resources for other units. One unit produced final products delivered to the clients. The interconnections and physical resource flows between the units are visualized in Figure 2.
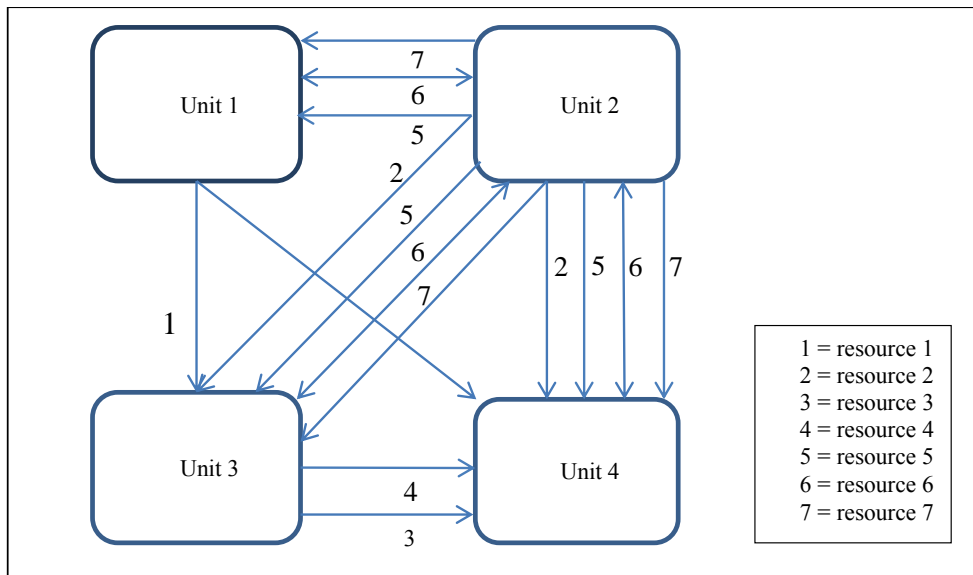
Figure 2. Physical resource flows and interconnections between production units

The data-gathering focused on production process operators working at control rooms of the units. Chemical process control is highly automated. Human production control work consists of computer–supported monitoring, exception management and disturbance handling. The most demanding human tasks in the process control are proactive disturbance management and the supervision of the whole multi-technical equipment. These tasks are information-intensive and cognitively challenging, containing periods of vigilant monitoring and periods of solving complex and dynamic problems. Control and supervision work is mainly conducted in integrated control rooms, requiring occasional operator visits to inspect physical process equipment in the factory floor.

The work performed at the chemical production site represents both blue and white-collar collaborative knowledge work. Production control work in a single unit is executed by shift teams of operators. There are five shift teams in each unit. A single production shift team represented work community structure of the production units at the lowest level of granularity. There were from two to five members in each production shift teams, and the team members rotated the task responsibilities within the team. Operators carry out the hands-on operation of the production process and experts take care of production management[1], support and longer term problem solving issues. Experts do not participate into the hands-on operation of the production process. Operator shifts work on 24/7 basis, five shifts rotating according to a schedule. Dedicated technical experts in the fields of electricity, automation and mechanical maintenance and the process chemistry work only in daytime.

We collected data about real-life work episodes of the operators with the aim of identifying and observing the performance of coordinative knowledge practices at within and between four units of the chemical production site. Multiple methods of data collection were employed – observation, interview and questionnaire[2]. First, empirical material was collected through structured observation (Malone and

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[1] Production management tasks consist of creating production schedules and monitoring performance metrics like production volumes.

[2] Examples of interview and questionnaire questions regarding work coupling, social capital and collaboration technology affordances are in Annex 1.

Crowston, 2001) of operator work within the control rooms of the production units. Second, interviews with individual or paired process operators were conducted. The main goal of the observation and interviews was to detect and understand the nature of work coupling in process control work. In addition, the data gathering aimed at identifying interaction patterns, knowledge and communication practices that were accomplished to perform the control tasks. The interview data collected are summarized in Table 1.

Table 1. Summary of the observation and interview data

	Number of shifts observed	Number of interviewed operators
Production unit 1	3	5
Production unit 2	2	3
Production unit 3	3	4
Production unit 4	2	4
Total	8	16

Observation of work activities and episodes of process operators were conducted both during day and evening shifts. During the observation, the process operators were interviewed in their everyday work environment, in the control rooms of the production units, in peaceful moments while they were doing their conventional work. The experts and production foremen where not present when observations and interview were made. Each interview lasted from one to two hours.

In the observation and interview sessions, work duties and work related interaction, knowledge sharing and the needs for shared decision making within own shift and unit, and between other shifts and production units were specified. The observation data were documented in a research diary. In particular, notes were made of interaction, communication and practical knowledge-related activities that participants engaged in as part of their work duties. The interviews were recorded and transcribed in full into textual form for the purposes of analysis. Analysis of the interview data was conducted by thematically identifying and coding activity episodes.

Third, data were gathered by a web-based pilot questionnaire. Respondents of the pilot questionnaire (n = 9) were process operators from the four production units. The goal of the questionnaire data collection was to detect communication and practical knowledge management tools and channels utilized in work activity episodes. Also the dimensions of social capital were operationalized in the questionnaire and identified both within and between the production shifts and units. Because of its small size, the questionnaire data was analyzed qualitatively.

Empirical findings

Work communities in our study represented quite clearly divided entities, based on the geographical location of the workplace, the process unit where they work, and the time frame within which they operate. In this section we describe work activity episodes[3] identified from the observations and the accounts of our interviewees. The episodes illustrate the variation identified in the types and degrees of work coupling. The episodes describe typical and also critical work activity couplings and

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[3] Work activity episodes detected from the observation and interview data are presented in Annex 2.

interactions between the shifts working at *different time in the same unit* and between the shifts *working at the same time but in different units*.

Work coupling

Our explanatory model suggests that there is variation in work coupling intensity regarding number, type variation and predictability of dependencies between work activities. First, we observed these dimensions of work coupling among successive shifts working in a single product unit. The shifts work on the same part of production process, but in successive time periods. When shifts change, there is a need for a clear and detailed communication and understanding of the state of the production process and operation control activities undertaken during the previous shift. The dependency of this kind is a flow dependency; one shift takes the responsibility of the process control after another. The number of dependencies between the work activities was high in the case study environment. The predictability of dependencies was also relatively high. However, predictability could also lead to communication breakdowns. These occurred in shift changes. When reports were given about the state of production during the previous shift, much about what had happened during the previous shift could be conceived as an ordinary state of affairs and thus not worthy of explicit mentioning. Too much could be expected to be visible and recognizable from the cues available in the work environment itself as an information landscape. Other problematic issues identified during observation included coordinating operations performed in collaboration with other units, since tasks upon the completion of which another unit depended on or had asked to be done could still be uncompleted before the shift change.

Secondly, we observed dimensions of work coupling among the shift teams working at the same time but in different production units. The number and the variation in the types of dependencies was moderate or even low. The intensity of work coupling was low in such cases because the production processes of the units were physically connected by a limited number of material substance streams. The work coupling was mainly related to the sharing and fit dependencies (Malone, 2004). The units shared certain resources like electricity and steam produced and delivered by one unit. At least one unit exhibited fit dependencies because it had to produce the final product from raw materials provided by other units. Predictability of dependencies was moderate. For example, the pattern of escalation in material stream disturbances was not always self-evident or well-known for all teams working in different units. In addition in situations where the shared resources were scarce and the delivery of such resources had to be carefully coordinated between units, the predictability of dependencies was moderate or low.

Overall, work coupling intensity manifested itself differently within the activities among shifts within the same unit and between shifts operating simultaneously in other units. The work coupling patterns were based on the physical and process technological coupling of the production processes of different units. Our study also revealed that different modes of the process control work incorporated different kinds of dependency patterns. In the normal operation mode, the dependencies were quite clear, their number was manageable and they were predictable. When one process unit having physical material flow interconnections with other units faced a disturbance mode, the management of the dependencies became more demanding for the shift teams.

Based on the above findings we may assume that different levels and nature of work coupling are also reflected in the knowledge sharing practices applied in the daily work at the plant.

Social capital

We also explored the structural, relational and cognitive dimensions of social capital at the study site. This included looking at the social relations between the actors within one production shift team, between actors within one production unit as a whole, and between shift teams working in different units. The structural dimension was analyzed by concentrating on work-related interactions. We explored how frequently the operators interacted with each other within their own shift, with other shifts in the own unit and with the shifts in other units. The strength of the structural dimension is the stronger the more frequently such interactions takes place. Unsurprisingly, the frequency of interactions was highest between the members of a shift team. The frequency of interactions was lower between the members of different shift teams in a unit and the most infrequent between the operators working in different units. Contacting the employees of other units was not experienced as equally easy or self-evident.

The relational dimension of social capital was explored by asking how well the members of the shift teams personally knew the members of other shift teams in their own unit, the shift teams of other units, and how the relationships could be characterized. The respondents knew reasonably well the members of the shifts in their own unit, and not that well those working in other units. However, the respondents said they felt that the we-spirit of the whole site was even stronger than the we-spirit experienced within single units.

The cognitive dimension of social capital was scrutinized by asking if the members of the units felt they "speak the same language" with other units. Not every respondent agreed with this statement. A critical tone was recognizable in the responses regarding the willingness and ability of other units to share information about their activities or the status of the ongoing production processes which might also affect other units at the site. While most of the respondents claimed that the operators in their own unit knew well the dependencies between the processes across different units, they still were unsatisfied with the willingness of other units to inform and communicate about activities impacting other units. Thus, the judgments of one´s ability to take into account the needs of other actors and the picture of such abilities among the co-workers were somewhat conflicting. However, the majority of participants felt they knew reasonably well the functional and physical dependencies between different units and the interaction patterns between the activities of one unit affecting the other units.

The relative strength of different dimensions of social capital varied when looking at work groups consisting of operators of one shift team, one unit or the whole plant site work community. It is hypothesized that these differences are reflected in the knowledge sharing practices among and between these different communities.

Spatio-temporality

The shift teams observed in our empirical settings had different possibilities to work in physical proximity and in the same time. The shifts working in the same unit but in

different time had possibilities to share detailed observations and communicate during the shift change. The shared work environments (own unit) and shared primary work object (the production process of the site) provided rich information to maintain joint awareness. On the other hand, the short time periods of physically being together hindered the possibilities to contact and communicate.

The shifts working in the same time but in different units experienced an opposite situation. They had more limited and practically nonexistent physical access to each other, not shared visibility and access to work environment and information, but plenty of shared time. The communicating and contacting were not as straightforward and effortless as when working in a shared control room, but there was much more time together to interact than between shifts rotating in a single unit.

Affordances of collaboration technologies

Conventions of collaboration and the routine utilisation of communication technology for the needs of daily work were explored both through the interviews and the questionnaire. The participants were also asked about needs for the development of collaboration and communication technologies.

Of synchronous means of communication, one-to-one tools were highly popular and frequently employed. Voice calls were used when reporting urgent issues to other units. In exceptionally demanding and time critical situations, local walkie-talkie channel was used to reach all control rooms simultaneously. SMS was primarily employed in order to meet one to many communication needs in cases when the time frame was not that critical.

The documentation of operation activities and coordination commitments made with other units mostly took place via a paper based or electronic log diary. This was shared with the members of one unit and not visible to or searchable by other units. The log diaries contained descriptions of the actions completed and actions left uncompleted. During shift changes within production units, various knowledge items have to be shared and communicated to enable safe and efficient operation. Commitments made with other units, and workspace (process) status forecasts communicated by other units need to be reported as well. Ideally, this information should be collected into the shared electronic diaries in the control rooms. In practice a variety of channels and platforms were employed, including paper memos, SMSs and conventional phone calls. Sending and receiving a SMS messages is simple and straightforward, but this does not necessarily mean that these would be documented and shared with others.

Predictive monitoring of possibly escalating disturbances between production units or the coordination of unit activities in exceptional operation situations (for example, when there is resource scarcity) was not actively supported. The units monitored the activities and process events occurring in other units via the automation and information system, if they had customised the user interface to support this peripheral monitoring. Alternatively, units did not monitor those events proactively at all. Synchronized information sharing about critical or alerting issues was not organised; urgent issues were communicated via voice calls. There was a need for a synchronous communication channel which would reach all units simultaneously and also record the messages delivered. A shared instant messaging channel or a shared virtual workspace visible on every control room's wall would potentially serve as a tool for one-to-many and many-to-many synchronous communication. Shared virtual workspaces could also serve as sites where knowledge items critical for process

coordination and disturbance management situations could be easily available to attract every unit's immediate attention.

A tentative typology of coordinative knowledge practices

The analysis of the relations between the actors within the work communities revealed variation at the different levels of the dimensions of social capital. There appeared to be variation in the use of the collaboration and communication technologies among the participants of the present study. Drawing on the patterns of variation in work coupling, social capital, spatio-temporality and the affordances of the collaboration and communication technologies in the field of chemical production, a tentative typology of coordinative knowledge practices was developed. Coordinative knowledge practices serve higher level monitoring, coordination and problem solving activities. Ideally, coordinative practices are goal-oriented, relatively established and shared activity patterns. These practices need to be built on the basis of typical and recurring work demands. Typical and recurring needs for coordinative knowledge practices are not necessarily clearly recognized or consciously developed in the organization as a whole when activities are distributed across several units. The following demands were identified through the empirical study.

Extending attention is a practice of where the span of deliberate awareness of distributed collaborators is proactively widened. This coordinative knowledge practice is often executed in work settings in which the intensity of work coupling is moderate between collaborators when considering the amount and type variation of dependencies in the work, but where at certain occasions, the predictability of dependencies is low. Typically, in such cases, work coupling contains both sharing and fit dependencies. Work coupling of this kind appeared between different units when there were a limited number of physical resource dependencies (electricity, steam, raw materials) between the units. When the conditions of operation were normal and the activity went on as expected, there was no specific need to monitor it actively or to pay attention to the dependencies. However, fluctuations in the demand and supply of resources created a need to mutually adjust the physical process conditions between different units. This need had either to be recognised independently in related units, or to be proactively communicated across related units. There were occasions when the conventional process status monitoring work mode (the habit by which measurements were regularly checked) had to be extended to cover extra parameters representing features of other units' process statuses relevant for one unit. How this widening of attention span was practically accomplished differed considerably between the shifts:

> "If there is some kind of exceptional situation in our unit, other units can't
> directly see how busy we are here. For example, in Unit 3 they should
> immediately shut down (certain part of the process). But they don´t understand
> this in Unit 3 right away. We need to stress it much more strongly, shouting
> that 'hey, we are facing a tough situation, you have to act', so that we can get
> the process to shut down in a controlled manner. Sometimes there are
> occasions, for example, related to the boilers, when there's much more hurry
> in other units than in ours. We try to let them know beforehand if we need
> something to be shut down in the near future." (Operator, Unit 2)

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> "In Unit 3 they may monitor our process, but I'm not sure about it. There can be certain shifts that monitor, if we have some (problems). But it's more common that we make a phone call, for example, for letting them know that we are again able to provide vapour. It's more common that we contact Unit 3, if we have a lack or surplus of vapour, and ask them to adjust their process driving parameters." (Operator, Unit 2)

In shared activity situations such as these, the collaborating employees working simultaneously in different units having resource dependencies expressed some uncertainty regarding the level of mutual awareness in other units. On the other hand, the interviewees felt that there is sufficient understanding of such dependencies between the units. As discussed below, the observed level of social capital among different communities varied, especially regarding the relational dimension of social capital. Shifts were not satisfied with other units' habits and willingness to share information about their own activities with other units. This issue was reflected in the rather low frequency of interaction between the units. This state of affairs can be interpreted as a sign of low level of structural social capital and only a moderate level of relational social capital within the units. This issue was further reflected in the work situations requiring proactive attention span widening among collaborators. The shifts did not systematically monitor the resource dependencies.

Communication knowledge seeking and sharing related to the management of dependencies in exceptional situations between the units can be supported in various ways. When there is a need to widen the attention span of distributed collaborators, collaboration technologies and tools capable of supporting both synchronous and asynchronous one-to-many communication modes could be employed. In the shifts observed in the present study, one-to-one communication channels were typically used in exceptional situations. However, using only one-to-one synchronous communication channels and tools appeared to be insufficient. From time to time, the employees expressed dissatisfaction with the low level of proactivity in the practice of monitoring how things were developing in the collaborating units:

> "Our operating screens (in Unit 2) are visible also for Unit 3 through the automation and information system. If they don´t return condenser water for us, we are going to face trouble very soon because we run out of water. We are just whining here because we haven't got any more water to pump. If they just would have wanted to monitor our water level, they could have done that. They just need to know what to monitor from the system." (Operator, Unit 2)

The above findings suggest that the monitoring and communication habits and tools employed in the units did not necessarily result in an optimal shared awareness and concerted action in exceptional resource management situations. The empirical analysis revealed that the need for coordinative knowledge practices serving the proactive widening of attention span within collaborating shifts in different units is shaped by the nature of work coupling, social capital, and technology affordances applied in the collaboration.

Maintaining continuity is a practice where understanding about the status of the shared work space is communicated and assembled between collaborators. This coordinative knowledge practice is manifesting in work situations where the intensity

of work coupling in the sense of number of dependencies is high, where the type variation of the dependencies is low and the predictability of the dependencies is moderate between activities of the collaborating communities. In such situations work coupling is typically constituted only of flow dependencies. In chemicals production, successive shift teams in a single unit form a work community and work coupling stems from the flow dependency between tasks. The shifts operate a common physical production process in successive time periods. During shift change there is a need for updated information concerning the present and potential future status of the production process under control:

> "The information exchange in shift change depends on whether you are working in the field or in the control room. The field operators check whether any manual task has been left unfinished from the previous shift. In the control room the most important activity in the shift change is that the ending shift reports face-to-face which process disturbances or deviations were observed and which operation strategies were already tested, so that the next shift do not try the same tricks which were already tried out." (Operator, Unit 1)

> "During the shift change we briefly discuss with the chief operator about whether there has been anything special before the end of the shift. We talk face-to-face about the main events. We check the electronic shift diary, as well as the stuff that has been left unreported or forgotten, personal observations and things that have been tested, and so on. In the diary there are descriptions concerning the control operations executed, for example." (Operator, Unit 3)

> "We make notes on a paper based process diary, and try to compile them in the electronic process diary, but this is sometimes left undone. We don't record obvious things into the electronic diary. The electronic diary (terminal) is also a bit too far and complicated to use. If there have been lots of events, you haven't got the time write down everything. The electronic diary should always be open and easily reachable". (Operator, Unit 2)

Collaborators possessed a high amount of social capital. They experienced high levels of mutual trust and accountability. Communication and sharing of information was straightforward because of the existence of a common ground − the shared object of work. At the same time, however, the collaborators had to be wary of making unconfirmed and unspoken assumptions about the activity status and history of the production process, which is the shared target and environment of their work.

Typically, in knowledge practice of this type, informal one-to-one synchronous communication tools were employed. There was a need for a more systematic use of communication tools supporting written documentation and asynchronous knowledge delivery, however. Multiple communication and knowledge sharing tools were employed in the assembly of the process status and operating activity log during the shift change. These tools included face-to-face communication, written paper based notes, electronic process diary entries and operation and alarms log provided by the automated system. It can be concluded that workspace status monitoring and briefing represent a recurring and routine coordinative knowledge practice. It is affected by the nature of work coupling, social capital and flexible application of a wide variety of collaboration tools employed by the work community.

Synchronizing bonded activities is a practice where collaborators acquire, share and communicate knowledge in real time to orchestrate distributed decisions and acts. This coordinative knowledge practice is necessary in work coupling settings which are characterized by a moderate or low number and type variation of dependencies, but low predictability of dependencies. The typical work coupling dependency mode characteristic of disturbance situations is sharing dependency. Examples of these kinds of exceptional situations include the need sharing of critical scarce resources like electricity:

> "Especially in disturbance situations, electricity breakdown is the worst. You should be able to call several places at the same time. It is easy in our control room where the processes can be operated from a single control desk, here it is easy to coordinate and get the situation under control very quickly. But if you need to call and coordinate with Unit 1, Unit 3 and Unit 4 about the breakdown and give approximations about the length of the outage, things become difficult. First they call us and ask what's going on, how long does it take, and are they allowed already to start their processes. After that, the foremen start calling us…you are in the middle of a huge phone call rally. In the middle of that rally you should be able to do the controlling things (…) You need to be able to communicate simultaneously to various directions, telling people that there is an electricity breakdown, that we try to troubleshoot it all the time, that we don't know yet how long it will take (…) during the hassle you haven't got the time to write things down, because you just need to keep yourself and your ass firmly seated, your fingers glued to the terminal, just plainly trying to control the disturbance." (Operator, Unit 2)

When there were moderate or low levels of work coupling between units, and in situations where predictable low intensity dependencies changed into unpredictable ones, work communities normally possess only moderate relational social capital. In trouble situations work communities need to collaborate intensively and in real-time to coordinate activities performed in different units. There is a need to follow instructions provided by the unit that allocates the scarce resource and monitors the situation by means other than one-to-one communication only. The low level of structural social capital (relative infrequency of day-to-day communication in normal situations) and a moderate level cognitive social capital (understanding of the details of the process dependencies in resource scarcity situations) do not provide strong capacities to cope with these kinds of unconventional situations.

Typically, informal one-to-one or one-to-many synchronous communication technologies were employed. There existed a need to employ tools supporting one-to-many and many-to-many synchronous communication, however, to ensure active delivery of knowledge about peripheral work space status and to delegate the monitoring and timing responsibilities among collaborating work units and shifts. Our empirical analysis revealed that the shift teams working simultaneously in the different units were accomplishing coordinative knowledge practice of this kind especially in demanding coordination task situations.

The tentative typology of coordinative knowledge practices discussed above is presented in Table 2.

Table 2. Tentative typology of coordinative knowledge practices

Coordinative knowledge practices			
	Extending attention	**Maintaining continuity**	**Synchronizing bonded activities**
Work coupling	- moderate amount of dependencies - moderate amount of type variation in dependencies - low predictability of dependencies	- high amount of dependencies - low amount of type variation in dependencies - moderate predictability of dependencies	- moderate or low number of dependencies - moderate of low amount of type variation in dependencies - low predictability of dependencies
Social capital	- moderate level of structural and relational social capital, satisfactory level of cognitive social capital	- high level of structural, relational and cognitive social capital	- moderate level of structural, cognitive and relational social capital
Affordances of the collaboration technologies applied in work task performance	- informal one-to-one synchronous communication tools	- informal one-to-one synchronous communication tools - face-to-face discussion -paper notes - formal electronic diaries - formal operation logs	- one to-one synchronous communication - many-to-many synchronous communication
Spatio-temporality	- physical dispersion high - same time	- physical dispersion low - different time	- physical dispersion high - same time

Table 2 suggests that the recurring coordinative knowledge practices observed in the empirical study reflect the differences in social capital possessed by the collaborators, the practical nature of work coupling intensity, spatio-temporality of activities and the affordances of the collaboration technologies applied in the practices.

Concluding remarks

Studies of knowledge management have lacked detailed conceptualisations about the nature coordinative knowledge practices and the ways in which they are accomplished in distributed work. In order to bridge this gap, this paper presented a model which approaches coordinative knowledge practices as relatively established ways to acquire, communicate and combine knowledge in distributed work. The model suggested that coordinative knowledge practices are shaped by four major factors, work coupling, social capital, spatio-temporality and affordances of collaboration technologies (see Figure 1). The empirical study explored how and whether it is possible to observe the influence of these factors in practice in real-life work settings. The study showed that these concepts can be successfully applied in empirical research to better understand and support the development of coordinative knowledge practices. The dimensions of the main explanatory components, that is, work coupling, social capital and affordances of collaboration technologies could be identified and operationalized in sufficient detail. The empirical analysis of the dimensions resulted in a tentative typology of coordinative knowledge practices of a multi-unit production plant (see Table 2 above).

Since the typology is tentative, it may not necessarily be applicable in types of work settings. The nature and degree of work coupling and affordances of collaboration technologies tend to be contextually sensitive. Empirical research conducted in other kinds of collaborative work settings will help in the elaboration of the initial model. It is clear that the need for coordinative knowledge practices is related to affordances of collaboration technologies and dependent on the nature of the core task at hand. The study showed that the ways in which the distribution of work and co-operation between work teams are organized affect the formation of social capital which in turn shapes existing coordinative knowledge practices and influences the need for their development.

Since the present study draws on a relatively small number of interviews and observations, the validity of the empirical findings should be assessed according to criteria of qualitative study. For this purpose, we employ the criteria identified by Guba and Lincoln (1985, pp. 298-331). First, the *credibility* of the study is based on the ways in which the empirical data were gathered. To guarantee the credibility of the data, the interviews were conducted as consistently as possible. Another central component of credibility is that the informants participated in the interviews voluntarily. Second, the criterion of the *transferability* of the findings is central in qualitative study. The findings of the present investigation are primarily transferable to large and mid-size process manufacturing companies. Third, the criterion of *dependability* deals with decreasing the number of disturbing elements to minimum. This study meets this criterion because certain control factors potentially affecting the inferences (the age profile of work shift members, workplace age profile of the work shift members) have been taken into account. Finally, *confirmability* concerns the issue of truthfulness. The cases form their own organizational setting, yet the moment captured in the interviews and survey are based on the conception of informants and therefore it is without bias.

The present study has also practical implications. The concepts of explanatory model help in the assessment and building of coordinative knowledge practices in organizations. The model helps in understanding the most influential factors shaping practices. The study also showed that coordinated work practices cannot be formed or enhanced solely by providing new technologies but rather by enhancing mutual

awareness of the critical dependencies existing between work activities. The findings can be utilized as guidelines for the formation coordinative knowledge practices and in the choice and development of technological solutions and tools for knowledge sharing and communication in work organizations and communities.

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Annex 1 – Examples of interview and questionnaire questions

Work coupling:

How are the production processes between your unit and other units interconnected?
Which process events in other units affect your unit? How?
How activities in your unit affect other units?
Which units and which variables you monitor in a normal operation conditions?
Which other units you communicate with during the shift, why and when?
What kind of operation events are most challenging?
What kinds of activities are related to the shift change?

Social capital:

Please respond to following statements (agree – not agree):
I know personally well the operators working in different shifts in my own unit.
I know personally well the operators working in other units.
I know the process specifics of other units.
We speak common language in different units of our site.
Operators in my own unit know well what the most challenging operation events in our unit are.
Operators in other units know well what the most challenging operation events in our unit are.
Everyone tries to do his best for the success of whole site.
We have got a strong we spirit in our whole site.

Collaboration affordances:
Which communication media you apply when there is need to collaborate with other unit in normal process conditions?
Which communication media you apply when there in need to collaborate with other units in abnormal process conditions?
How you track and document the plans and decisions made during the shift?
How you monitor activities and decisions made in other units?

Annex 2 – Work activity episodes detected observation and interview data

Operating and communicating in normal process conditions between the units.
Operating and communicating in abnormal process conditions between the units.
Documenting and communicating the abnormal process events for the next shift.
Informing other units about exceptional but planned process event.
Informing other units about exceptional resource shortage or deviation.
Coordinating the operation between two units in abnormal process conditions.
Coordinating the operation of the whole site in resource scarcity situation.
Evaluating of applied process operation strategies between units.
Asking for extra information considering process conditions in other units.

Documenting and communicating best practices regarding certain operational conditions in own shift.

■ *Case Study*

The Role of Knowledge Intermediaries in the Management of Experience Knowledge

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Effectively collecting, sharing and cultivating experience-based knowledge in work organisations is demanding. As the challenges are getting more intensive, there is a need for dedicated personnel who are able to steer, enable and support knowledge sharing activities. In the knowledge management literature, these types of individuals may be characterised as *knowledge intermediaries*.

This paper presents results from an empirical study of an inquiry into the work tasks of knowledge intermediaries. The study focused on exploring the challenges and demands knowledge intermediaries experienced in enabling experience knowledge sharing and reuse. The study was conducted in two industrial enterprises that both manufacture complex machinery products and provide after sales installation and maintenance services for the machines at clients' sites. Empirical data were collected through interviews with technical support personnel who serve as knowledge intermediaries in after sales services.

The study analyses and describes prototypical activity episodes that illustrate the nature of knowledge intermediary work and the information interaction challenges faced in their work. Typical demands and challenges for the management of experience knowledge include the following: (i) problem space assembly and narrowing in urgent support request situations; (ii) assembly of the hidden experience-based knowledge; and (iii) new component and product knowledge acquisition and updating. The paper contributes to the understanding of the needs for and practices of knowledge intermediaries, and it offers some guidelines for the enhancement of experience knowledge sharing in workplaces. Copyright © 2013 John Wiley & Sons, Ltd.

INTRODUCTION: EXPERIENCE MANAGEMENT

The goal of knowledge management (KM) is to enhance knowledge-related activities in the organisation in order to optimise the value of its knowledge assets. In practice, this goal is achieved by monitoring and facilitating knowledge-related activities; by creating and maintaining knowledge infrastructures; by renewing, organising and transforming knowledge assets; and by using the knowledge assets to realise their value (Wiig, 1997).

Definitions of KM most often refer to knowledge processes to be explicitly managed in organisations

in order to enhance organisational and business performance (Vera and Crossan, 2005). In addition to formal knowledge managed in organisations, the *experiences* of employees and the organisation as a whole are valuable knowledge assets of the organisation. Knowledge and solutions developed in practical work activities need to be captured, conceptualised and shared to maintain and develop performance in organisations. Knowledge about actions and decisions executed in past problem situations are a valuable knowledge resource requiring attention in enterprise context. Knowledge stemming from the lived experiences and expertise of the workers of an organisation is a critical asset of the organisation. The accumulated experiences gained in practical action and problem solving need to be shared and transferred to benefit the whole organisation. Experiences that can potentially steer and inform future activities are particularly useful. Hence, experience is a reasonable target for explicit KM efforts.

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Bergmann (2002) launched both the term and field of study called *experience management*. He defined experience management as 'knowledge management that is limited to the management of *experience*'. Experience management deals with collecting, modelling, storing, reusing, evaluating and maintaining experience (Bergmann, 2002).

Past experiences of a particular firm or work team can be captured in a variety of databases and documents, but most often, they reside undocumented in the personal memories of an organisation's workers. New experiences are created all the time in problem-solving situations. The collection of already documented, undocumented and emerging experiences requires specific mechanisms. To be manageable, experiences need to be modelled and stored. Modelling consists of selecting experiences to be reused and finding suitable ways to present and formalise experiences to serve reuse situations. Because there are different kinds of problem-solving situations where needs for experience reuse arise, tailored ways to model experiences are required. Reuse requires that experiences are selectively made accessible, that the value of experiences can be evaluated and that they can be adaptively applied to solve a new problem. Finally, experiences need to be maintained. Maintenance of experiences requires removal of invalid or outdated experiences after evaluation and updating experiences or the experience modelling approach, if needed (Bergmann, 2002).

Experience management requires both social and technical development methods and activities to be adequately supported. There is a practical need for ICT-supported tools to assist experience KM and reuse, but the maintenance of experience knowledge also requires intelligent human interventions. The analytic and facilitative activities, which aim at supporting experience modelling, reuse, evaluation and maintenance, can be termed as knowledge intermediation. The personnel who steer, enable and support these multidimensional experience knowledge sharing activities can be characterised as *knowledge intermediaries* (Ehrlich and Cash, 1999; Sieloff, 1999; Markus, 2001). A knowledge intermediary is a person who serves as a boundary spanner and gatekeeper, whose responsibility is to enhance knowledge transfer and communication of knowledge among groups within the organisation. A knowledge intermediary also researches, collects, reshapes and stores knowledge into knowledge repositories and facilitates the reuse of organisational knowledge for adding business value (Chen, 2010).

This paper explores the everyday demands and challenges involved with the management of experience-based knowledge. Our study focuses on an information-intensive blue-collar work context, technical support of field maintenance service, which has been relatively understudied in the extant research literature. In the context of field maintenance

service business, demands for effective collecting, sharing and cultivating experience-based knowledge are intensive. The speed and variety of new product releases pose serious challenges to field maintenance service personnel who execute the installation and maintenance of new products in the clients' sites. The task of the technical support personnel who remotely help the field maintenance personnel is even more demanding.

Empirical studies of knowledge intermediation situations and challenges make it possible to better meet the needs of managing experience knowledge. The structure of the paper is as follows. Firstly, the research related to experience KM and knowledge intermediaries is reviewed. Secondly, the research methods and overall empirical settings of the case study are presented. In the Results Section, activity episode analysis is reported. Finally, guidelines and proposals for the enhancement of knowledge intermediation are given.

EARLIER RESEARCH ON KNOWLEDGE INTERMEDIARIES

In the KM literature, growing attention has been devoted to the practical management of knowledge capturing, sharing, transfer and reuse processes. The explosion of the amount and availability of both codified and uncodified knowledge has created new KM needs like purposeful combining and filtering of knowledge. Both organisations and researchers are increasingly focusing on understanding and identifying professional roles for managing these processes. Davenport and Prusak (1998) have explored KM activities, responsibilities and roles in different ranks of organisation. Although maintaining that KM should be everyone's job in an organisation, they stressed that dedicated staff are needed for the execution of day-to-day KM activities, knowledge projects and for the steering of the whole KM function. At the lowest levels of an organisation, extracting knowledge from those who have it, putting it into a structured format and maintaining and refining it are the duties attended to by dedicated KM workers. At the middle level, managers of knowledge projects steer KM projects pursuing specific objectives such as knowledge repository building or best practices capturing. Finally, at the executive level, there are chief knowledge officers whose responsibility is to steer the company level KM infrastructure and processes, and manage other KM professionals (Davenport and Prusak, 1998).

The KM professional dedicated to the knowledge reuse support tasks was profiled and first named as a *knowledge intermediary* in the analysis of the KM processes of Hewlett-Packard (Sieloff, 1999). In the academic KM literature, one of the first elaborators of the concept of knowledge intermediary was

Markus (2001). Markus proposed that the role of knowledge intermediaries has not received enough attention (Markus, 2001). She identified tasks that knowledge intermediaries execute in knowledge reuse: they elicit, abstract, distil, index, author, re-author, summarise, filter, polish and pack knowledge from different repositories for reuse. These are tasks that knowledge producers dislike and that are often too time-consuming for them. For example, human intermediaries may capture lessons learned from projects to author compact learning histories. The challenges knowledge intermediaries face in their work can be that although their work is demanding, they are not sufficiently appreciated and they may well find it hard to persuade stakeholders to cooperate. Lack of resources may hinder knowledge intermediaries from producing valuable knowledge objects such as learning histories capturing lessons learned not only from an individual project but also across multiple projects. As a result of these challenges, growing attention is being paid to the management of knowledge capturing, sharing, transfer and reuse processes. Furthermore, organisations are becoming increasingly interested in gaining an understanding of the professional roles that need to be developed in order to take care of these processes in organisations.

The empirical literature has so far elaborated the nature of knowledge intermediation by specifying the nature of the sometimes invisible or unrecognised information source interpretation and identifying work that intermediaries do when they provide their services (Ehrlich and Cash, 1999). Secondly, the work duties and degrees of shared context between different 'client' groups of intermediaries have been scrutinised (Markus, 2001). Finally, knowledge intermediation has been classified according to the variety of application situations and purposes intended for the intermediated knowledge (Dixon, 2000).

Markus (2001) has studied knowledge reuse processes in different work settings extensively. In her synthesis seeking to build a theory of knowledge reusability with an emphasis on KM systems, repositories and organisational memory systems, she constructed a typology of knowledge reuse situations, reusers and reuse purposes. When analysing knowledge reuse in work, one can distinguish between knowledge producers and knowledge reusers. Knowledge producers are those who are the sources of the knowledge to be reused, and knowledge reusers are those who utilise and apply the knowledge in their work context. Central factor differentiating knowledge reuser types is the degree of similarity and symmetry between the identity, competence and work context profiles of knowledge producers and knowledge reusers. According to Markus, there are four different types or communities of knowledge reusers:

(1) shared work producers,
(2) shared work practitioners,
(3) expertise-seeking novices and
(4) secondary knowledge miners.

Shared work producers work as a team or otherwise closely with each other, interacting frequently. Members of the team may have a common occupational background (e.g. be a team of software developers), or their occupational background may differ as in a research and development (R&D) team where members come from different units of the firm. They execute their work in a shared work context. The purpose of shared knowledge creation and transfer is to support knowledge reuse later within the own team. The same individuals serve both as knowledge producers and as knowledge reusers within the community. The knowledge transferred and reused can be, for example, logs of executed work and procedures, reports of lessons learned, accounts of design principles or case descriptions explaining decision making in a certain situation (Markus, 2001).

Shared work practitioners have similar work tasks and similar occupational competences, but they work separately in different work contexts, for example, in a different team, business unit or organisation. Shared work practitioners create knowledge to support and to be utilised by this distributed community. The same individuals serve as knowledge producers and knowledge reusers in the community. The knowledge shared is related to the solutions applied and observations made in challenging and unconventional work situations. This knowledge can be utilised when practitioner faces a new problem situation or when innovativeness needs to be activated (Markus, 2001).

Expertise-seeking novices are a group that occasionally needs certain special expertise, which they do not possess themselves. The knowledge to be reused is produced outside this group of reusers. Because they do not need the special expertise very often, they are satisfied if it is available when they need it from practitioners having more expertise in the issue at hand. This kind of knowledge reuse situation is literally about *transferring* knowledge, and it clearly differs from *sharing* knowledge between equally knowledgeable peer colleagues. There is a considerable difference in the level of expertise between the producer and receiver of knowledge (Markus, 2001).

Secondary knowledge miners work full-time exploring and producing new knowledge. They try to respond to totally new and unexceptional emerging questions by mining, analysing and synthesising knowledge recorded into the existing knowledge bases of the organisation. Secondary knowledge miners are typically experienced professionals, and their core duty is to repurpose knowledge to fulfil diverse knowledge needs of variable

knowledge reusers. In this kind of knowledge reuse situation, knowledge receivers are likely to be different kinds of knowledge end-users. The everyday work tasks between the knowledge producer and reuser are not symmetric (Markus, 2001).

Different reuser types have different requirements regarding knowledge repositories, and the knowledge residing in the repositories needs repurposing to meet the needs of the different reuser groups. The requirements for the repositories depend on whether the repository knowledge producers are documenting only for themselves, for similar others, for dissimilar others. To serve as many reuser groups as possible with a certain repository, adequate incentives must exist for the knowledge producers to create more widely reusable records.

Knowledge intermediaries' primary role and duty is to repurpose the repositories others have created and make them more appropriate for several reuser groups and reuse needs. Intermediation can be supported both by technological and human expertise means. Most of the research considering the support of intermediary role deals with the technological issues. Markus stated that the allocation of intermediation tasks between human and technological intermediaries requires more research.

Dixon (2000) studied companies and their practical socio-technical approaches to experience KM. She found that successful approaches have included the creation of a special role as a human knowledge intermediary. The role of ICT tools in knowledge intermediation has been mainly to support collection tasks, when a human has been the elaborator and polisher of the content gathered with the help of ICT tools.

Dixon analysed in her multiple case study the distribution and transfer of experience knowledge in companies. She created a typology describing experience knowledge transfer types and situations. The typology was developed using a number of different characterising dimensions. Firstly, the transfer types differ regarding the *identity and symmetry of the experience knowledge producer and receiver groups*—is the producing and receiving group the same or different, and is their work environment and context similar or not? Secondly, transfer types differ regarding the *nature of the task* where the transferred knowledge will be utilised—is it a routine or non-routine task, and is the task where knowledge is applied recurring or not? Thirdly, transfer types differ regarding the *type of knowledge* to be transferred—is the knowledge explicit or tacit? In terms of these three dimensions, Dixon formulated a typology of knowledge transfer types or scenarios (Dixon, 2000).

Dixon proposed that one of the transfer types, expert transfer in particular, describes the duties of knowledge intermediaries. In expert transfer, there is a need for special expertise in an acute problem-solving situation, which occurs occasionally, but is related to a routine task. The producer of the knowledge is an expert from a special support centre of the company, and the receiver can be, for example, a field worker working in the local office. The work tasks of the expert are different from those of the field workers', but the experts have extensive and deep knowledge of the tasks performed by the field worker and his work environment and context. If the problem situation at hand can be described in a precise and concise way, the solution to the problem can be given directly for example via email. (Dixon, 2000)

Behboudi and Hart (2008) studied human knowledge intermediaries in a large law firm. He found that there can be knowledge-oriented human intermediaries and technology-oriented human intermediaries. One can detect both formal human intermediaries and informal human intermediaries operating in the organisation. The main responsibilities of formal human intermediaries are to act as facilitators of knowledge transfer and reuse, and as facilitators of KM systems and other types of technological infrastructure supporting KM. (Behboudi and Hart, 2008.)

Research regarding the role of knowledge intermediaries has mainly addressed their roles and responsibilities. There is a lack of empirical research seeking to understand contextual and situational challenges and preconditions in knowledge intermediation. In this paper, the work tasks and information interaction challenges faced by personnel working as knowledge intermediaries are analysed and described. The work tasks that are particularly interesting to analyse are the ones that require the application of creative problem-solving strategies and decision making. The analysis describes prototypical experience KM activity episodes, which illustrate the nature of the knowledge intermediary work patterns and persistent performance bottlenecks it contains. The ultimate goal is to create understandings and ideas for developing the management of experience-based knowledge.

RESEARCH SETTING AND METHODS

The empirical case studies forming the basis of this paper were carried out in two globally operating maintenance service provider enterprises in 2007. The enterprises provide business-to-business services related to the maintenance of machines and equipment, which the same company group designed, manufactured and marketed. The other case enterprise provided maintenance services also for machines, which were manufactured by other manufacturing companies.

The goal of the research project was (i) to analyse practical KM practices applied in field maintenance service work and in the technical support unit; (ii) to identify developments in those practices; and (iii) to

design scenarios for future practices involving the application of social media and Web 2.0 technologies. Empirical data for the research project were collected by exploratory, semi-structured thematic interviews with maintenance personnel working in the field, technical product support personnel working in office and their foremen. The empirical fieldwork, observations and interviews, sought to explore and discover how technical support personnel practised their work as knowledge intermediaries and what kinds of information interaction challenges they faced in their work.

Global enterprise A builds, installs and maintains complex production machinery. The maintenance service unit of the enterprise both installs and maintains machines in clients' sites worldwide, and these installation and maintenance services are provided from local offices. The technical product support unit is co-located with the production site. The product support engineers' (PSEs) main duty is to give problem-solving support to installation supervisors and maintenance engineers in the local maintenance offices in the field worldwide. Problem-solving support is requested from the clients' site where the installation supervisor or maintenance engineer is working with the client's machine. If the PSE cannot help the requester immediately, she starts to analyse the problem details and collects extra information and insights from the R&D and production departments in order to provide troubleshooting support for the clients' site. PSEs typically have a rather long working history with the enterprise, and they have worked earlier as installation supervisors or as maintenance engineers by themselves.

Enterprise B is a part of a global company that maintains machinery consisting of mechanical, electrical and software components. Machines are installed in clients' sites, and field maintenance technicians provide scheduled preventive maintenance and corrective troubleshooting maintenance. Field maintenance technicians can request troubleshooting support from special field support advisors (SFSAs). These advisors give immediate support, and if needed, they can also visit clients' site to support problem solving. Advisors also collect information from the R&D and installation functions if it is needed for troubleshooting. SFSAs also have a long working history with the enterprise and have worked earlier as maintenance technicians or as trouble shooters in the enterprise.

Interviewees in enterprise A were three PSEs and their supervisor. The respondents worked in full-time positions in a dedicated product support function of the company. In enterprise B, four SFSAs were interviewed. The interviews lasted from 1 to 2.5 h, and they were conducted in the meeting rooms or coffee rooms of the companies. The interviews were recorded, transcribed in full and analysed by thematic coding.

Firstly, a brief description of the overall work environment and the main duties of the field support personnel was developed. Secondly, more detailed descriptions of work tasks, knowledge contents handled, the tools to support practical KM activities during the task execution and task challenges related to information ergonomics were coded from the interview transcripts.[1] Thirdly, the coded excerpts were analysed and recurring patterns of task episode accounts related to the challenges of providing support were identified from the accounts. The accounts were then condensed into short problem-solving episode descriptions, which represent interviewees' accounts in a generalised form. The brief description of the work environment and duties and condensed episode accounts with illustrating interview excerpts are presented in the next section.

RESULTS: PROTOTYPICAL ACTIVITY EPISODES IN KNOWLEDGE INTERMEDIARIES WORK

In both organisations, experience-based knowledge needed to be effectively shared among geographically scattered field service maintenance personnel working around the world in their own geographically defined service areas, and among maintenance personnel, product development and design personnel.

Because the two groups of technical support professionals worked in a position where they had to manage both the knowledge they possessed themselves and the knowledge they needed to seek and collect, their role in experience KM can well be characterised as that of a knowledge intermediary. The details of the work tasks they performed and the cognitive features characterising them are explored in the following sections with illustrative episode descriptions condensed from interviewees' accounts.

Problem space assembly and narrowing: help requests with maximum urgency and minimum details

Product support engineers and SFSAs get troubleshooting requests most often by phone, sometimes also by email. The urgency of problem situation varied, and the requesters' skills to provide context and situation details related to the problem case also varied. This influenced the possibilities associated with the most basic steps of problem space narrowing. Requests where the problem situations urgently required solution (if for example the

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[1]With information ergonomics is meant especially cognitive and information processing ergonomics related to the information-intensive work tasks.

client's machine was totally shut down) and the help requester was already very stressed were likely to be very demanding:

'There might come an email from the field with a cry "oh no my machine is not working, what's the problem, please help me, help me!" Well, then I start with a question that which machine you have got? Next question is that how it is not working - just everything cannot be broken. Other requesters are more specific with their questions, they provide details of the case right away. (…) There are big cultural differences in the conventions.' PSE 2, Enterprise A.

'There are several possible reasons for a certain failure state, and then you just need to start to cast that what might be the right reason. Often requester just announces that something is not working, and can't even describe how. You need every time ask the same questions about what is it actually happening there. No one can describe in the phone right away, that what the machine does and what not, you need always ask certain set on basic questions.' PSE 1, Enterprise A.

Part of the problem-solving expertise in technical fields is the ability to apply rather general trouble-shooting protocols, which allow for the narrowing down of possible root causes for the problem symptoms. However, these protocols are only effective if there is already some knowledge about the variety of possible cause–symptom pairs to be searched, and knowledge how to observe and detect them. This knowledge about potential cause–symptom pairs, the likelihood of their occurrence in a certain specific problem case (with a certain machine type, in a certain kind of client environment) and the ability to detect their occurrence is a core category of experience knowledge, which is needed in technical troubleshooting. When trying to narrow down the amount of possible cause–symptom hypotheses in a certain application field, invariably certain basic contextual information about the case is needed.

The help requesters, even though they too are professionals in the technical field, need to be provided with frameworks in order to be able to deliver the case information needed to start the proper troubleshooting. PSEs and SFSAs needed to ask help requesters to follow certain checking steps before the essential problem-seeking and remedy design could start. Providing help in checking steps was challenging if there was time pressure, if help requester was stressed and if the possibility to directly share details of the case with your own senses (for example, see the problem object) was absent because of the remoteness. This generated additional cognitive load, and considerable support time, was spent in non-value-adding *remote checking of the basic hypothesis and the narrowing down of problem space*. The requester's ability to independently narrow down the problem space was of course related to their expertise level (e.g. whether they were novices, moderately skilled or experts). Other factors influencing a requester's inability to effectively launch the first steps of problem-solving protocol were the product support request delivery rules, the lack of field support documentation and the lack of orientation of field personnel in troubleshooting. The help requesters were not aware of or were not provided with guidance as to how to collect basic case information before launching their help request. Only after the collection of basic information can the technical support personnel start to screen potential solutions effectively.

The episodes previously described characterise one facet of experience knowledge intermediation: the duty of providing a framework (or frameworks) in order to be able to find a match between a specific problem at hand in the field and the potential applicable solutions that exist (either documented or undocumented) somewhere in the corporate memory. The intermediary serves as an actor supporting the interpretation and pattern matching between the experience knowledge needed in the field and the experience knowledge repository. The cumbersome and time-consuming part of the support process relates to having to repeatedly spend time on doing the basic information collection work, which could have been provided in advance by the help requester fairly automatically. The time spent on this cumbersome information gathering stage lengthens the lead time of problem resolution and consumes the availability of support personnel.

Assembly of the hidden and forgotten experience knowledge: if only we could know what we know

The PSEs and SFSAs can often deliver solutions to field technicians' problems immediately in the phone on the basis of their experiences and memories of past problem cases. Most of the support personnel also kept their own personal problem case notes. There is also an official electronic problem case note database in both enterprises; however, the use of the official system was neither mandatory nor clearly recommended.

In difficult problem cases, support personnel consulted R&D and production units to get further advice and detailed knowledge about the products. In some of the problem situations, even the technicians in the field (maintenance engineers and installation supervisors) had to directly contact designers and product managers of different design areas by phone. Immediate solutions to the problem were generated together on the phone without the involvement of the technical support personnel.

'It is quite common that installation supervisors call directly the R&D experts from the field to ask for advice if they know the right person. That's quickest way to get help for them.' PSE 3, Enterprise A.

Specifically when the solution was expected to require some kind of change to the actual design of the machine already installed into the client' site, the field technicians contacted the R&D engineers directly. This was because the design changes could be mandated only by the R&D engineers.

When the field personnel contacted the R&D and production units directly without involving technical support personnel, a solution was created for a symptom recognised in a certain machine type. Only the participants being involved in the discussion (the field technician requesting help and the single R&D engineer) were aware of the existence of the solution. These ad hoc solutions became visible only after a delay caused by the technical support personnel:

'If an R&D expert changes something in the machine setup, it is common that information about changes does not reach the technical product support team. We do not know how the machines are changed. We hear about these changes very often only after another installation engineer recognises in the field that hmm the machine design seems to be changed. We here in the product support haven't heard anything about that earlier.' PSE 3, Enterprise A

Even though the code of conduct stated that every support request should be transmitted to the technical support unit, especially more experienced installation supervisors and field maintenance technicians contacted the R&D and production department directly, especially if they knew a person who could help them and provide a solution immediately. Direct consultations and solutions designed were thus mostly left undocumented, because neither the R&D and production department nor the field personnel documented the problem and the solution. These solutions were therefore hidden from the technical support unit personnel, which made it very difficult to maintain an overview about the solutions created in personal communications. The technical support personnel could not be certain that they did 're-invent the wheel' or, worse, develop incompatible solutions to the same problem.

Direct consultations between field technicians and R&D were sometimes left undocumented and undistributed to the technical support centre. It was also the case that situations addressed by the technical support engineers themselves where sometimes left poorly documented and unshared. When they were involved in the problem solution process, the PSEs or SFSAs typically made personal notes about the nature of the problem and the solution:

'I have got a bad memory for case solution details. I might remember that this kind of a case has occurred earlier, but I can't memorize the solution. But that's why I keep personal written records about the solutions. Next time, if I have a vague idea that I might have faced this kind of problem earlier, I can go back to my records and retrieve the solution. It might take a while to find the right one, but I find it.' PSE 2, Enterprise A.

The failure to keep or share solutions that have already been developed for recurring problems relating to a new product created extra cognitive and communication workload for the support personnel. Not all the members of the support unit were aware of the solutions that have already been established. Because of this, they might well 'invent the wheel again' and 'disturb' busy designers asking the same questions again.

Because documenting the details of problem solutions was not mandatory, PSEs and SFSAs could leave the case totally undocumented. If the problem recurred later, they might have already forgotten the solution. Maintaining shared awareness about collective experience knowledge without mandatory communication and documentation practices is likely to result in processes that are extremely sensitive to disturbances and mismatches. One reason for the difficulty in documenting and sharing solutions that have already been established was related to the rigidity of the documentation systems:

'Well we do have got a shared network folder for case solution reports among SFSAs, but it is very messy, no one is maintaining and screening it, and the cases solution reports are very old there.' SPSE 1, Enterprise B.

'The system (quality issue notification system) is rigid (…) It's hard to search from there. Even if you know that there has been a certain problem and it's written there, it's difficult to find it. The report content there is a kind of big mess. It is not categorised appropriately.' PSE 2, Enterprise A.

Special field support advisors were unanimous about the importance of recording and sharing experience knowledge. Case reporting should be developed so that problem case notes could be more easily searched by product type and by client. The majority of SFSAs maintained that they wanted to get more training and support regarding new products.

The episodes previously described pinpoint the characteristics of the technical support personnel's knowledge intermediation tasks, which related to challenges concerning the maintenance of shared awareness about the existence and location of certain items of experience knowledge in the enterprise community. Inadequacies in the practices and tools supporting the documentation process created extra work and rework, when searching, detecting and assembling the partly hidden, partly forgotten, but critical experience knowledge.

Two-way new component and product knowledge acquisition and updating

When designing and producing machinery products, it is commonly the case that new models of the machine contain not only many similar components and functionalities as earlier product generations

but also new features and functions, and new technologies that either support existing functions in a more efficient manner or provide support for totally new functions. New functionalities and technologies naturally create new kinds of installation and maintenance challenges. Particularly challenging were situations where technical support personnel needed to provide support requests that concerned new machine generations and new component types utilised in the machines. In both enterprises, support personnel suffered from the insufficient availability of new product information and component documentation. Often the first indication that a new product or component had been released and installed into clients' sites was when the installation supervisors or field maintenance technicians contacted PSEs and SFSAs to get troubleshooting advice with the new product or component. These situations understandably created confusion among the technical support personnel. They resulted in the initiation of a time-consuming, error prone assistance and documentation seeking process. In these situations, PSEs and SFSAs had to contact the R&D department to get requirements specifications, design drawings and functional descriptions of the new products in order to be able to help field personnel.

The first installations and first weeks of use of new machine models and new functions in machines in the field on the client's sites were critical phases considering the further development of the machine. Managing and utilising this valuable experience knowledge was a challenge for the technical support personnel. Knowledge about the problems of the new products that had emerged in first installations did not circulate among support personnel because of the lack of proper communication and circulation of problem solution documentation inside the support function and between the support function and the R&D department. Again, it is important to note that installation supervisors and field maintenance technicians working in the field were not required to document the advice and solutions they got from technical support function and from the R&D and production department:

'Quite often, especially regarding software problems occurring in the field, we try to give a rapid solution proposal to the maintenance technician having faced the problem in the field. However, we rarely do get any feedback if the solution worked, especially in the longer run. This kind of feedback does not circulate among field personnel and I forgot to call back and ask how the solution worked.' SFSA 1, Enterprise B.

'If there are application changes made after the maintenance technicians' support request for example into the automation functionalities of the machine, distributing information about these changes is very often poor. Changes are not reported to the support personnel. After this, when new support requests concerning

automation application occur from the field, the support personnel is unaware about those changes made. And again, one needs to start seek the latest information about the changes.' PSE 2, Enterprise A.

Feedback knowledge about the installability, maintainability and efficiency of the solutions, which were applied in the client sites, was critical considering the likely success of subsequent installations and the efficiency and effectiveness of subsequent troubleshooting there. The task of documenting and circulating experience knowledge about new products and their installability and maintainability was left to support personnel. Their possibilities to collect, analyse and integrate observations made by the field personnel was limited, because observations were not communicated directly to the R&D and production department. This made the systematic utilisation of field feedback in the further development of the products and maintenance instructions very difficult.

The episodes previously discussed illustrate the challenges in the intermediation of experience knowledge, which requires integration of observations across cases and the follow-up of the success of applied solutions in the field. Lack of communication and documentation, which are necessary preconditions enabling the proper integration and validation of new product knowledge, raises the risk of providing ungrounded and inappropriate support in the field.

DISCUSSION AND DESIGN GUIDELINES

This paper presents the results from an empirical study on knowledge intermediaries in two industrial enterprises. Prototypical experience KM activity episodes illustrating the nature of the knowledge intermediary work patterns have been presented. The experience KM activity episodes identified include the following: (i) problem space assembly and narrowing in urgent support request situations; (ii) assembly of hidden and forgotten experience-based knowledge; and (iii) new component and product knowledge acquisition and updating.

The activity episodes that we have investigated show how PSEs and SFSAs serve as critical enablers of knowledge intermediation and management of experience knowledge. They clearly serve as human knowledge intermediaries. Managing experience knowledge so that it can provide support to maintenance service activities in the field involves several tasks that required human expertise and the contextual interpretation of knowledge needs of the support requesters. The tasks involve iterative match-making between the characteristics of problem cases at hand and the experience knowledge base of the enterprise. Another task dimension is

the maintenance of the currency, comprehensiveness and accessibility of the experience knowledge, which allow the establishment of relationships between problem cases and their solutions, new product 'childhood diseases' and knowledge concerning the relative successes of the solutions provided.

However, a considerable proportion of the support personnel's working activities were spent in low added-value experience knowledge-related activities such as seeking, collecting, polishing and integrating the experience knowledge over the phone. These were necessary precursor tasks providing the foundation for the more valuable diagnostic and repair solutions remotely provided to field personnel. These phone-based activities created unnecessary cognitive and also communication load for the support personnel and, more importantly, rendered efficient experience knowledge retrieval, reuse and its later application practically impossible. The characteristics of the challenging cognitive tasks of knowledge intermediaries observed in this study partly correspond to the observations of Ehrlich and Cash (1999), who found that an important part of the invisible intermediation work of customer support personnel and librarians consisted of the reframing of the clients' problems, critically interpreting and integrating different sources of information to help clients.

The task profiles and situations observed are similar to the knowledge reuse and knowledge transfer types elaborated by Markus and Dixon, with the exception that the receivers of the knowledge transfer were not as diverse as in Markus' study. The knowledge intermediaries in this study took care of duties similar to those of secondary knowledge miners. The task situation of PSEs and SFSAs resembled those involved in expert transfer as described in Dixon's typology. The difference is that the expert transfer that PSEs and SFSAs execute can also be related to non-routine tasks and problems the knowledge receiver face in the field work.

In this study, one additional knowledge transfer situation type in addition to those identified by Markus and Dixon has been identified. This is a transfer situation where the knowledge producer knows the work context and task profile of the knowledge receivers well but the problem situation occurs rarely, and the task to be executed and the problem to be solved are not routine. This transfer category could be termed *tailored transfer*. The cognitive task features and information challenges characterising tailored transfer found in this study are summarised in Table 1.

The PSE and SFSA's activity episodes show that the ad hoc style of experience KM creates serious information ergonomic problems. Technical support personnel serve as knowledge intermediaries, who seek, collect, evaluate and deliver experience knowledge to the field personnel and from the field personnel. As in the enterprises studied, electronic web-based case reporting systems are rather common nowadays in maintenance service industry. The goal of these systems is to support the detailed, context-anchored and conceptually strong reporting of troubleshooting cases. The linkage of troubleshooting cases to clients' environments and other contextual factors and also to product structure can be realised with the help of metadata, linking options and keyword generation. However, we found that information usability issues and pre-established habitual information use patterns lowered the utility, effectiveness and efficiency of these systems. If the existing product structure information that is electronically available is not up-to-date, then the development of metadata in case forms and the linking of troubleshooting cases to product structure data is difficult, ambivalent and too loose. This renders searching in case reporting systems ineffective. For example, in the systems that are used in the case enterprises, it was impossible to ascertain that using a component type title as a search term would result in finding

Table 1   Characteristics of tailored transfer in experience knowledge intermediation

Task features related to the experience knowledge management needs	Information challenges related to the task type
Urgent problem support requests from the field	No conventions or rules for background and situation details specification in support need announcements, too many optional channels for delivering support need announcements
Experience knowledge base assembly	Laborious seeking, screening and gleaning of scattered information from different systems; unavailability of undocumented, person-based solution case knowledge; personal and organisational forgetting of undocumented knowledge
Product knowledge acquisition and updating	Recognition of unannounced changes in products, lack of follow-up data considering product design chances

every report related to that particular component type. Another problem that reduced the benefits that could be obtained as a result of using case reporting systems was that reporting was optional and users were not required to identify or add metadata concerning the problem case.

We would identify some of the critical characteristics of an experience knowledge case repository as:

- The availability of product structure and metadata to be utilised in the indexing of case notes is a basic design requirement for the ideal electronic experience management system.
- The search capabilities are based on the previous discussion.
- The system and the division of documentation work have to support case recording tasks so that they do not create too much extra documentation work.
- The possibility to link and cluster different kinds of electronic documents into a case note based on automatic metadata supports the filtering of notes applicable to certain problem-solving conditions.
- New product announcements, info files, manuals and other support documents should be delivered automatically to support personnel as soon as they are available. The materials should be indexed with metadata to enable their efficient on-demand retrieval.

CONCLUSIONS

An understanding of the importance of knowledge intermediation as a part of the everyday execution of any service work is becoming more important in parallel with an increase in the complexity and richness of the information environment of service business execution (Chua *et al.*, 2006; Delen and Al-Hawamdeh, 2009). Knowledge and solutions developed in practical work activities need to be captured, conceptualised and shared in order at least maintain if not enhance performance in organisations. Knowledge about actions and decisions executed in past problem situations are a valuable knowledge resource requiring attention in enterprise context. Knowledge stemming from the lived experiences and expertise of the workers in an organisation is critical asset of the organisation. The accumulated experiences gained in practical action and problem solving need to be shared and transferred to benefit the whole organisation. Important and sometimes even critical information and observations about the feasibility and quality of design solutions and maintainability issues must be disseminated from the field maintenance service personnel to the product development and design functions of the manufacturing organisation.

In today's information rich work environments, the success of work performance is affected by the overall motivational, emotional and cognitive appropriateness and efficiency of work environment and the information systems designed to support and also augment human performance and experience (Bubb, 2012).

The practical and critical design questions relate to the intermediary tasks and the roles that ICT-supported tools can play in the intermediation process. As the results of this study show, there is clearly a need to understand better the details of the role the knowledge intermediaries play in the process of experience knowledge capture, access, sharing and reuse. Knowledge intermediaries serve as intelligent, context-aware concentrators between diverse experience knowledge creators, knowledge sources in repositories and reusers. Their productivity and the effectiveness with which they execute their tasks are highly dependent on the information ergonomic quality of the knowledge records and access methods the knowledge bases that the company provides. Further, the quality of records is dependent on the documentation practices, codes and cultures of the enterprise. In conclusion, it is important to be aware that the development of experience KM and the support of knowledge intermediaries represent, among other things, profound socio-technical design challenges, which are never solved solely by improving electronic tools. The design of solutions should start with the analysis and understanding of work process interfaces (Boreham *et al.*, 2002) among different experience knowledge creators and reusers in different units of the enterprise. This creates motivation to follow the division of documentation duties and to utilise the electronic tools in a reasonable and efficient way.

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■ *Research Article*

Mobile Email as a Business and Personal Performance Driver in Everyday Knowledge Work—A Multi-method Case Study

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Mobile email is one of the first widely accepted mobile business application in enterprise settings that can be used by mobile phones. In this paper, a study about the role of mobile email as a performance driver in the everyday knowledge work of different business users in multinational information and communications technology enterprise is presented. Everyday communication task contents and volumes of knowledge workers were identified and analyzed by interviews, communication task diaries, and survey to understand the communication task goals and patterns of typical knowledge workers in enterprise settings. The study reveals that the biggest share of the knowledge workers' overall business-related communication (regardless of the communication tool and application) is centered on the internal communication tasks, and respectively, mobile email is used most intensively in the internal communications tasks. When comparing the relative importance of mobile email as communication solution for business users in different work positions, the study shows that mobile email is the particularly important everyday performance driver for managers who travel a lot and whose communication volumes in overall are extensive because of their role as central activity progress enabler for other work communities. Intensive users of mobile email gain more personal benefits than non-intensive users. The importance of mobile email is only moderate in the everyday business communication of those who are not in managerial positions. This implicates that mobile email as a business performance driver should be understood and evaluated by corresponding it with the internal process performance objectives and measures. Copyright © 2013 John Wiley & Sons, Ltd.

INTRODUCTION

Despite the rise of instant messaging, video conferencing, micro-blogging, and variety digital collaboration platforms, email is still the major digital communication and collaboration tool in work settings. Although majority of work email processing is executed on the desktop (Gill, 2013), mobile email is one of the first mobile business applications that are used in a large scale and persistently in enterprise settings. In the empirical studies of business use of mobile email, the users express strong dependence on the application (Mazmanian *et al.*, 2005; Mazmanian *et al.*, 2006; Middleton and Cukier, 2006).

Although the understanding of the impact of mobile email for the individual work–life balance and performance of a knowledge worker has been studied quite deliberately (e.g., Middleton and

Cukier, 2006), the distinctive role of mobile email as an enabling communication method of business interactions and especially as an overall driver of business performance is left mainly unexplored. There are many unanswered basic questions regarding what are the contents and goals of everyday business communication activities conducted with the help of mobile email: what "new" tasks get done, which "old" things get done differently when mobile email is utilized in business communications executed out of office, and in which situations mobile email is used instead of other tools and why?

The core question for the enterprises investing in mobile email and other mobile business applications is why and how they actually serve as overall business performance drivers. Enterprises considering whether to provide mobile email to their employees wonder how the overall patterns of business interactions will be shaped by the introduction of mobile email as a new communication opportunity and what is the added potential value the enterprise can get. If one can answer this fundamental question

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of what activities having business value are made possible with mobile email in business interactions, one is able to start to instrument measures for the business benefits of mobile email investments.

In this paper, explorative analysis of micro-practices (cp. Mazmanian *et al.*, 2005) of the business communication activities of mobile knowledge workers is presented. The paper describes in detail how mobile email is integrated into everyday work processes of knowledge workers having variable task profiles, how mobile email impacts their work performance, and which factors mediate this impact. This paper also elaborates the specific functional role mobile email has compared with other communication tools in knowledge work. The first goal of the analysis is to understand the overall business-related communication goals and communication tasks, task patterns, and task volumes of knowledge workers in enterprise settings. The second goal is to explore the degree and variation of mobile email utilization in various communication tasks. The third goal is to figure out how the utilization patterns and overall intensity of mobile email use are related to the subjective work performance experiences of knowledge worker.

EARLIER RESEARCH

Despite extensive amount of empirical research about the impacts of new information and communications technologies (ICTs) into working life in general, there is a need for practical, detailed accounts of usage patterns of new technologies in knowledge work and analysis of the relations between actual usage behaviors and performance outcomes (Devaraj and Kohli, 2003). Although the various impacts of mobile, smart-phone-based communication into the conditions and nature of knowledge work are researched extensively, there is limited amount of academic studies concentrating specifically on the performance impacts of mobile email. This is surprising, considering the centrality of email for knowledge intensive work in general and the high penetration of smart phones containing mobile email client. Another characteristic of the earlier studies is that the actual tasks and tasks management purposes where mobile email is applied are rarely scrutinized.

Majority of the studies published so far explore the relations between mobile email use and work–life balance and psychological wellbeing. While enabling more control over work and means to balance work load, the use of mobile email in work clearly blurs the borders between work and free time by making working possible and flexible anytime and anywhere (Middleton, 2007). Evidence considering the consequences of this flexibilization is controversial. On the one hand, it is observed that active use of mobile phone in both work and leisure time has not created uncomfortable experiences of

overall hurry and time pressure (Bittmann *et al.*, 2009). On the other hand, there is evidence that intensive mobile email usage patterns can develop into a level of addiction (Turel and Serenko, 2010). If the habit of accessing work-related mobile email is developed into addiction, negative outcomes both in work and in family life, especially perceived work overload and technology–family conflict, will be detected (Turel *et al.*, 2011). As an attempt to understand the intervening factors leading to either positive or negative perceived net effects of mobile email utilization among employees of international financial institution, Besseyre des Horts *et al.* (2012) applied a classical work well-being assessment model, job demand-control-support model (Johnson and Hall, 1988), to analyze the consequences of the use of BlackBerrys. Although the use of mobile email indisputably increased experienced job demands, the possibility to control these job demands varied with the availability and nature of social support, which explicate acceptable use behaviors considering availability. Depending on the nature of social reinforcement both from work sphere and non-work sphere, attempts to control the increased job demands resulted either as increased experiences of strain or increased experiences of learning.

In the first studies of business performance impacts of mobile email, various performance measures have been operationalized and applied. In a survey study exploring the performance impacts of mobile email among employees of sixteen German companies, the dimensions of process improvement and process acceleration were applied to reflect the performance effects. Mobile email influenced business performance by accelerating and enhancing work processes, improving information delivery, and easing coordination of work processes. As the central intervening variable shaping the perceived performance effects was users' attitude toward mobile email, not the actual use. (Beurer-Zuellig and Meckel, 2008) In a survey executed in international telecommunications company, productivity and work efficiency impacts of mobile office service comprising of mobile email, calendar, and contacts management client were explored in individual worker level. It was found that positive productivity and efficiency impacts emerged via the ability to execute tasks requiring rapid action immediately and from the better situation awareness and idle time utilization the mobile services enabled. In shared work processes level, the productivity impacts are related to the improved communication and information sharing and faster decision making. (Vuolle, 2010)

In principle, mobile technologies enable both potential hindrances and benefits for the performance of an individual knowledge worker. The reality of constant connectivity enabled by various electronic communication tools and modes provides both pressures and possibilities for the organization of

individual work. In a shadowing study of knowledge workers' activities during one working day in office, it was found that workers spend the biggest share of their working time in communicating, on average, 5.5 h per day. Working days are fragmented by rather short communication episodes. Workers observe and process the arriving messages all the time, making decisions as to how deeply and in which time frame they involve themselves with each piece of arriving information. The messages can trigger a variety of modifications to the work flow and enable reordering, rescheduling, and prioritizing tasks. Communication flow serves also as an indicator of task load and progress in collaborative tasks. During office day, not involving traveling email was the most frequently used mediated communication mode; it was accessed, on average, 17 times per day. Email was accessed via mobile handheld device, on average, 2.3 minutes per day, and mean total time spend in activity episodes containing use of mobile email was 4.9 minutes (Wajcman and Rose, 2011)

Mobile email can maintain overall sense of control over the information flow during the course of the day and being on the move. Email provides a variety of ways to monitor and respond to incoming messages and provides flexibility to the timing of monitoring and responding. Knowledge workers value this possibility to adjust the moment and intensity of activity of both receiving messages and responding to messages. However, these same capabilities may create feelings of inability to disengage from work, when expectations of being constantly available and responsive, regardless of the time of the day of week, gradually develop. (Mazmanian et al., 2006) Use of mobile email creates autonomy paradox for knowledge professionals. On the one hand, mobile email enhances autonomy by providing flexibility, peace of mind, and sense of control over their work duties and commitments, and on the other hand, it restricts autonomy by intensifying expectations of being reachable and accountable anytime and anyplace (Mazmanian et al., 2013).

Outside office-based white collar work settings, there is limited number of empirical studies about mobile email utilization. In an early study of mobile law enforcement action teams, it was found that mobile email provided only modest work and communication effectiveness gains. Even though the work supported by mobile email contained intensive information, communication, and coordination needs, the positive performance outcomes were not as strong as expected. Limitations in the technical characteristics and functionality of the mobile email solution and weaknesses in the organizational implementation process explained the low performance effects. (Straus et al., 2010).

In the literature, knowledge worker performance and productivity are approached and discussed somewhat interchangeably. Although productivity (understood as a ratio of outputs to inputs) is rather difficult to measure in knowledge work, multidimensional drivers for successful performance in individual knowledge work are explored in the literature. Thus, it is emphasized that the measurement of performance in knowledge work should not be only financial but to detect also intangible means and ends of knowledge work (Okkonen, 2004). One possible way to categorize performance drivers is to classify them into input, process, and output factors. Input factors consist of both personal features and resources of the individual such as satisfaction, motivation, and innovativeness, and the qualities of organizational environment of the work. Information technology and practices and processes of knowledge management form part of this enabling environment. Process factors include factors related to the details of work organization and sub-processes critical for knowledge work such as time management and personal knowledge management. Output factors relate to the quantity and quality of work products. (Drucker, 1999; Davenport et al., 2002; Laihonen et al., 2012) Particularly when considering mobile, distributed knowledge work, which is performed in teams, it proposed that conventional performance factors such as task, team structure, and work process should be extended with more contextual factors such as workplace, organizational policy, and ICT infrastructure (Bosch-Sijtsema et al., 2011). It can be hypothesized that utilization of mobile email reflects and shapes the ways how both the conventional and the contextual performance factors are practically managed in work.

As the literature review shows (summarized in Table 1), various personal work performance effects and outputs are already detected in the empirical research of mobile email use in knowledge work. However, the studies so far do not identify the potential variability in the micro-practices of the mobile email use between groups of knowledge workers having variable job duty profile and physical working environment. In addition, previous studies do not detect the potential variability in the nature, the amount, and the intensity of the mobile email use between knowledge workers having different job profiles. Finally, the connections between task-goal-specific usage practices and intensity of mobile email use, and work performance effects are not yet studied in detail. This study provides insights into these dimensions, aiming to enhance understanding the impact path of technology use to performance effects.

RESEARCH SETTING AND METHODS

The multi-method field study was conducted as a qualitative case study in a multinational ICT enterprise with a total of approximately 32 000

Table 1   Summary of the earlier research findings related to the performance (process and output) effects of mobile email adoption/use and the factors mediating the effect

Knowledge work context studied	Knowledge worker job profile	Performance effects detected	Influencing/moderating/intervening factors	Study
A sample of consulting, banking and finance, IT and software, telecommunications, insurance, transport, public sector, and other industry users	Mobile field staff, sales force, and consultants	Accelerating and enhancing work processes, improving information delivery, and easing coordination of work processes	User's attitude towards mobile email	Beurer-Zuellig and Meckel, 2008
Variety of industries	Workers not extremely nomadic or mobile	Variable experiences of work–life balance	Flexibilization of time use and place of work	Middleton, 2007
International telecommunications company	Managers, sales force, and experts	Personal productivity	Fluency, shorter reaction times, improved communication and information sharing, situation awareness, faster decision making, increased output, and utilization of idle time	Vuolle, 2010
Mobile law enforcement teams	Detective squad members	Work and communication effectiveness	Technical characteristics, functionality, and organizational implementation process	Straus et al., 2010
International financial institution	Managers, department heads, and line officers	Job strain, learning, and job control	Social support in managing availability expectations	Besseyre des Horts et al., 2012
IT company and higher education institutions	IT managers and senior administrators	Perceived work overload, reduced organizational commitment, and work–family conflict	Mobile email addiction	Turel et al., 2011
Venture capital fund, investment banking, and law services	investment bankers, private equity partners, and lawyers	Autonomy paradox: sense of work control, escalating work engagement and commitment, limited discretion, and authority	Control over interactions in the short term, flexibility, and peace of mind	Mazmanian et al., 2006; Mazmanian et al., 2013

IT, information technology.

employees. The role of the mobile email as enabler of business-related communication was studied in one division of the enterprise. The division was motivated to participate and to financially support the study exploring the productivity impacts of mobile office service. The target group was the Finnish units and persons working in sales and other customer interface positions as well as in product development and management, and using mobile enterprise email in their work. Users that were selected to be the study informants presented the entire user population of the enterprise reasonably well.

The empirical data collection was conducted in three phases with qualitative interviews, user diary, and survey. First, six mobile enterprise email users were interviewed about the nature of their work tasks, the communication activities in their everyday work, and the usage of mobile email and other mobile applications in their work tasks. All of the interviewees had used mobile email at least 1 year. The goal of the semi-structured theme interviews was to explore with whom knowledge workers communicated during working days (both office and out of office days), for what business-related purposes they communicated, and which communication tools and applications they used for these purposes. The interviewees were also asked to describe the grounds for the tool and application choice in different communication activities and use situations. In addition, interviewees were asked to freely characterize which performance impacts mobile email had in their work. Interviews lasted approximately 1,5 hours and were executed by the researcher. Interviews were recorded and transcribed. From the interview data, a comprehensive set of notions of typical everyday business communication activities, media choice reasons, and mobile email performance impacts was inductively detected.

In the studies of micro-practices of technology use, diary studies are most often used to capture the use of only a certain technology such as email (e.g. Mazmanian *et al.*, 2005; Mazmanian *et al.*, 2006) or in certain use contexts, such as "on the move" (e.g. Sohn *et al.*, 2008) or with user populations, which do reflect real business users and knowledge workers, but in a simulated business environment (e.g. Schrott and Glückler, 2004). In our study, a more comprehensive approach to diary study was chosen. We studied with the help of communication diaries both the distribution of the technology use of different tools and applications, and the distribution of the content and goals of the communicative activities in everyday business communication, and we considered the use situations both in office and out of office.

The set of business communication activities detected from the interview data served as a content schema for the communication diaries, which eight employees of the enterprise kept for five working days to keep track of all business-related communication activities they performed. The participants

(selected by convenience sampling) were recruited by sending an email invitation to participate study, and the participation was based on voluntariness. Participants worked in sales, senior manager, and expert work positions. The diary keeping tool was a simple excel form with activity categories and columns for marking the number of each activity per day. In the diaries, employees expressed the number of each business communication activity they performed per day with a certain tool (desktop computer or mobile phone) and with a certain application (voice call, text message, or email). The diary form is presented in Appendix 2. They were also asked to give the number of their out-of-office working days during the diary keeping period. The numerical data of the diaries was descriptively analyzed with statistical analysis tool SPSS (IBM, United States), applying frequency distributions, comparison of means, and correlation.

The limitation of the diary research method is that it is cognitively demanding and time consuming for the business user respondents, and it is hard to get business respondents to commit themselves to the recording of daily activities. On the other hand, log records of phone calls, text messages, and emails helped respondents to memorize the communication episodes of each day quite reliably.

In order to explore more profoundly and with a bigger sample of business users the patterns of utilization and performance impacts of mobile email, a survey questionnaire was executed. In the survey, different communication activities pursued with mobile email, their frequencies, places of use, and subjectively perceived performance impacts were operationalized into items. Items were generated on the basis of dimensions observed in the interview and diary data. The survey items are listed in Appendix 1. The questionnaire form was in electronic web-based format, and it was delivered to the whole mobile email user population ($n = 195$) of the Finnish unit of the enterprise. Respondents worked in sales and other customer interface positions as well as in product development and management and have about 1.5 years use history of mobile email. The utilization of mobile email was in the roll-out phase in the unit, and mobile email was used mainly by employees having work requiring at least some amount of traveling. Altogether, 115 responses were received, so that response rate was 59%. The survey data was explored descriptively by frequencies and analyzed by cross tabulations.

RESULTS

In this results section, first, on the basis of the analysis of interview data, a qualitative classification of communication activities is presented. Second, on the basis of diary and interview data, distribution of communication activities and communication tool choices for each activity is explored and contrasted

with the amount of traveling and work role of the user. Next, on the basis of survey data, frequency and intensity of utilization of mobile email in diverse communication activities are explored, and associated personal performance effects of use are identified. Finally, observed work role based variations in effects are preliminarily explained.

Content of everyday business communication activities

The interviews with business users of mobile email revealed the variety of communicative tasks knowledge workers exercise with different communication tools and applications. The identified communicative tasks can be qualitatively classified into four broad categories: communication with clients and other business partners outside the own enterprise, communication with internal colleagues in the own enterprise, communication related to the leadership and administrative management within the own enterprise, and communication related to the personal issues.

Everyday communication with clients and external business partners consisted mainly of proposing and accepting meeting times and requesting information from the client related, for example, to the preparation of a bid or related to a certain problem situation such as invoicing details clarifications or troubleshooting technical faults. Often occurring communication task was to answer whatever questions colleagues outside the own company had about the products and services that the enterprise provided.

Communication activities with the colleagues in the own enterprise were diverse. Interaction related to proposing or accepting meeting times, requesting information, and receiving and answering questions were typical contents of internal communication episodes. Also, receiving drafts of documents such as bids or contracts and reviewing and accepting final versions of business documents and transactions such as invoices were typical communication tasks.

Administrative managerial tasks such as accepting subordinates' requests, receiving announcements about a need to accept issues in enterprise information systems (such as enterprise resource planning), receiving and delivering messages directed to the team that one is leading, and sending requests and other news to the foremen were typical administrative and team management tasks knowledge workers reported to be included into their everyday communication.

Communication related to the personal issues related to the organizing of everyday private life such as managing personal, hobby, and family issues.

The aforementioned set of communication tasks elicited from the interview data was used as an empirically grounded content schema in the communication diaries respondents kept. The content schema to record the daily business communication activities was developed to make the diary keeping task quicker and easier for the respondents. There were altogether 24 tasks in the content schema. In the following sections, the research results related to the volume and distribution of everyday business communications tasks are presented.

Distribution of business communication activities

Knowledge workers communicate most often with their colleagues in the own enterprise and less often with clients and other external business partners. In Table 2, the communicative tasks and their average execution frequencies within five working days that were extracted from diary data are presented.

The table shows that internal communication task volume exceeds greatly the volume of external communication (shaded tasks are the tasks performed with the internal colleagues). The communication activities are also qualitatively diverse among internal colleagues. Interestingly, the amount of traveling and the total volume of communication are very related. The difference of total amount of communication activities during the week between those who traveled only 1 day during the week and those who traveled at least 2 days was statistically significant in the level 0.05 (Mann–Whitney U-test). The more the user had traveling days during the diary study period, the more she executed business communication tasks.

Role of mobile email in business communication activities

The diary data revealed that there were 20 different business communication tasks (out of the total of 24 tasks), where at least one respondent utilized mobile email. Mobile email is a multipurpose communication application when applied into business communication activities. The only tasks where mobile email was not applied at all during the diary keeping period were for asking latest news and progress details from the customer or from the subordinate, proposing meeting to a colleague in the own company and reading announcements about important intranet and other enterprise information system content updates/reports, which the user ordered to her email. Asking latest news and progress in the work projects were considered so informal and interactive tasks that mobile email was not used for that purpose. The obvious reason for not using mobile email for proposing meetings for internal colleagues was that internal meetings were timetabled via shared electronic calendars, which were accessible also from the mobile phone.

Characteristic for tasks where mobile email was used most intensively compared with the other communication channels and tools was that they were related to quite simple information delivery tasks between internal colleagues in the own

Table 2   Average number of communicative task executions during the period of five working days (here included only the tasks that were executed at least six times)

Communicative task	Number of task executions regardless of tool and applications	Number of task executions by mobile email
Answering to a question from a colleague/manager/subordinate working in our enterprise	24	12
Receiving questions from a colleague/manager/subordinate working in our enterprise	24	10
Receiving drafts of important documents	22	12
Requesting information from a colleague in our enterprise	17	4
Asking latest news and progress details from my subordinates	16	0
Receiving messages directed to my team	11	8
Receiving announcements about the need to approve a request from enterprise information system (ERP and so on)	10	3
Approving my subordinates' requests (answering OK and so on)	8	6
Approving drafts or requests I have received (e.g., bid, contract, proposals, and bills)	7	2
Proposing meeting to a client	6	2
Asking latest news and progress details from the customer	6	0
Requesting information from a client related to problem solving (e.g., related to a bill)	6	1

ERP, enterprise resource planning.

enterprise. Respectively, mobile email was not used as extensively in the communicative interactions with external colleagues. In the interviews especially, users in the sales positions described that limited use of mobile email with clients was related to the certain distance and respect towards the client. It was more comfortable and socially convenient to make a voice call or write a more formal and detailed email with a PC for the client than send only short email from the mobile phone.

Connections between the amount of traveling, work role, and mobile email use

A bit surprisingly, the total amount of communication tasks executed with mobile email did not differ statistically significantly between those who traveled a lot and those who traveled less. When examining the total volumes of the tasks executed via mobile email by individual users, the managerial position did not either create a statistically significant difference. It was also recognized that managers in this small diary sample (four managers) did not travel statistically significantly more than those who were not in managerial positions (four managers). However, because of the very small sample, these results are only very suggestive. The relationships between work role, traveling, and mobile email use will be elaborated further when survey results are analyzed in the next section.

Frequencies of application of mobile email for specific tasks

Although the diary data provided an initial picture of the variety and volume of mobile email use for different communication activities, survey data offered a more comprehensive and confirming evidence about the use and utilization profiles. More than half of the survey respondents used mobile email at least for a certain task daily, and one-third utilized mobile email to a certain task several times in a day.

Next, scrutiny was to explore into which communication activities and how widely mobile email is applied relatively often in the user population (Figure 1). Approximately every third user receives and answers questions from internal collaborators at least daily with mobile email. Every forth user requests information from internal colleagues and receives messages to her team at least daily, and approves meeting times proposed by internal colleagues.

Use frequency of mobile email for different work tasks differed considerably according the professional group. According to survey data (Figure 2), managers are most active and are frequent users of mobile email compared with users in other occupational roles. In particular, different kinds of communicative tasks requiring approval of the manager were more frequent in the mobile email use profiles of managers.

Similar to the diary data, survey data revealed that managers do not spend statistically significantly more time outside office than other professional groups.

Reasons for using mobile email versus other mobile communication options in business communication

There are many other communication application options than mobile email available for business communication purposes when knowledge worker is out of office—voice calls, voice mails, instant

Tasks where mobile email is used at least daily

% of all respondents (n=115)
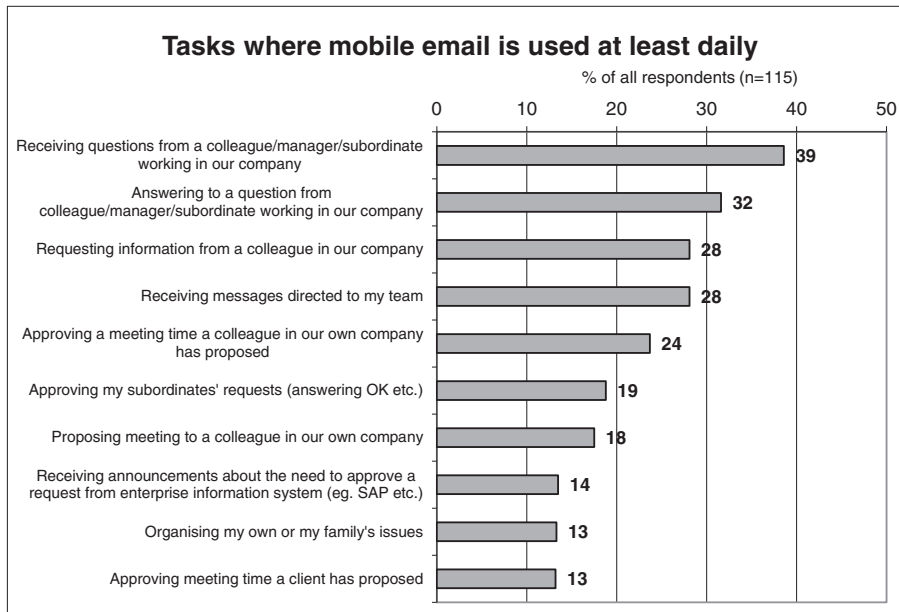
Figure 1   Daily utilization purposes for mobile email

Means of mobile email use fequencies in different tasks within professional groups

(scale: 0 = never, 1 = occasionally, 2 = weekly, 3 = couple of time per week, 4 = daily)
(*** = means of professional groups differ statistically significantly, t-test)

☐ Managers
☐ Sales/customer interface
☐ Experts/product management/production
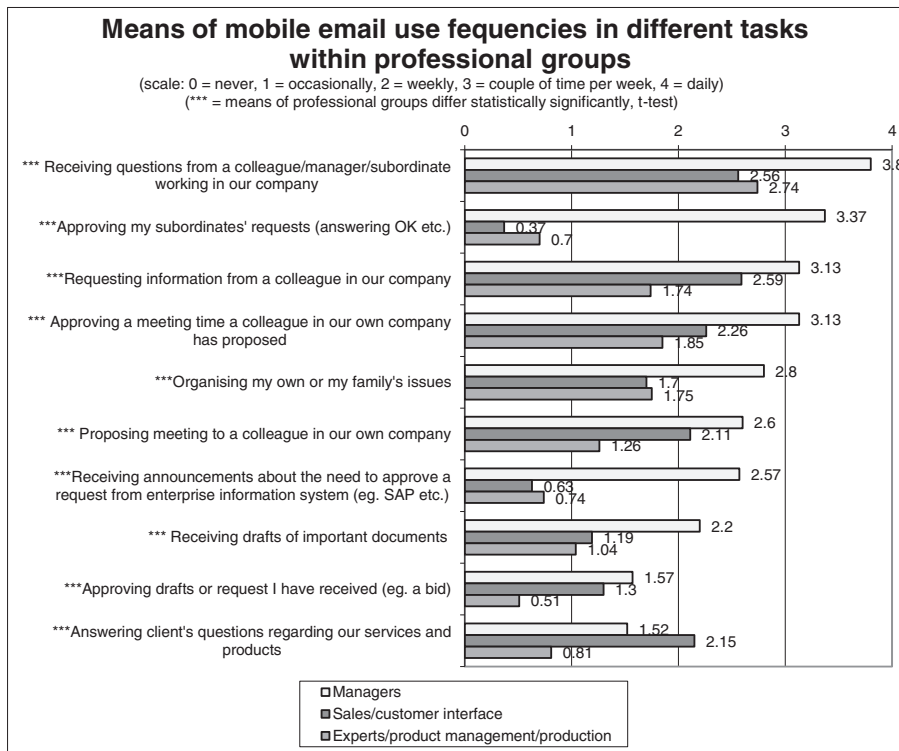
Figure 2   Differences of use frequencies between professional groups

messages, text messages, and email accessible with portable PC and wireless internet connections. Why is mobile email used quite extensively, when there are several other communication possibilities? In the interviews, the intensive mobile email users explained that their usage was rich because of the flexibility and multiple use modes of mobile email. Mobile email was useful when one wanted just to have a short and quick glance if anyone had sent an email message, who had sent a message, and what was the title of the message. These functional features afforded very polite and silent use of mobile email, for example, during meetings. If urgent, one was able to open the message, read it, and send a response without interrupting others in the meeting or raising your phone to your ear. In addition, mobile email (in push mail mode) was always accessible without any considerable delay, and it could be used immediately when the phone is on. With very little effort, mobile email manages to keep situation awareness and response times of, for example, traveling manager in a very high level.

Evaluation of usefulness of mobile email

Although mobile email is a multipurpose communication tool, for certain tasks of the knowledge worker, it is particularly useful. In addition to the frequency of application to a certain tasks, the survey respondents were explicitly asked to mention in which two tasks mobile email was most useful. As Figure 3 shows, mobile email is most useful in processing questions and information requests from internal colleagues. Mobile email is clearly a means for mobilizing information resources inside one's own work community.

There were slight differences observed between professional groups regarding experiences of usefulness of mobile email for different work tasks. Sales personnel and personnel operating in the customer interface mention more often than other professional groups the benefits of mobile email in communications with external clients. They mentioned more often than others as most useful tasks the requesting of information from the client in problem solving situations ($p = 0.003$) and the answering of the client's questions regarding services and products ($p = 0.004$). Managers mentioned more often than others the task of approving subordinate's requests ($p = 0.005$) among most useful tasks. They did not mention the possibility to receive messages addressed to their team at all among the most useful tasks where mobile email can be utilized. In this, managers differ considerably from other professional groups ($p = 0.004$).

In overall, mobile email enables different professional groups to find appropriate task-technology fit. The usefulness of mobile email is centered around tasks related to the internal communication and coordination of work.

Personal performance effects of mobile email utilization

Business users might differ from each other considering the variability of their mobile application use conventions. Some users can utilize mobile email into wide variety of tasks, whereas others might apply it into narrower communicative purposes and ends. Also, the frequency of applying the application for different purposes varies. To explore the performance effects of mobile email use, a measure describing the overall intensiveness of mobile email use was computed. The measure was computed by calculating the number of different tasks where mobile email was utilized at least daily or even several times in a day. Respondents who used mobile email daily for less than five different tasks were categorized as not intensive users, and those who used at least for five different tasks daily where categorized as intensive users.

Personal performance effects were studied with fifteen statements (Appendix 1), capturing both process and output aspects of mobile email use as a performance driver. Intensive users of mobile email expressed more often than non-intensive users that their work satisfaction had improved ($p = 0.011**$), their productivity had improved ($p = 0.007**$), and that they have been able to increase the amount of their work outputs ($p = 0.002**$). Intensive users expressed more often than non-intensive users that decision making related to their work had become quicker ($p = 0.021*$). Interestingly, intensive users of mobile email also expressed more often than non-intensive users that their amount of free time had increased ($p = 0.006**$), but also, the amount of work-related stress had increased ($p = 0.005**$). Intensive users reported more often than non-
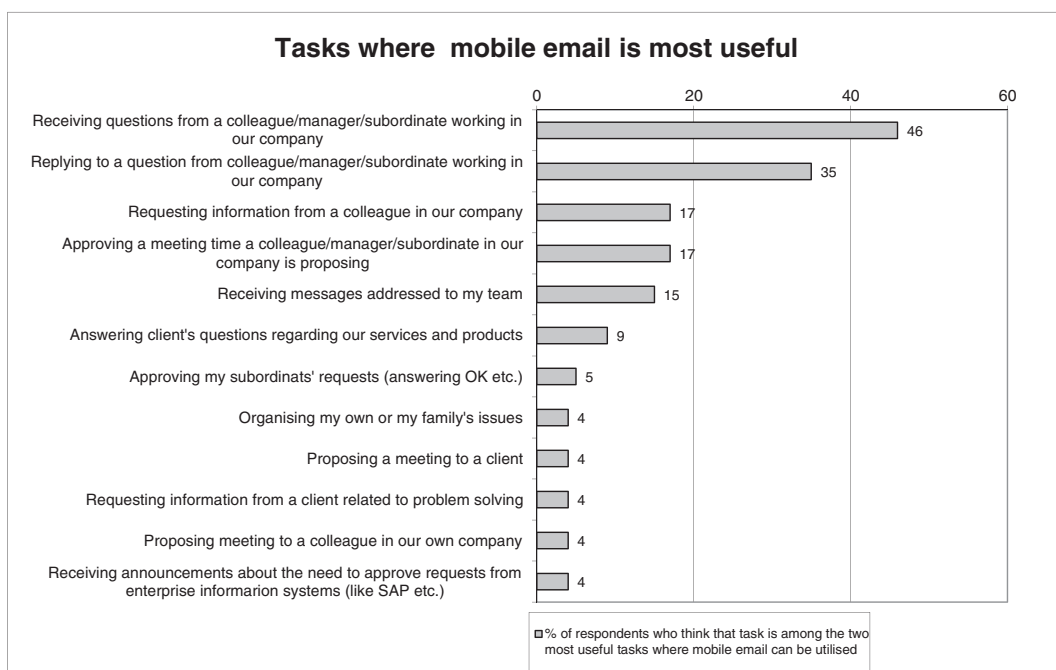

Figure 3   Usefulness of mobile email

intensive users that their work had become more fluent and efficient, they have been able to avoid excess traveling, planning and foresighting of their work tasks has become easier, and their time management had improved, but these differences between groups were only statistically indicative. The experiences of performance impacts of intensive users did not differ statistically significantly from non-intensive users in every aspect.

When analyzing the group of most intensive mobile email users, most of them are managers (56%), and one-third (30%) of them are professionals working in sales and client interface. As mentioned earlier, managers did not travel more often than other professionals in our sample ($p = 0.285$). The professional position does not explain alone the intensity of mobile email use. Among professionals traveling at least 16 hours per week, managers are most intensive mobile email users ($p = 0.011$). However, in overall, those traveling at least 16 hours per week were more often intensive users of mobile email than those traveling less ($p = 0.030$). In other words, both the amount of traveling and professional position are related to the intensive mobile email utilization in work.

DISCUSSION

This study enriched and sharpened the understanding of performance impacts of mobile email utilization in knowledge work. The results of this empirical case study revealed the way the mobile email is utilized in everyday knowledge work and how it impacts both business communication processes and subjective work performance of the knowledge worker. Knowledge workers and especially managers spend most of their working days communicating with their subordinates, colleagues, and business partners. They make critical actions and episodes happen in the business processes by communicating, practically by giving responses and approvals, accepting documents, asking bigger and smaller questions, and saying yes or no. At best, communication can be the booster of the business process, at worst the bottleneck and the source of fatal delays and errors.

When the performance impacts of new wireless communication technologies are evaluated in enterprise settings, it is important to recognize that mobile email use is centered into internal communication purposes. The marketing images and metaphors of being all the time reachable for the client contacts are a bit misleading, because as our study reveals, the most critical use of mobile email realizes within the interactions between internal colleagues. The biggest share of the knowledge workers' everyday business communication is related to the internal processes of the enterprise, and thus, the communication tool and the application innovations influence most directly the internal process performance measures.

Mobile email plays a major role as the performance driver in personal knowledge work when user wants to manage her role and dependencies in the internal collaboration networks efficiently. Mobile email provides flexible way to maintain awareness and organize personal task load, which very often materializes as management of different kinds of requests worker receives and responds via email. Although email can be used as a task inventory, a work schedule, and a coordination platform for group work, mobile email enables maintenance of work load and even executing decision and information delivery work in a flexible and accessible way. Knowledge worker, especially in managerial position, serves often as a resource hub for subordinates and colleagues. When a worker is a central actor in a dense network of interdependencies, mobile email is extensively utilized and also provides clear personal performance benefits.

The limitation on the study was that it was conducted in a single enterprise context. Another limitation was that performance effects were possible to be studied only via subjective evaluations of personal performance process and outputs.

A further research goal is to find candidates for the internal process performance measures and metrics, both subjective and objective, which are sensitive for communication effectiveness and quality. Relevant key figures and indexes could be those that are related to the response time to the different kinds of information requests and to the preparation and finalization lead times of critical business communication transactions. Also an extremely important business performance driver is the sense of situation awareness, which the mobile email effectively supports and which is quite easy to be evaluated subjectively. For the objective evaluation of situation awareness of critical business process episodes and triggers, one could create performance metrics that are based, for example, on the presence and availability of information of the knowledge workers.

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APPENDIX 1: SURVEY ITEMS

Where do you use mobile email?

How many hours have you worked outside office during the last five working days?

How often have you used mobile email during the last five days in the following places?

- home
- own work desk in office
- meeting rooms and other places outside own work desk in own work place
- in a different site of our own organization
- at clients' or business partners' place
- in public transportation
- abroad
- in hotel
- in stations, cafes, restaurants, and so on

Utilization of mobile email for different work tasks

Assess how often you use mobile email to perform the following tasks (scale: 1 = occasionally, 2 = couple of times in a week, 3 = weekly, 4 = daily, and 5 = several times in a day):

I propose a meeting for a client.

I propose a meeting for a business partner/supplier or equivalent.

I approve a meeting time proposed by a client.

I approve a meeting time proposed by a business partner/supplier.

I ask details from a client (e.g., related to the planning of a bid).

I ask details from a client related to problem solving (e.g., problems related to invoicing and an error).

I reply to questions from clients related to our services or products.

I propose a meeting to an internal colleague/manager/subordinate.

I approve a meeting time proposed by an internal colleague/manager/subordinate.

I request information from the members of our own organization.

I receive questions from an internal colleague/manager/subordinate.

I answer the questions from an internal colleague/manager/subordinate.

I receive drafts of important documents.

I approve documents or requests I receive (e.g., bid, contract, presentations, and bills).

I approve my subordinates' requests (by answering OK and so on).

I receive announcements about the need to approve a request from enterprise information systems (e.g., SAP).

I receive messages addressed to our team.

I manage my own or my family's issues.

Performance impacts

Assess the following statements according to a scale of 1–7 (scale: 1 = I totally disagree…7 = I totally agree, plus "I can't respond").

Because of utilizing the mobile email application:

My work satisfaction has been improved.

My work has become more fluent.

My work has become more efficient.

I am now able to perform tasks requiring quick reaction or response immediately.

I have been able to avoid excess travel (e.g., to the office).

I have been able to utilize idle time (e.g., when waiting) for working.

My productivity has been improved

Decision making related to my work has become quicker.

Planning and foresighting of my work tasks have become easier.

My time management has improved.

I have been able to maintain better situation overview.

Communication and knowledge sharing have improved.

Amount of work-related stress has increased.

Amount of free time has increased.

I have been able to increase the amount of my work outputs.

APPENDIX 2: DIARY FORM

Daily diary of mobile email , mobile calendar and SMS use

Instruction to use the daily diary: Keep your mobile phone voice call log, emails and calender entries you processed saved during the diary keeping dates.

How many times you executed today the following tasks with email and calendar applications in your mobile phone? Mark the number of each task completed followed by a symbol indicating the application feature you utilized: M=mobile email, C= mobile calendar, V=voice call, S=short message

	Day 1	Day 2	Day 3	Day 4	Day 5
Background information (overall amount of messages processed on desktop computer and on mobile handheld device)					
Number of emails sent during the day					
Number of emails received during the day					
Number of short messages sent during the day					
Number of short messages received during the day					
Number of reservations in your calendar for the day					
Tasks related to the sales or customer interface in overall / number of tasks executed by mobile handheld device					
I proposed a meeting for a client.					
I proposed a meeting for a business partner/supplier.					
I approved a meeting time proposed by a client.					

I approve a meeting time proposed by a business partner/supplier.					
I con tacted a client to ask how is it going.					
I asked details from a client (e.g. related to the planning of a bid).					
I asked details from a client related to a problem solving (e.g. problems related to invoicing, an error etc.)					
I asked details from a business partner/supplier.					
I receive questions related to our products or services from clients.					
I answered questions related to our products or services from clients.					
Tasks related to internal collaboration in your own organization executed by mobile handheld device					
I proposed a meeting to an internal colleague/manager/subordinate.					
I approved a meeting time proposed by an internal colleague/manager/subordinate.					
I requested information from the members of our own organization.					
I received questions from an internal colleague/manager/subordinate.					
I answered the questions from an internal colleague/manager/subordinate.					
I received drafts of important documents					
I approve documents or requests I receive (e.g. a bid, contract, presentations, bills).					
I read announcements about important updates from intranet or other operative information systems, which I have ordered to email.					
Tasks related to management and administration executed by mobile handheld device					
I approved my subordinates requests (by answering OK etc.)					

I received announcements about the need to approve a request from enterprise information systems (e.g. SAP etc.)					
I sent a request / an issue to be approved to my foreman.					
I asked how is it going from my subordinates.					
I sent progress details to my foreman.					
I sent messages to my team.					
I receive messages addressed to our team.					
Other tasks executed by mobile handheld device					
I manageg my own or my family's issues.					
Other tasks (describe)					

CrossMark

ORIGINAL ARTICLE

Enhancing information interaction as a means for situation awareness maintenance in mobile field work

Heljä Franssila[1]

Abstract Maintenance of situation awareness is of critical importance for the safe and productive execution of mobile field work. However, there is scarcity of research considering maintenance of situation awareness in mobile field work settings. The case study analyses information interaction as a means to maintain situation awareness. The empirical data for the study were collected from security service personnel participating in a pilot of guarding service based on NFC (near field communication) technology. NFC enables ubiquitous and location- and context-aware computing. Interviews, on-site observation and a questionnaire were conducted to define situation awareness requirements and to assess both current user experiences and future scenarios of NFC-based information support for security service work. Results of the study show that information interaction challenges were related to non-value-adding information activities when trying maintain situation awareness. Challenges were related to disturbances in information flow between clients, security service back office and field. It was found that maintaining situation awareness in circuit guarding was more challenging than in local guarding. Future NFC functionalities providing information support in particular for maintenance of short-term situation awareness were assessed as promising.

Keywords Internet of Things · Security service work · Mobile work · Information interaction · Situation awareness · Case study · Information waste

1 Introduction

Mobile work executed on the move in variable field settings poses challenges for the efficiency of communication and flow of information needed in the safe and productive execution of work. When the work consists of monitoring and inspecting high amount of different locations and premises by driving and walking, sometimes in a time pressure and alone, means for deliberate information searches are limited.

NFC (near field communication) is a technology based on RFID (ISO 2013). It enables wireless communication within short distances, like a couple of centimetres. It is one of the enabling technologies for building the Internet of Things (ITU 2016), networking physical objects wirelessly into Internet and enabling interaction by physical touching. Physical objects are typically equipped with a NFC tag which is touched with a mobile device containing a NFC reader, and a wireless connection enabling communication is launched between the tag and receiver.

There is difference to design, apply and appropriate mobile technologies into business-to-customer (B2C) settings than into business-to-business (B2B) and business-to-employee settings (B2E) and to professional use. Typically, in B2E settings the employees cannot choose whether they use or not use certain technologies in their work. The decisions about adopting certain technologies are

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made by employer, not the individual user. Further, there has been a tendency that several new mobile technologies are first accepted among consumers, and after that by business users (e.g. mobile email, tablet computers). End-user and customer acceptance of NFC-based business-to-business services have been under scrutiny in recent years. There are already plenty of reported successful pre-commercial prototype pilots completed in business-to-customer services (Tuikka and Isomursu 2009). There are less case studies reporting pilots with professional users, especially in business-to-employee and professional services. Pioneering professional service pilots have been executed, however, in janitorial services, cleaning and security and guarding services settings (Ailisto et al. 2007).

Originally developed in the context of complex, dynamic high-risk work environments like aviation, energy production and distribution, emergency response, and military operations (Lau et al. 2013), situation awareness as critical socio-cognitive enabler of safe and accurate operation has attracted lots of research interest, both theoretical and applied in scientific domains of human factors, ergonomics, human–computer interaction and cognitive engineering. Situation awareness can be characterised as an ongoing formation of mental picture of relevant information in dynamic task environments, enabling basis for decision-making and efficient action (Endsley 2013). Accuracy and scope of situation awareness can be enhanced by training but also securing that information needed in the situation awareness maintenance can be accessed by cognitively optimal means. The diversity of real-world working environments where the formation of situation awareness has been studied is considerable. Situation awareness formation has been studied, e.g. in off-shore drilling (Roberts et al. 2014), in joint military-civilian crisis management exercise context (Rousseau et al. 2010), in primary health care (Brady and Goldenhar 2014; Yule et al. 2008), in aircraft maintenance (Endsley and Robertson 2000) and in facility management (Gheisari and Irizarry 2011). However, there is scarcity of empirical studies analysing situation awareness maintenance in mobile field work executed mainly alone, and by walking in changing client premise environments, having only mobile hand-held device as information interface. The mobile, changing real-world work task environment differs considerably, e.g. from control and operation rooms and cockpits as designed informational environments.

This paper reports findings from a case study of a field pilot of pre-commercial NFC service prototype designed for supporting security and guarding service field work. The NFC service piloted was a simple service utilised in guarding patrol route. The guards touched during their patrol route with NFC phone the check tags located in the premises they were guarding. The touch served as a confirmation that the location had been checked in the patrol route. The confirmation information was sent into the background system, where the monitoring of patrol route completion was possible for the guarding shift foremen, service officers and security service clients. The focus of the case study reported here is in analysing information interaction of mobile security service personnel as a means to maintain situation awareness. In addition, the case study explores the future potential of NFC functionalities as part of means of maintaining situation awareness in mobile security service work, executed in multiple, changing geographical locations.

In the next chapter, earlier studies on supporting mobile work with mobile information and communication technologies are discussed. After that, the concept of situation awareness is presented and discussed as a central information interaction driver in security service field work. In order to evaluate the quality and effectiveness of the information interaction, information waste as an analytical concept from Lean Information Management is presented. Then, research questions, research design of the study and research results are presented, followed by the discussion of the results.

2 Earlier research on supporting field service work with mobile technologies

Earlier research on the support of field work with mobile technologies and services suggests that in general mobile technologies can create both tangible and intangible benefits for the end-users, mobile field workers. In building, maintenance and construction industry mobile services can raise productivity, safety and convenience of field work (Leskinen 2006). Further, mobile services can enhance coordination, communication, transparency of activities, quality and speed of reporting. Mobile services may simplify work processes and enable better access to information resources (Lähteenmäki et al. 2006).

The potential of near field communication and other information technologies enabling ubiquitous and location- and context-aware computing should be assessed based on the information access requirements mobile workers face in their everyday work. The mobile nature of work and the fact of not having local access to conventional operational information resources like databases containing up-to-date information about clients, client sites, service requests, personnel resources and colleagues on work shift create barriers to the information interaction of mobile workers. Not all task-relevant information is readily available and immediately accessible for the mobile worker when on the field. There is unpredictability in the nature of the tasks the mobile worker is going to execute in a remote location. For

example, in repair service work and in emergency services, the information requirements of the task may unfold as the worker arrives on site. Sometimes travelling (e.g. to meet a client) takes considerable amount of time. Travelling time is often used for tasks which can be undertaken out of office or at the stationary work place. Studies of mobile workers' strategies in diverse occupational fields have shown that when planning trips workers strategically prepare for being able to work around the problems related to unpredictable information needs on site unfolding when on the move. Mobile workers collected opportunistic bunches of documents and tools (both non-digital and digital) to serve as backup in case unpredictable needs for information arise during the trip. Mobile workers prepared both for unanticipated information needs and limited or haphazard access to technology, for example, by taking paper documents with them in case of a lack of secure Internet access on the field site (Perry et al. 2001).

Even small-scale mobility when working in different locations of a single facility creates information interaction challenges. For example, in hospitals nurses make regular rounds visiting patients in their individual rooms, but the information systems containing patients' records are located in back-office rooms. Nurses have either to carry patients' records and patient journals in paper format with them on their rounds or try to rely on their memory. When doing treatment procedures during the round, they need to write the earlier and new measurement records down by hand and register them later into the electronic system, because they cannot carry equipment like laptops with them for doing the electronic records updates immediately. Writing notes by hand and later registering them into electronic patient record systems create extra redundant work and increase risks for errors (Skov and Høegh 2006).

In mobile work involving collaborative, distributed and coordinated work tasks, for example, small teams or work couples in different locations, the work process and speed of task completion may change with the introduction of mobile tools. In news production, for instance, the planning and negotiation of tasks and task allocation are traditionally carried out in co-located news office conferences. Editors working in the news room and reporters going to the field execute assignments and make decisions together. Mobile applications supporting mobile and remote reporting of assignments and news production make it possible to reorganise the news planning and production processes. The information needs of neither the editors nor the reporters change when the way that the various phases of news production are completed change and when reporters work more in the field. The need for diverse types of situation awareness and activity awareness information increases when news reporting assignments and production processes are executed in distance and without collocated

interaction like in the office news conference (Väätäjä and Egglestone 2012).

Providing more context sensitive or microlocation-based information to support mobile workers on the move has been tested with different technologies, for example, in health services. The usability and user acceptance challenges have been related to the burden that bringing new gadgets into mobile work may create and to the overall unease workers may experience with interfaces where the content updates are based on location (Kjeldskov and Skov 2007; Ropponen et al. 2013). An alternative for user interfaces adapting automatically to the location is the integration of the interface into the objects of the working environment itself. This enables more control for the end-user in the reception of the context-based information. This kind of Internet of Things approach can be implemented with NFC technology. So far the reported pilots and trials of NFC technologies in business-to-employee sector have been in security and guarding, construction and facility management, health care and home nursing, and among traffic wardens. Typically, applications of NFC technology in security and guarding services field work aim at improving security, creating more transparency to the work process, enabling tracking, and making work attendance monitoring and reporting faster, easier and more client friendly. However, one of the critical (un)success factors for the adoption of NFC technology in business-to-business services is the lack of awareness of NFC-enabled services (Wallin 2009). Several NFC service trials and pilots have been conducted in different kinds of mobile field work settings but there is a lack of detailed exploration and analysis of mobile workers' experiences of working with NFC technologies.

3 Information interaction in the maintenance of situation awareness

When investigating dynamic, work-related information needs in a various jobs, the concept of situation awareness has been often applied. The concept of situation awareness (SA) helps in understanding and analysing the content and function of information in dynamic unfolding work situations. There are multiple definitions given to the concept in human factors and human–computer interaction literature, but according the one of the most cited, situation awareness is defined in a following way: "Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley and Jones 2011). Situation awareness refers to updated appropriate understanding of what is going on at work.

There is an ongoing conceptual debate in the human factors field about whether situation awareness should be understood as a property of an individual, a group, a system or human–system–environment complex, and whether it is more an *interactive process* or *a cognitive state or product* (e.g. Salmon et al. 2015; Lundberg 2015; Stanton et al. 2010). According to the definition presented by Endsley, situation awareness as *a cognitive state* of an actor refers to situation information an actor holds and that is important in carrying out a dynamic job or pursuing a specific goal. The information that is relevant for successful performance and decision-making in the work activity is to a certain extent always job and domain specific. Key elements of information that generally support situation awareness are, regardless of the domain, defined in the three-level situation awareness model (Endsley and Jones 2011). First, situation awareness is supported by perceiving the status, attributes and dynamics of the relevant elements of the work environment. This information can be obtained by various means. Second, relevant information must be correctly understood (comprehended) and interpreted in relation to the goals of the task at hand. The observed and collected pieces of information must be put together to form a meaningful overall picture of the situation with the task goal scenarios in mind. Third, situation awareness is maintained with the help of the ability to form projections of the future status of the work environment. Projections enable the proactive and informed anticipation of future scenarios and events in the work (Endsley and Jones 2011). Another, the socio-technical systems approach to situation awareness, in turn, views situation awareness as an *interaction process* between humans and other system components. In this view, situation awareness is not a property of either a human actor or a technological system providing situation information, but is realised in the interaction between the human actor, environment and technological system (Stanton et al. 2010).

When considering how to support information interaction to enable the efficient creation and maintenance of situation awareness, the first and most straightforward requirement is to detect *what* are the relevant elements of the environment to be perceived, and *in what way* the information related to the status, attributes and dynamics of those elements can be obtained in the realistic work situations. Supporting the unified interpretation of the information and adequate projections of future scenarios of the work environment are goals that are less straightforward to assess. The analysis of task execution paths requiring information can show the "what" and "how" of conditions for situation awareness maintenance. Further, for understanding how to enhance maintenance of situation awareness with information technologies, criteria for evaluating quality and effectiveness of information interaction are

needed. Despite the acknowledged importance of the concept of situation awareness, agreed-upon evaluation criteria for assessing information interaction in real-world work settings are sparse. When evaluating situation awareness in real-world settings, the main focus has been in evaluating situation awareness mainly as psychological *state* of the actor, and not the quality of the means and procedures applied to achieve that state (see Gawron 2008). In other words, studies of situation awareness as an interaction process lack adequate evaluation criteria. Also the system and interface design guidelines for supporting better situation awareness have mainly focused on specifying the necessary information contents and evaluating their availability via the systems (e.g. Endsley 2013). Specific measures to assess information interaction efficiency and options have not been discussed. For understanding how different information representation options and technological tools influence situation awareness as a product state, measures focusing on cognitive states do not inform systems and technologies design or choices very much.

Understanding and revealing information use, information requirements and appropriate ways to support information interaction in work with information systems, products and technologies can be challenging. To help in the analysis of the information use and information requirements related to the critical elements and their status in the environment the idea of information journey may prove helpful. Information journey is a conceptual framework to aid in the analysis of information interaction related to a certain activity. Basically, information behaviour in a certain activity contains four phases, which form a cycle: recognising information needs, acquiring information, interpreting and validating information, and finally using the interpretation (Blandford and Attfield 2010). It is hypothesised that following and analysing real-world and experimental information journeys of field workers can reveal the information needs and other requirements related to the maintenance of situation awareness.

As a candidate for evaluation approach to situation awareness as *a process*, the concept of information waste from Lean Information Management could be useful. In Lean Information Management, a central means to streamline processes and activities are to eliminate waste in all stages of production. Any critical resources of the enterprise can be wasted: physical resources, information, time and intellectual capital (Hicks 2007). In Lean Information Management special emphasis is on observing barriers that hinder smooth flow of information within and between work activities and in limiting their harmful effects on the work process. In communication and information-intensive work processes requiring rapid situation assessments and decision-making difficulties to find and integrate information from various sources creates waste in

the form on time and cognitive costs (cp. Franssila et al. 2015; Kirsh 2000).

Hicks (2007) identified four types of information waste based on the empirical observations of extra, non-value-adding activities which cause disturbances and obstacles in the information flow. The information waste categories concretise extra work activities that need to be executed to fix disturbances in the information flow. Ideal information flow represents situation, where right information is in the right time in the right place in a right format available for efficient task goal fulfilment by the actor. Disturbances and extra activities are analysed by comparing actual information flow to ideal information flow. The information waste categories identified are: failure demand, flow demand, flow excess and flawed flow. *Failure demand* refers to extra activities required to overcome lack of information or information system functionality. *Flow demand* refers to a situation where additional resources are spent on identifying, accessing and locating necessary information that should ideally be available without extra efforts. *Flow excess* relates to activities which are needed to distil relevant information from excessive information. *Flawed flow* refers to the need to verify, correct and repair inappropriate information (Hicks 2007). In earlier research conducted in real-world work settings empirical support for the analytical power of all four information waste categories has been found (Hölttä et al. 2010; Franssila 2012; Morvik 2013). Information waste categories provide useful and unique way to capture information interaction challenges and barriers experienced during information journeys in work execution. Categories are applied in this study to analyse and evaluate the process of situation awareness maintenance.

4 Research questions

The primary goal of the study was to understand information interaction in the maintenance of situation awareness in security service work. Information interaction as means to maintain situation awareness in security service work was evaluated from the viewpoint of information waste identification and elimination. Information interaction related to work activities was analysed by considering information journeys of security service personnel during their work shifts. Information journey provides a framework to follow information interactions as they unfold as part of the task goal fulfilment. The second goal of the study was to explore the role of mobile information technologies in information interaction the security service work. In particular, the utility and future potential of NFC technologies to enhance the effectiveness of information interaction and the maintenance of situation awareness in security service field work was

analysed. Scenarios of NFC technology were evaluated from the viewpoint of their potential to eliminate information waste. The research questions are:

1. What kind of information interactions the information journeys of conventional working days in the security service work contain?
2. What kinds of information requirements, resources, barriers and challenges exist in the current information interaction related to maintenance of situation awareness?
3. What kind of information waste categories do the barriers and challenges present?
4. What kind of future features and functionalities of NFC technology could support the maintenance of situation awareness and elimination of information waste?

5 Research settings and methods

5.1 Presentation of work and work context

The work of guards in security service consists of guarding clients' premises on a 24/7 basis, reporting about exceptional events observed within the premises when needed and responding to alarms and emergencies. Guards move mainly by walking, and they work alone when they are executing their patrol route. There may be only one or a couple of premises (like big office buildings) in the proximity of the guarding back office to be guarded. This kind of guarding is called local guarding. There can also be several single client premises distributed around a wider geographical area to be guarded, and this kind of guarding mode is called circuit guarding. In both guarding modes, guards are executing patrolling routes in the premises. Guards working in circuit guarding typically move by car from one premise to another and do their rounds in each premise by foot. Local guarding is executed only by foot.

5.2 Presentation of the NFC pilot

The study was conducted in parallel with a commercial, real-world pilot of an NFC service. The study took place in three units of a security and guarding service company located in a metropolitan area and operating in large office buildings, shopping malls and warehouses. The NFC service pilot had been going on for 1 year when this study was conducted. It was possible to collect insights about the detailed information interaction situations and requirements and activate users' ideas and insights about potential future uses of the technology. The participants of the study represented both those who already had used the NFC

service and those who had not used it in their work. The participants were guards and their foremen from two units operating in local guarding and from one unit operating in circuit guarding. The NFC service which was piloted consisted of check tags, mobile phones with an NFC reader and the background system for representing and managing tag reading information. Phones utilised Series 40 software platform. Check tags were placed into the premises to be guarded, and the guards needed only to touch the tags with the phone when conducting their patrol rounds. After reading a single tag, the phone application showed an acknowledgement message and was ready to receive the next tag reading. The back office of the security service company and the client was able to see and manage the tag readings information in a browser-based application.

The NFC service was the only application the guards used for collecting check tag readings during the piloting period in the units that were participating in the pilot. The motivation behind the pilot was to test the suitability and effects of NFC technology compared to the conventional bar code reader tools which were widely used in the company and industry as guarding task completion monitoring technology.

5.3 Data collection

In earlier studies—especially in environments where it is impossible for the researcher for safety and confidentiality reasons to participate in authentic, real-world work situations (like military environments, emergency services)—SA requirements and resources of a certain work activity have been studied by interviewing operators and other subject matter experts of the work domain (Connors et al. 2007; Endsley 1993; Endsley and Robertson 2000; Roberts et al. 2014; Stanton et al. 2006). To control the impacts of the level of expertise and idiosyncratic personal working style on the assessments of SA requirements and resources, focus groups (Brady and Goldenhar 2014) and surveys (Endsley 1993) have been applied as data collection methods to involve larger sample of participants.

In this study, empirical data were collected by interviews, on-site observation and a questionnaire to define situation awareness (SA) requirements and situation awareness (SA) resources available in security service work environment. Goal-directed task analysis (GDTA) (see Endsley 2013) and critical incident technique (see Crandall et al. 2006) were applied as approaches to obtain SA requirements and resources. GTDA focuses on identifying with work domain practitioners the main goals, collaborators, decisions and associated situation awareness and information requirements in the work activity under scrutiny. With the help on critical incident descriptions, the practical activities, interactions and uses of a variety of

information resources for situation awareness maintenance were identified. In addition, assessment of barriers and challenges related to the maintenance of situation awareness were analysed from the critical incident accounts.

The empirical data of this study were collected in two phases. First, exploratory semi-structured thematic subject matter expert interviews with security service personnel ($n = 7$) were conducted. The informants represented security service personnel having different task and expertise profiles. The informants consisted of one security service manager (extensive background in field service duties), two local guarding foremen serving supervising duties (extensive background in field service duties), two guards from local guarding (one with extensive background and one with shorter experience), one circuit guarding foremen serving supervising duties (extensive background in field service duties) and one circuit guard (extensive background in field service duties). Interview questions were about the current work, its goals and practices, especially information management and communication practices, needs for their development and NFC service experiences. Interviews were conducted in back-office control rooms of the security service. During visits at the sites, it was possible to make observations about the utilisation of the client information management system, field events recording and report forms, alarm system manuals and mobile hand-held tools used during patrolling in premises. In addition, observations were made about documentation in the folders that were located in the patrolling cars. Because of safety and confidentiality reasons, it was impossible to participate in the patrolling rounds.

5.4 Data analysis

From the interview data, first the information use requirements related to the guarding work goal execution were teased out. Next, statements considering critical success factors, barriers and challenges affecting the quality of work performance, information interaction and the maintenance of situation awareness during work were identified. In the analysis, information interaction barriers and challenges were interpreted with the help of the information waste categories. Each barrier and challenge was classified into a certain information waste category.

Based on the factual content analysis of interviewees' statements, a questionnaire describing and operationalising potential occurrences of information waste was designed by the researcher. The 8 statements in the questionnaire were expressed in positive terms to avoid bias towards too critical assessments of current information interaction experiences. In addition, 7 short scenarios related to the potential future uses of NFC functionalities were developed and included in the questionnaire. The statements

operationalised the potential of new NFC functionalities in reducing the specific information waste bottlenecks revealed by the interview data. In addition, background questions considering work mode (local or circuit guarding), experiences of using the NFC service and the respondents' work experience were included in the questionnaire. The web-based questionnaire was sent to 50 security service staff members via email, and altogether 35 responses were received. Responses were received both from users ($n = 19$) and from non-users ($n = 16$) of current NFC service. Personnel from local and circuit guarding are equally well represented. The questionnaire data were analysed quantitatively with SPSS, and frequency distributions and crosstabs were applied as analysis methods. In addition, a sum variable measuring overall usefulness assessment of future NFC functionalities was computed from individual usefulness statement variables. In the descriptive analysis the variety and relative frequencies of the experiences of different information interaction challenges were counted. In the crosstabs analysis distributions of the results from local and circuit guard samples were compared. Among both local and circuit guarding samples differences between those who participated into NFC pilot and those who not were compared.

6 Results

6.1 Information interaction within the information journeys of security service work

The guards and the foremen enter a shift to check carefully the information on latest events on the premises to be guarded. This is done by reading the shift report that the shift foreman has entered into the email and via reading handwritten notes at the log book of the back office.

Guarding in the *local guarding* units contains surveillance work in the control room of the premises, face-to-face client service in the form of guidance and monitoring of the premises visitors, and active patrolling around the premises. When disturbances and deviations emerge in the security situation, the guard writes an exception report which describes the situation and activities executed to solve it. In the control room, surveillance and alarming information systems support the work. There are also instances when information from several security information systems needs to be integrated into exception reports by hand.

Guarding in *circuit guarding* units consists mainly of patrolling rounds. Because the circuits are longer than in local guarding, guards spend most of their working time on the move, inspecting distributed premises in their circuit. The guard always has a mobile phone with her when visiting the patrolled premises. During the patrolling round, the guard checks each location in the premises by reading either a check bar code with a bar code reader or a check tag by a mobile phone with a NFC reader. Another part of the work is emergency visits to the premises, which typically start from alarms received from the security information systems.

Shift foremen work mainly in the back office, coordinating guarding activities, being in contact with clients and helping guards in the field in many ways. Shift foremen collect and send the exception reports delivered by the guards from the field to the service officers and the clients. They also write a shift report at the end of each shift.

6.2 Situation awareness requirements and barriers in the information interaction of security service work

Situation awareness information requirements in *local guarding* are related to needs to detect characteristics of the normal and abnormal conditions and events in the premise environment. When patrolling in the building, a guard needs to remember to check all the check tags, because the tag readings form basis of the work completion report and reporting to the client. Situation awareness requirements, resources, current information interaction means to access or deliver SA information and barriers experienced in the local guarding are described in Table 1.

In local guarding most often the source of situation awareness information is the premise environment and security protection systems. There are sometimes interruptions in the information flow from the client to security service. In particular, special or occasional events causing changes in the clients' premises influence the overall security situation and locking and alarm systems. A part of the reporting of guarding work is still managed by writing by hand on paper, such as exception reports delivered directly from the field. Paper-based exception report forms and email-based shift reporting are still in use.

Situation awareness information requirements in *circuit guarding* are related to the needs assess the normal and abnormal conditions in the distributed premises. Important element of situation awareness information is notifications of exceptions and events taking place with various time-scales in the premises. Situation awareness requirements, resources, current means to access or deliver SA information and barriers experienced in *the circuit guarding* are described in Table 2. The guard is demanded to remember and know the premises' details, like several kinds of lock, entrance and alarm systems in patrolling the clients' premises. As in local guarding, disturbances in the information flow from the client to the security service considering occasional events and changes in the clients' premises influence possibilities to maintain situation awareness

Table 1 Situation awareness requirements, resources, current information interaction means to access or deliver SA information and barriers experienced in the local guarding

Role	Goal	Sub-goals	SA Information requirements related to the subgoal	SA Information source/originator related to the subgoal	Current information interaction means to access/deliver SA information related to the subgoal	Information interaction (II) barriers and challenges experienced in the access/delivery of SA information related to the subgoal	Information waste category associated to the II barriers and challenges
Guard in local guarding	Ensuring security and eliminating security risks for premises and people	Monitoring and managing security situation in the clients' premises (both from control room and by patrolling)	Characteristics of a normal situation	Premise environment	Observation		
			Characteristics of an abnormal situation	Security protection systems	Security protection systems		
			Nature of planned events, exceptions and changes, and their duration		Spoken notifications, email	Absence of notification from client about planned events, exceptions and changes	Failure demand
		Monitoring people flows in the clients' premises	Characteristics of a normal situation	Premise environment	Observation		
			Characteristics of an abnormal situation	Security protection systems	Security protection systems		
		Closing and opening security protection systems at the clients' premises	Premise-specific details of security protection system location and operation	Security protection system manuals	Memory, security protection system manuals		
		Updating client information records	Abnormal events in the premise environment to be recorded	Premise environment	Memory, paper based reporting		

Table 2 Situation awareness requirements, resources, current information interaction means to access or deliver SA information and barriers experienced in the circuit guarding

Role	Goal	Sub-goals	SA Information requirements related to the subgoal	SA Information source/originator related to the subgoal	Current information interaction means to access/deliver SA information related to the subgoal	Information interaction (II) barriers and challenges experienced in the access/delivery of SA information related to the subgoal	Information waste category associated to the II barriers and challenges
Guard in circuit guarding	Ensuring security and eliminating security risks for premises and people in distributed client locations	Inspecting the security situation in the clients' premises by patrolling	Characteristics of a normal situation	Premise environment	Observation		
			Characteristics of an abnormal situation	Premise environment	Observation		
			Route details of inspection circuit	Circuit description document	Memory	No memory aids on the circuit to aid remembering route details and special commitments	Flow demand
			Special commitments regarding circuit activities	Circuit description document	Memory		
			Nature of planned events, exceptions and changes, and their duration	Client	Spoken notifications, email reading before circuit starts	Absence of notification from client about planned events, exceptions and changes	Failure demand
			Exact location of planned events, exceptions and changes	Client	Spoken notifications, email reading before circuit starts	Disturbances and omissions in information flow considering planned events, exceptions and changes from security service back-office to guards in the circuit	Flow excess
			Impacts of past events, exceptions and changes	Client	Memory, spoken notifications, email reading before circuit starts		
		Closing and opening security protection systems at clients' premises (like ports, entrances and alarm systems)	Premise-specific details of security protection system location and operation	Circuit description document / Security protection system manuals	Memory	No memory aids on the circuit to aid remembering route details and special commitments	Flow demand

Table 2 continued

Role	Goal	Sub-goals	SA Information requirements related to the subgoal	SA Information source/ originator related to the subgoal	Current information interaction means to access/deliver SA information related to the subgoal	Information interaction (II) barriers and challenges experienced in the access/delivery of SA information related to the subgoal	Information waste category associated to the II barriers and challenges
		Managing exception, emergency and alarm situations at clients' premises	Characteristics of a normal situation.	Premise environment	Observation		
			Characteristics of an abnormal situation	Premise environment	Observation		
			Premise-specific details of security protection system location and operation	Security protection system notifications	Notifications into mobile phone	No memory aids on the circuit to aid in remembering premise-specific security protection systems location and operation	Flow demand
				Circuit description document			
				Security protection system manuals	Memory		
		Updating client information records	Detection of abnormal events in the premise environment	Premise environment.	Memory, paper based report recording	No memory aids on the circuit to aid remembering abnormal event details to be updated	Failure demand

Table 3 Situation awareness requirements, resources, current information interaction means to access or deliver SA information and barriers experienced in the shift foreman position

Role	Goal	Sub-goals	SA Information requirements related to the subgoal	SA Information source/originator related to the subgoal	Current information interaction means to access/deliver SA information related to the subgoal	Information interaction (II) barriers and challenges experienced in the access/delivery of SA information related to the subgoal	Information waste category associated to the II barriers and challenges
Shift foreman	Coordination of guards' work on guarding area	Monitoring guards' work progress	Number and location of guards on the circuits.	Premise environment	Mobile phone calls	Difficulties to maintain awareness about the progress of circuit execution and completion, and the location of guards when an emergency visit has interrupted the circuit	Failure demand
			Progress of guarding work	Guards' notifications from the field			
				Security protection systems	Security protection systems		
		Informing guards about situation changes on premises during the shift	Characteristics of an abnormal situation	Premise environment	Mobile phone calls		
			Nature of planned events, exceptions and changes, their duration and exact location	Client	Email, event reports	Absence of notification from client about planned events, exceptions and changes	Failure demand
			Impacts of past events, exceptions and changes	Client information system	Client information records		

Table 4 Assessment of situation awareness maintenance issues

	Statement variables	% of circuit guarding personnel who agree ($n = 18$)	% of local guarding personnel who agree ($n = 15$)	% of all respondents who agree ($n = 34$)
Short term situation awareness (SA related to the information changing often)	Clients announce exceptions and changes considering the situation in their premises mostly in time for the security service	16	53	31
	Notifications considering exceptions and changes in client's premises from clients reaches guards properly when they are executing their patrol route in the field	32	33	31
	Information considering the duration and exact location of the exceptional situation reaches guards appropriately when they are executing their patrol route in the field	26	27	26
	It is easy to create comprehensive overview of the events and issues handled in the previous work shift when I come to work	32	67	46
Longer term situation awareness (SA related to the information not changing very often)	It is easy to create a comprehensive overview of the events and issues handled in the previous days/weeks, when I come to work from vacation.	26	33	29
	It's easy and quick to find the exception report considering certain event from the paper report archives when e.g. client is asking detailed information about the event	32	67	46
	It is easy to remember the patrol route and issues to be checked (guarding specifications and instructions) related to the each premise by heart	78	67	71
	It's easy to remember how to use different devices and applications (alarming systems, locks, gates etc.) in each premise	84	67	77

when on the field. Reporting of abnormal events on the field is still paper based. In overall, there are more disturbances in information flow from clients to security service back office and guards in the field than in local guarding. Also the number of premise-specific details to be remembered is higher in circuit guarding.

Situation awareness information requirements in shift foreman duties are related to being aware of exceptions and events in client premises. Another important element of information is details about location and routes of the guards in the field. Situation awareness requirements, resources, current information interaction means to access or deliver SA information and barriers experienced in the *shift foreman* position are described in Table 3.

Considering *all staff* in the security service, during the shift change the guards and shift foremen ending her work shift and the guard or foreman starting her work shift have varying possibilities for exchanging information about observations made during the shift which is ending. Guards can read email only in the back office. Sometimes there are information flow interruptions between the ending and starting work shifts. For example, when a guard comes

from a longer vacation period back to the work, it might be challenging to achieve situation awareness about relevant events within the premises during the last days or weeks.

The results (see Tables 1, 2, 3) of exploratory interview data show that security service personnel experience information interaction barriers and challenges related to three information waste categories. First, they need to pay extra attention to detect, find and integrate relevant information from various operative sources (flow excess). Second, they need to remember relevant information not directly accessible in the field (flow demand). Third, there are sometimes disturbances in the flow of task critical information from clients to security service (failure demand). Instances of needs to correct or repair incorrect information (flawed flow) were not found.

The analysis of interview data and the information requirements of situation awareness maintenance revealed that the required information was divided into two subsets. The first subset of information was changing very often, and another subset was information which was relatively unchanging but accessed by the actors only sporadically, not very often. To describe these differences in the subsets of SA

Table 5 Assessments of the potential usefulness of new NFC-enabled functionalities in the security and guarding service field work

	% of local guarding personnel ($n = 15$) finding the feature useful	% of circuit guarding personnel ($n = 19$) finding the feature useful	% of all respondents ($n = 35$) finding the feature useful
Possibility to track with the help of check tag reading log the exact location of a guard within a building if she cannot be contacted by phone (e.g. in emergency or other high-risk situation)	93	79	86
Possibility to fill in and send a simple exception report by phone directly from the premises (so that the identification information of the exact location and client will be automatically filled into the report form by touching the check tag)	73	90	83
Possibility to attach photos into the exception report filled and sent with the phone	67	68	69
When patrol route is completed, the phone application acknowledges if the all check tags were read successfully	80	63	71
Announcements about temporary exceptions and special arrangements in the client's premises (which the shift foreman has entered into the background system)	73	89	82
Guarding specifications and instructions related to a certain premise	57	72	67
Exception details which a security system (like alarm system) has automatically channelled into the background system	67	50	59

information, the concepts of short-term situation awareness and long-term situation awareness were introduced.

6.3 Experiences of information interaction means to maintain situation awareness

In the web questionnaire, respondents' experiences related to the current status and development needs of information interaction in security service work were explored. The key issues were grouped into two broad categories: information required for maintaining short-term situation awareness and information required for maintaining long-term situation awareness. The questionnaire statements operationalised also the three information waste types observed in the interview data: flow demand, failure demand and flow excess.

The security service personnel's satisfaction with short-term situation awareness maintenance was lower than satisfaction with longer-term situation awareness. The problems experienced in the short-term situation awareness maintenance were mainly related to the uncertain delivery of information about temporary, day-to-day exceptions and changes by clients, which were sometimes not delivered at all.

The personnel in circuit guarding were more dissatisfied than personnel in local guarding with the clients' delivery of exception and change information to the security service

(Mann–Whitney U, $p = 0.039*$). Circuit guarding personnel more often faced difficulties in creating a comprehensive overview of the events and issues handled in the previous work shift (Mann–Whitney U, $p = 0.029*$). Less than half of all guarding personnel experienced the information exchange during the work shift changes as satisfying (Table 4).

Information supporting longer-term situation awareness is in some cases available in electronic form and sometimes only in paper. Maintenance of longer-term situation awareness especially when returning from the vacation was also found quite difficult. Only a minority of respondents (29 %) were satisfied with the current possibilities to get updated when returning to work. It seems to be easier to maintain longer-term awareness about things in the work environment which are relatively stable, such as the circuit service instructions and the usage of different kinds of systems in clients' premises. Personnel of circuit guarding had difficulties more often than local guarding personnel in finding event records from the paper archives (Mann–Whitney U, $p = 0.012*$).

The information interaction with current practices and tools contains features which cause time and effort waste. There are failures both at the information creation phase and in the flow of received information into the field. Failures are related particularly to information relevant for maintaining short-term situation awareness and in creating an overview of events in near history in the premises.

6.4 Assessments of the usefulness and future potentials of NFC-enabled service in security service field work

In the web questionnaire, seven short scenarios of potential future NFC functionalities were presented, and respondents (both those who had already used NFC service in their work and those who had not) were asked to assess their potential usefulness.

The tracking functionality which potentially enhances security of the guard who is facing a challenging emergency or high-risk situation when patrolling alone was most often assessed to be useful. Also functionalities which automate and make exception reporting directly from the field faster and more information rich were assessed to be potentially useful by most of the respondents (Table 5).

Functionalities supporting automatic information content delivery directly to the field with the help of readable NFC tags were evaluated to be useful but not as often as functionalities enhancing security and facilitating mandatory reporting. There were no statistically significant differences in the assessments of potential usefulness of future NFC functionalities between respondents working in local and circuit guarding.

There were no statistically significant differences in assessments of overall usefulness between those who had already used the piloted NFC service and those who had not. In local guarding sample there were no differences between NFC pilot participants and those who had not participated the pilot.

Overall, NFC functionalities which could enhance accurate and timely access and delivery of changing, human-generated information considering the status of premises to be guarded were viewed positively by guarding personnel.

7 Discussion

Information interaction related to the maintenance of situation awareness in mobile field work in security services contains challenges. Information flow from clients to the back office of the security service and further to the guards on the field was prone to disturbances and inefficiencies. The means of maintaining accurate and timely awareness about exceptional and temporal changes in the operational status of the premises to be guarded were not totally satisfactory. The information interaction challenges reported here differ somewhat from those observed in earlier studies of mobile field work. The challenges were not so much related to the concurrent coordination of work between back office and field like in the study of journalists (Väätäjä and Egglestone 2012), but to the accuracy and completeness of basic information delivery between client, back office and field

personnel. The information needs of guarding personnel are well known, but delivering exception information into the field in a location aware and timely manner, to be received when needed has been hard to support. Security personnel do not need to prepare themselves with documentation to be available "just in case" when on the move, as was demonstrated in earlier studies of mobile work (Perry et al. 2001; Perry and Brodie 2006). The need to mobilise information residing in the back-office information systems was crucial. However, that information was not always accurate, complete and updated. Information flow difficulties between different locations and stakeholders in the facilities management—client, security service and guards—created more problems than the ability to mobilise already existing recorded information promptly from the back office to client information systems. The need to avoid redundant information recording, both during the circuit and again in the back office, was a development need similar to the ones observed in studies of hospital settings (Skov and Høegh 2006).

Based on the results of this study, NFC services which support the personal security of the guard and which make communication *from* the field and *to* the field easier, faster and less error prone have the potential to be well accepted by security service personnel. The quality and efficiency of information interaction in mobile security service work can be enhanced by enabling short term, sporadically updating information to flow accurately and effortlessly in a microlocation aware way. Hence, maintaining situation awareness in guarding work can be supported with the Internet of Things.

This study contributes to the theoretical understanding of situation awareness by proposing a new conceptualisation of short-term and longer-term situation awareness. Frequency and predictability of updates in critical information are important determinants for maintenance of situation awareness. However, also low frequency of need to apply certain critical, but not very often updating information can affect maintenance of situation awareness.

When activity and task context extend restricted and spatially bounded control rooms or cockpit environments, means to monitor contextual information about the status of environment change from characteristics of interface affordances to more socio-technical system characteristics. In this kind of context, disturbances and even lack of notification conventions and flexible technical means to enable information flow between client and service provider may hinder situation awareness. The warnings of various authors (e.g. Salmon et al. 2015) about not blaming only individual, but system as a whole about situation awareness failure are justified.

It is important for the support of information interaction to concretise the practical bottlenecks in the information

journey when executing activities in the field in distributed, mobile field work. As Patrick and Morgan (2010) point out, situation awareness can contribute to performance success in any kind of work settings, not alone in complex, dynamic tasks in military and industrial environment. It is important to have analytical tools which are sensitive and domain-free to various kinds of information barriers and their root causes in the maintenance of situation awareness. Information waste as conceptual approach to detect barriers of situation awareness maintenance directly from operator descriptions may prove applicable in various work life settings.

At the methodological level, by using the concept of information waste and by identifying information waste types, this study tested of novel approach to the evaluation of situation awareness in distributed work. In addition, it added to the existing research approaching and evaluating situation awareness as a process rather than a psychological state of an individual actor. This approach enabled the detection and specification of socio-technical factors and barriers in attempts to maintain situation awareness. The study contributes to the theory of situation awareness measurement by providing evaluation framework for assessing maintenance of situation awareness as interaction process within socio-technical system. When utilising information waste types as evaluation framework design recommendations can be directed to all elements of socio-technical system. Recommendations can be related to both human information sources and communication protocols or to information appliances and interfaces.

It is important to recognise that lack of situation awareness and difficulties in situation assessment in particular in mobile field work can stem from variety of root causes. The core deficit may not be inaccurate mental model of the individual operator or inappropriate design of information system interface (cp. Salmon et al. (2008)). Instead, the root causes for difficulties to maintain situation awareness can be related information access and accuracy disturbances within the whole socio-technical system. The earlier research has not provided dimensions for assessing the quality and effectiveness of means to maintain situation awareness in socio-technical system level. Compared to earlier studies in situation awareness literature, the evaluation of situation awareness by detecting information waste incidents during practical information search and use situations is unique.

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