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KNOWLEDGE COORDINATION IN DISTRIBUTED SOFTWARE MANAGEMENT: AN ANALYSIS OF BREAKDOWNS IN MULTIMODAL VIRTUAL MEETINGS

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KNOWLEDGE COORDINATION IN DISTRIBUTED SOFTWARE MANAGEMENT: AN ANALYSIS OF BREAKDOWNS IN MULTIMODAL VIRTUAL MEETINGS

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Abstract

Software organizations are increasingly relying on cross-organizational and cross-border collaboration, requiring effective coordination of distributed knowledge. However, such coordination is challenging due to spatial separation, diverging communities-of-practice, and unevenly distributed resources. We have therefore studied virtual meetings among the managers of a cross-organizational and cross-border joint venture who was highly dedicated to multimodal communication. Since coordination is most clearly noticeable when it is lacking, we investigated knowledge coordination by analyzing communication breakdowns on recordings of their combined teleconferencing and real-time collaborative modeling. As a result, we offer theoretical propositions that explain how distributed software managers can deal with communication breakdowns and effectively coordinate knowledge through multimodal virtual meetings.

Keywords: Knowledge coordination, Virtual meetings, Multimodal communication.

1 Introduction

The Internet and associated technologies have made it easy to communicate in real time across the globe through channels, such as instant messaging, net meetings, and video conferences. While these technologies enable coordination amongst distributed actors (Thomas et al. 2007), virtual organizations still experience significant challenges in coordinating their efforts mediated by information technology. In fact, management of knowledge and communication infrastructures are key risk areas in software development in distributed settings (Persson and Mathiassen 2010). Due to spatial separation, diverging communities-of-practice, and unevenly distributed resources, virtual organizations face specific coordination challenges, such as communicating and retaining contextual knowledge, distributing knowledge evenly across sites, overcoming differences in access to knowledge, communicating and understanding the salience of knowledge, and interpreting silence (Cramton 2001). Thus, effective knowledge coordination is essential in distributed settings (Kanawattanachai and Yoo 2007).

We have investigated knowledge coordination in distributed software management based on access to unusual and rich data from their multimodal synchronous communication during virtual meetings. These software managers successfully coordinated knowledge between two sites and across the functions of overall management, marketing, and product development based on a combination of teleconferencing and real-time collaborative modeling. We analyzed communication practices based on a combination of audio recordings of the software managers' verbal exchanges and video recordings of their real-time collaborative modeling. This study thereby respond to calls for research of "collaborative tools that facilitate the flow and creation of knowledge among individuals working

on a complex, cognitive, interdependent task" (Kanawattanachai and Yoo 2007). Hence, investigating multimodal synchronous communication practices in the virtual meetings of distributed software management, we pose the research question: *How do multimodal synchronous communication practices affect knowledge coordination in virtual meetings among distributed software management?* Coordination is however most clearly noticeable when it is lacking (Malone and Crowston 1994). We therefore investigate knowledge coordination performance in the multimodal synchronous communication of distributed software managers' virtual meetings by analyzing when it fails. We thereby address the persistent issue of communication breakdowns in virtual teams (Bjørn and Ngwenyama 2009; Daim et al. 2012) and the lack of evidence in the management of communication issues in virtual team meetings from a knowledge coordination perspective (Kanawattanachai and Yoo 2007).

2 Knowledge Coordination

Coordination, defined as managing dependencies between activities, is a key activity in any organization (Malone and Crowston 1994) and is linked to organizational performance in virtual settings (Maznevski and Chudoba 2000). Successful coordination is characterized by the integration and harmonious adjustment of individual activities towards the accomplishment of a larger goal (Singh 1992) or simply by working together effectively (Malone and Crowston 1991). Geographical dispersion requires special attention to coordination due to time-zone differences, locally situated knowledge, and lack of presence awareness (Espinosa et al. 2007; Sole and Edmondson 2002). National diversity may imply coordination difficulties related to communication routines, linguistic differences, and weak interpersonal relationships (Daim et al. 2012; Kayworth and Leidner 2000; Maznevski and Chudoba 2000). Task distribution may further require special attention to coordination regarding task coupling (Sutanto et al. 2011), task awareness (Espinosa et al. 2007), and inter-functional conflict resolution (Daim et al. 2012; Robey et al. 2000). Finally, technology mediation may imply coordination difficulties related to limited informal communication and organizational identification (Fay 2011). While effective coordination requires sharing of knowledge, research suggests it is difficult to share knowledge across sites (Cramton 2001; Majchrzak et al. 2005; Sole and Edmondson 2002). Baba et al. (2004) argues "members based in different cultures can bring together divergent bodies of knowledge whose integration yields new organizational capabilities, but only after they recognize both the existence and the validity of their differences". Researchers have coined this the mutual knowledge (Cramton 2001) or the situated knowledge problem (Sole and Edmondson 2002). To address this, it has been suggested to communicate differences in context enabled by information technology (Majchrzak et al. 2005); to focus on how different technologies offer distinct advantages and disadvantages for enhancing effectiveness (Hertel et al. 2005); and, to explore ways to support coordination that are close to cross-organizational collaboration under co-located working conditions (Martins et al. 2004). More specifically, Malhotra et al. (2001) suggests a need for shared understanding, frequent interaction, rapid creation and sharing of context specific transient information. These needs can be addressed by use of "common-language" metaphors, synchronous and frequent teleconferences, and timely discussions of new entries in the knowledge repository to enable members to learn the context (Malhotra et al. 2001). Hence, existing research reveals important challenges that call for investigations of how mediated communication can improve knowledge coordination in virtual settings (Espinosa et al. 2007; Kanawattanachai and Yoo 2007; Kotlarsky et al. 2008; Malhotra et al. 2001). Responding to this call, we view knowledge as a process of simultaneously knowing and acting with focus on application of expertise (Alavi and Leidner 2001) and we define knowledge coordination as the management of dependencies between knowledgeable actors (Malone and Crowston 1994). Successful knowledge coordination is characterized by the ongoing integration of actors towards the accomplishment of a larger goal or simply by having these actors working together effectively (cf. (Malone and Crowston 1991; Singh 1992)).

3 Multimodal Communication and Breakdowns

The processes for creating, storing, retrieving, transferring, and applying knowledge can be supported by information technologies (Alavi and Leidner 2001). However, the way media is used influences how knowledge is shared (Dennis et al. 2008). A study of media use in virtual settings suggests multimodal communication may help overcome coordination challenges (Bélanger and Watson-Manheim 2006). Multimodality generally refers to employment of more than one form of communication, and in the investigated case, it specifically refers to verbal communication through teleconferencing combined with visual communication through real-time collaborative modelling in a shared mindmap. Oviatt (1999) argues "well-designed multimodal systems integrate complementary modalities to yield a highly synergistic blend in which the strengths of each mode are capitalized upon and used to overcome weaknesses in the other". Other research suggests multimodality may help manage situations of information overload that potentially lead to loss of perspective and greater tolerance of error (Eppler and Mengis 2004). Synchronicity in mediated communication may also positively influence knowledge coordination. Defining synchronicity as the ability to support individuals working together at the same time with a shared pattern of coordinated behavior, Dennis et al. (2008) argue convergence processes (understanding the meaning of information) benefit from media that facilitate synchronicity. Comparing synchronous and asynchronies text based communication in a class setting, Hrastinski (2008) argues an increase in the degree of synchronicity improved personal participation because it provided increased psychological arousal, motivation, and convergence on meaning. Taken together, these findings suggest synchronicity may help distributed software managers overcome knowledge coordination challenges (Cramton 2001), such as communicating contextual knowledge, distributing knowledge evenly across sites, overcoming differences in access to knowledge, and communicating the salience of knowledge.

We analyze software managers knowledge coordination in multimodal virtual meetings through communication breakdowns because coordination is most clearly noticeable when it is lacking (Malone and Crowston 1994). This breakdown perspective for investigating the use of information technologies for knowledge work in virtual setting has also been suggested in previous research (Thomas et al. 2007). We identify distinct types of communication breakdowns (Bjørn and Ngwenyama 2009) and investigate how they affected the distributed software managers' knowledge coordination. A communication breakdown causes a disruption in work practices, shifting the actors' attention towards an appropriate recovery strategy (Bjørn and Ngwenyama 2009). Breakdowns in distributed settings can range from instances of failed turn-taking (Garcia and Jacobs 1999; Sarker and Sahay 2004), communication technologies becoming present-at-hand (Winograd and Flores 1986), and lacking recipient feedback (Walther and Bunz 2005) to conflicts due to differing perspectives across organizational roles (Robey et al. 2000). Breakdowns in distributed settings can be distinguished into four levels (Bjørn and Ngwenyama 2009). (1) Lifeworld breakdowns occur when taken-for-granted constitutive knowledge is challenged. The lifeworld is the inter-subjective reality that is built on the interpretations of all personal work experiences as well as the collective experiences of the members of an organization (Bjørn and Ngwenyama 2009). (2) Organization breakdowns occur when existing policies, procedures, technologies, and norms are challenged. Organizational structures comprise explicit, articulated and visible structures, such as policies, norms, symbolic artefacts, ritual activity and patterned behaviour (Bjørn and Ngwenyama 2009). (3) Work-process breakdowns occur when the efficacy of teamwork practices is challenged. The work practice level comprises profession-specific norms, collaborative practices and languages (Bjørn and Ngwenyama 2009). (4) Technology mediation breakdowns occur when the practical use of communication technology is challenged. Communication technologies are open-ended applications (collections of rules and resources); while their use is determined by how the participants adapt the application to their organizational context and work requirements, the functionality of the specific technology can constrain its users (Bjørn and Ngwenyama 2009). We analyze these levels to understand communication breakdowns among software managers during multimodal virtual meetings.

4 Case Study

We adopted a case study approach for a number of reasons (Yin 2003): our research is guided by a how question; knowledge coordination in virtual meetings is a contemporary phenomenon that needs further investigation in real-life contexts (Kanawattanachai and Yoo 2007); and, the relationships between multimodal synchronous communication practices and knowledge coordination are not well understood. In addition, we had access to a case with unique and interesting multimodal communication characteristics during virtual meetings (Yin 2003). The team's task was to finalize the development of the mindmapping tool they used to support collaborative modeling. We were thus able to investigate how a virtual team, which was highly dedicated to multimodal synchronous communication, managed to coordinate knowledge.

The investigation involved the managers of a joint venture between a small Danish software company in Copenhagen, *Software.DK*, and a Russian R&D outsourcing provider in St Petersburg, *Software.RU*. *Software.DK* was established in January 2006 by four Danish partners, who between them had 30 years of experience of developing computer simulations and intelligent learning solutions. Previously, they had developed a portfolio of advanced medical micro-simulators based on collaboration with *Software.RU* and other software development outsourcing companies in India. *Software.RU* had more than 350 Russian employees and had been engaged in more than 300 projects with companies from Denmark, Finland, Germany, Sweden, and the US. S*oftware.DK* initiated the joint venture in February 2006 with the goal of developing a web-based, collaborative mindmap tool to support systems development. *Software.RU* and S*oftware.DK* established the joint venture in April 2006 and named it *Comapping*. *Software.RU* initially assigned two developers to the joint venture while *Software.DK* provided management, architectural, and design expertise. With two people in *Software.DK* initially working full-time on the joint venture along with the two Russian developers, there was a proof of concept ready the following month. *Comapping* shifted focus and hired three managers to develop a commercial strategy for the new tool. The managers were, however, not able to agree on a strategy and were therefore released. It was at this point, in early 2007, we initiated contact with *Comapping*. After the first version of the tool was finalized, we observed all virtual meetings between the Danish and Russian sites in April 2007. The CEO of the joint venture, a board member and technical manager of *Software.DK*, and the Russian systems development manager then managed *Comapping*. Three months later, *Comapping* reached a major milestone when a Fortune 500 Company invested in the tool. Customization to the new partner's requirements then became the primary concern and staff increased to eight full-time developers. Our case study ended in August 2007, when *Comapping* reached this milestone and started reorganizing. Virtual meetings were held between the *Software.DK* board member (representing management), the joint venture CEO (representing marketing), and the Russian systems development manager (representing product development). The meetings were based on teleconferencing via Skype (www.skype.com) combined with real-time collaborative modeling via *Comapping's* mindmapping tool (www.comapping.com). The conference language was English and all virtual meetings took place within normal working hours as the time-zone difference was only two hours. The managers had represented the virtual meeting structure in the mindmap tool. The mindmap had two important nodes "current sprint" and "next sprint." Their sub-nodes represented assignments, often including priority and completion indicators. When multiple users navigate the mindmap, each individual's cursor is visible to other users as a small box with the name of that individual. Mindmap manipulations, e.g. deleting, adding, or changing a node, are instantly visible to other users. Virtual meetings usually started with a walkthrough of all sub-nodes of "current sprint," also known as the sprint backlog in Scrum (Rising and Janoff 2000). The Russian manager would report the status of each node and the meeting participants would delete nodes if assignments were completed. They could also elaborate other assignments with new sub-tasks, give them a new priority or status, or introduce new assignments during this initial walkthrough. Virtual meetings would then continue with a walkthrough of "next sprint". This could lead to changed priorities for some sub-nodes or relocation of sub-nodes to "current sprint." By the end of a virtual

meeting, the managers would revisit "current sprint", and consider the feasibility of assignments and agree on a deadline for the sprint (Persson et al. 2011).

We collected data from January 2007 through August 2007, including recordings of the virtual meetings and interviews focused on the wider context. During the meetings, the first author was present offsite as a passive observer, while audio recording conversations and video recording real-time collaborative modeling in the mindmap. We observed seven meetings from April 2007 to July 2007. Even though they had not released the mindmapping tool when data collection started, all its basic functionality was available for the managers' virtual meetings. Before we started observing virtual meetings, we conducted semi-structured interviews about the organization and work-group contexts. We initiated these with a face-to-face meeting with the manager followed by interviews with other staff members via Skype. Towards the end of our observations, we conducted a new series of interviews with key members *Software.DK*. In total, we conducted eleven interviews. We identified communication breakdowns in the seven virtual meetings based on both verbal and visual communication. We furthermore analysed the eleven semi-structured interviews to understand the context, antecedent conditions, and outcomes of the observed virtual meetings. We used Atlas.ti V5.5 (Muhr 2008) to code the virtual meeting recordings directly. The first author and an assistant made two rounds of initial coding of some of the virtual meetings, reviewed by the second author. Following these reviews, the first author and assistant coded all virtual meetings from scratch. In this process, 90% of the instances initiated no dispute. In cases of disagreement, the coders discussed options until they reached agreement. Finally, we identified the actor(s) who primarily triggered and alleviated a breakdown

5 Results

We identified 61 breakdowns, corresponding to 0.25 (61/247) per minute. Work process breakdowns was the most frequent accounting for 54% (33/61) (Table 1). The remaining breakdowns were equally distributed between lifeworld, organization, and technology mediation issues. The marketer contributed most frequently to triggering organization and work-process breakdowns (Table 1); the actors contributed more equally to lifeworld breakdowns; and technology mediation breakdowns were most frequently, 70% (7/10), triggered by technology issues rather than a specific actor. The manager and developer contributed most frequently, 82% (65/79), to alleviating communication breakdowns.

		Lifeworld	Organization	Work Process	Technology Mediation	Total
All Actors		11	7	33	10	61
Actors triggering communication breakdowns	**Manager**	3	0	6	2	11
	Developer	3	1	9	1	14
	Marketer	4	5	17	2	28
	No Actor	2	1	1	7	11
Actors alleviating communication breakdown	**Manager**	6	5	18	7	36
	Developer	6	4	14	5	29
	Marketer	3	1	8	2	14

*Table **1** Distribution of communication breakdowns*

5.1 Technology mediation breakdowns

Technology mediation breakdowns challenged the practical use of communication technologies. This type was rare and technology issues rather than actors triggered 70% (7/10) of them (Table 1). Table 2 provides an overview of all technology mediation breakdowns. The technical difficulties were poor sound quality, network connection failure, error in the mindmap tool, and erroneous participation

representation in the mindmap; the breakdowns triggered by actors involved attention to e-mail errors, how to operate the mindmap tool where these technologies became present-at-hand (Winograd and Flores 1986), and problems related to turn-taking.

Incident	**#**
Poor sound quality	3
Network connection failure	2
Error in the mindmap tool: slow update of manipulation in the mindmap	1
Erroneous participation representation in the mindmap	1
Attention to e-mail errors	1
Attention to how to operate the mindmap tool	1
Failed turn-taking among participants	1

*Table **2** Technology mediation breakdowns*

While turn-taking is considered a challenging issue in mediated synchronous communication (Garcia and Jacobs 1999), we observed only a single significant turn-taking breakdown (Quote 1):

Concurrently:
***Manager** (Denmark): Then we have ...*
***Marketer** (Denmark): I also ...*
[Eight seconds pause]
***Manager** (Denmark): ... the website*
***Marketer** (Denmark): The website, I think, the help button, I will do that.* [Marketer moves his marker to the node "Web site" and then to its sub-node "Help"]
***Manager** (Denmark): Ahha ...* (Acknowledging)
***Marketer** (Denmark): That should be moved up.* [Marketer assigns the task "Help" to himself]

*Quote **1** Virtual meeting, April 24, 2007*

In Line 1, the manager and marketer speak simultaneously, causing a period of silence. In the recovery of the breakdown in Line 2, the manager directs attention to the shared reference point, "Web site," in the mindmap. By referring to a specific node, the manager brings immediate attention to what he intends to communicate and reduces the likelihood of misunderstandings. The marketer then repeats the manager's statement in Line 3 and places his marker on the "Web site" node. Quote 1 illustrates how the manager and marketer quickly recover from the turn-taking breakdown by interrelating communication across the two technologies. Thus, the failed turn-taking breakdown had a limited adverse effect on knowledge coordination between the manager and marketer as they exploited both communication modalities to recover immediately from the breakdown.

5.2 Work process breakdowns

Work-process breakdowns occurred when the efficacy of practices were challenged. This type was the most frequent, constituting 54% (33/61) of all breakdowns (Table 1). Table 3 provides an overview of the individual incidents. The most frequent breakdowns were "participants request repeat of articulation" and "uncertainty concerning how to use the mindmap tool." These account for 38% (23/61) of all observed communication breakdowns.

Incident	**#**
Participants request repeat of articulation	12
Uncertainty concerning how to use the mindmap tool	11
Participants reveal misrepresentation of information articulated by another participant	6
Talking on the phone during the virtual meeting	2
Failed coordination of mindmap manipulations	1
Misrepresentation of information in the mindmap	1

*Table **3** Work-process breakdowns*

The most frequent incident is "participants request repeat of articulation," constituting 20% (12/61) of all work-process breakdowns. This is a very common conversational breakdown presented in Quote 2:

Manager *(Denmark): Another thing, when you log in, it should also have the box for signing up a new user.*
Developer *(Russia): When you log in ... say it again.*
Manager *(Denmark): I am just writing it up under website ... When logged in, make sure there is a box to allow new users to sign up.* [Manager creates node as a sub-node under "Web site"]
Manager *(Denmark): So, if I am using my computer and would like to sign someone else up there is no way I can do that right now without logging out.*
Developer *(Russia): Ahhh ... Okay ...*
Manager *(Denmark): So, that is a huge bug.* [Manager prioritizes node to level 2]

*Quote **2** Virtual meeting, May 21, 2007*

The manager states a requirement in Line 1, but the developer appears inattentive and requests the manager to repeat his statement in Line 2. In response, the manager repeats his initial requirement in Line 3 while also creating a node, followed by an elaboration in Line 4. The developer acknowledges in Line 5 and the manager state it is a huge bug in Line 6. Quote 2 illustrates how the manager alleviates the breakdown by mirroring his verbal communication in the visual modality. The combination of verbal and visual communication is similar to the one in Quote 1. However, instead of mirroring across modalities the previous quote showed interrelated communication with content in one modality building on content in the other modality. Line 6 in Quote 2 illustrates an inconsistency between the manager's verbal and visual communication. While stating it is "a *huge* bug," the manager only sets the node priority to level 2, moderating his verbal statement by his visual communication. The combination of modalities illustrates a moderating relationship in which communication in one modality may give additional or even contrasting meaning to content in the other modality. The manager immediately exploits both modalities to address the developer's request to repeat his statement. This shows how an actor increased attention to visual communication, as he perceived another actor as inattentive. While such communication breakdowns may escalate or cause more breakdowns, the incident of the inattentive developer had little significance for the manager because the developer immediately explicated his lack of attention.

5.3 Organization breakdowns

Organization breakdowns occurred when virtual meeting participants challenged existing organizational policies, procedures, technologies, and norms. This type was the least frequent, constituting only 11% (7/61) of the incidents (Table 1). The marketer, who was the most recent member of *Comapping*, contributed to triggering 71% (5/7) of these breakdowns (Table 1). Table 4 provides an overview of all organization breakdowns.

Incident	**#**
Unclear procedures for business strategies	1
Unclear responsibilities for documentation of agreements	1
Norms of efficiency are challenged	1
Inability to recall previous undocumented agreements	1
Unclear responsibilities for paying fees to external party	1
Participants focus on what should be discussed in the technical focused virtual meetings	1
Undecided procedures for server-upgrading	1

*Table **4** Organization breakdowns*

One organizational breakdown triggered by the marketer was "unclear procedures for business strategies." This particular incident unfolded as a debate over six minutes, making it the most time-consuming observed breakdown. The incident illustrates the difficulties in knowledge coordination across organizational roles (Robey et al. 2000). In the following, we analyze the initial part of this incident:

Marketer *(Denmark): "*Developer,*" we talked about the desktop application.*

Developer *(Russia): Yeah.*
Marketer *(Denmark): And also "*Manager,*" we were thinking that the desktop application should be launched no later than two months.*
Manager *(Denmark): No later or not earlier?*
Marketer *(Denmark): Well, I have told people, well only a few. I was thinking we should launch it between one or two months from today's date.*
Manager *(Denmark): Well, hehe ...* (Short laugh).
Marketer *(Denmark): Is that possible? I'm just thinking how should we integrate this into the current sprint?*
Manager *(Denmark): I think that you need to stop telling people when things will come, before we have decided.*
Developer *(Russia): Hehe ...* (Laughing)
Manager *(Denmark): We don't know the impact of the desktop application. We don't know how long it will take yet.*

*Quote **3** Virtual meeting, May 21, 2007*

In this incident, the marketer refers in Line 1 to a previous discussion with the developer regarding a desktop application version of the *Comapping* tool. He also refers to a previous discussion of a deadline in Line 3 and points out he had shared this information with other people in Line 5. Almost concurrently with the manager's short laugh in Line 6, the marketer in Line 7 asks whether this goal is possible and how they can integrate it into the current sprint. In response, the manager states the marketer should stop revealing such information without coordinating with other managers. The developer briefly laughs, suggesting disagreement with the marketer; this disagreement becomes more pronounced later during the incident. The marketer agrees by the end of the incident (lasting six minutes) that they should not prioritize the desktop application. The marketer's commitment to external parties preceding Quote 3 was not effectively coordinated. While the marketer's referral to a discussion with the developer in Line 1 suggests coordination between the two, his attempt to include the desktop application in the current sprint in Line 7 was unsuccessful. The manager explicitly pointed out this lack of coordination on the desktop application issue in Line 8, and, later in the incident, the developer also challenged the marketer's practice revealed in Line 3. The part of the incident following Quote 3 focuses on how to prioritize *Comapping* features from a business point of view. In an interview, the manager pointed out that task prioritization had been a significant challenge between him and the developer during the start of *Comapping*. Back then, they maintained a list of prioritized tasks. However, they ended up with a large number of tasks with first priority, and it was difficult for the developer to prioritize between them. Subsequently, they adopted time boxing in the form of sprints (Jalote et al. 2004; Rising and Janoff 2000) and started to use the mindmapping tool. This straightforward structure of tasks represented in the mindmap allowed actors to coordinate knowledge more easily and as needed before, after, and during meetings.

5.4 Lifeworld breakdowns

Lifeworld breakdowns occurred when virtual meeting participants challenged taken-for-granted constitutive knowledge. This type of breakdown constituted 18% (11/61) of the incidents and was the only type evenly triggered by the three participants (Table 1). Lifeworld breakdowns predominantly concerned a need for conveying taken-for-granted professional or cultural knowledge. Table 5 provides an overview of all observed lifeworld breakdowns.

Incident	**#**
A need for conveying fundamental professional knowledge	4
A need for conveying fundamental cultural knowledge	4
Ambiguous language use	1
Uncertainty regarding name articulation	1
Unawareness of the physical location of a new participant	1

*Table **5** Lifeworld breakdowns*

One breakdown related to "a need for conveying fundamental cultural knowledge" involved an effort to explain a technical requirement based on a use case. However, differences in contextual knowledge triggered a dispute as illustrated in Quote 4:

Manager *(Denmark): So it is just if you go to a public library and you log in without having remember me clicked you don't want the next person to be able to access your account.*
Developer *(Russia): Yeah of course but in a public library you usually have to log in to the machine.*
Manager *(Denmark): Well, no not here, it could be anywhere, it could be an Internet cafe, whatever.*
Developer *(Russia): I see ... But I think all these guys usually have some kind of user session.*
Manager *(Denmark): No, it doesn't matter if I go to some computer no matter where it is and I have just logged in without having a special system and I don't click remember me, the next person should not be able to access my account.*
Developer *(Russia): Then just close the browser.*
Manager *(Denmark): Yes, I understand that then if that is what you need to do we should put a notice about that.*
Developer *(Russia): Probably, yes, but we can do nothing about it you understand ...*

*Quote **4** Virtual meeting, May 21, 2007*

The part of the incident preceding Quote 4 concerns a sub-node of the next sprint called "Log out on close if remember me has not been checked." The developer follows the established routine by accounting for the status and challenges related to the task represented by the node. However, the manager disputes the developer's account of the task's key challenge. The manager refers to an exemplary use situation at a public library in Line 1. However, the developer challenges the circumstances of the exemplary use situation in Line 2. In response, the manager states these circumstances are not valid in his lifeworld and instead refers to another exemplary use situation in Line 3. Again challenged by the developer in Line 4, the manager further elaborates his concern in Line 5. The developer suggests a solution in Line 6, which the manager states they should make a notice of in the product in Line 7. In Quote 4, the actors express different perceptions of the exemplary use situation grounded in their Danish and Russian lifeworlds. While the exemplary use situation seeks to ease difficulties in communicating requirements, it causes a breakdown because of differences in participants' lifeworlds. However, the manager quickly alleviates the breakdown by shifting to a different reference point and thereby limiting the need for knowledge of Russian and Danish contexts. In our analyses of the virtual meeting, we considered all communication that was not task-related as breakdowns. While such communication can be attempts to share knowledge required as a prerequisite for task execution, we saw them as distractions from task-focused knowledge coordination. Limited sharing of contextual or cultural knowledge may require significant levels of trust between actors; and, according to the chairman of the *Comapping* joint venture and the manager, a high level of trust had been established through past collaboration between the two companies before the joint venture. Limited sharing of not only contextual but also professional knowledge across sites can similarly require significant levels of trust. Only 36% (4/11) of the lifeworld breakdowns pertained to a need for conveying fundamental professional knowledge. In one incident, the marketer stated he did not understand the technical issue being discussed and did not expect he had to, with which both the manager and the developer agreed. This allows complementary instead of similar expertise in the virtual meetings through coordination of knowledge between the managers.

6 Discussion

To help understand and further investigate knowledge coordination in virtual meetings, we present three theoretical propositions based on the findings from the case. The propositions explain how multimodal communication practices can impact knowledge coordination performance through attention to technology mediation, work processes, organization, and lifeworld breakdowns (Bjørn and Ngwenyama 2009).

A technology mediation breakdown challenges the use of technology. One of the observed breakdowns was failed turn taking between the manager and marketer. The manager's combination of verbal and visual communication (Quote 1) effectively and efficiently alleviated the breakdown. Failed turn-taking is a common challenge in mediated communication (Garcia and Jacobs 1999) as "norms of turn-taking in conversation and presence that are usually well-established among individuals in a face-to-face context are not applicable when interactions, synchronous or asynchronous, occur in a virtual medium" (Sarker and Sahay 2004). However, there was only a single

significant turn taking breakdown during the seven virtual meetings and four hours of activity. This indicates the communication practice of combining verbal and visual communication helps prevent and overcome failed turn taking. Another similar but more obvious alleviation of technology mediation breakdowns is when one modality is used as a substitute for another temporarily unavailable modality, as by the observed incidents of poor sound quality and errors in the mindmap tool (Table 2). The practice of interrelating, moderating, and mirroring communication across verbal and visual modalities also helped alleviate work-process breakdowns challenging the efficacy of the managers' knowledge coordination practices and routines. In one of these breakdowns, an actor's inattentiveness prompted the other actor to mirror his previous verbal communication in the visual modality (Quote 2). This kind of work process breakdown incident was occurring relatively frequent (Table 3) likely because of lack of cues such as body language in mediated communication compared to face to face communication (Walther and Bunz 2005). Although the practice of overt acknowledgement of receipt (Walther and Bunz 2005) was not systematically adopted in the virtual meetings, the actors were able to effectively address moments of inattention by mirroring past communication in another modality (Quote 2). These findings motivate that: *The practice of mirroring, moderating, and interrelating communication across verbal and visual modalities helps actors overcome technology mediation and work-process breakdowns in virtual meetings.*

Organizational breakdowns occurred when virtual meeting participants challenged established policies, procedures, technologies, and norms. One of these breakdowns illustrates the difficulties in knowledge coordination between different organizational roles (Robey et al. 2000) in relation to the coordination of commitments to external parties and the related prioritization of tasks in *Comapping* (Quote 3). However, as participants communicated through manipulations in the mindmap, it became transparent how individual actors' knowledge coordination activities were related and whether what was communicated was consistent with what had previously been agreed upon. In this way, collaborative modelling helped the actors immediately identify knowledge differences and inconsistencies and supported subsequent resolution through teleconferencing. In fact, organizational breakdowns were relatively rare in the virtual meetings, they were non-repetitive, and the newest participant predominantly triggered them (Table 1 and Table 4). These findings suggest the observed virtual meetings achieved high knowledge coordination performance mainly by avoiding organizational breakdowns, hence overcoming the challenges related to task coupling (Sutanto et al. 2011), task awareness (Espinosa et al. 2007), and inter-functional conflict resolution (Robey et al. 2000). During the observed virtual meetings, the participants negotiated the specification of tasks, their priority, and the time box in which they should be addressed. In these activities, the mindmapping tool helped the actors continuously negotiate issues and maintain a shared understanding through a simple and ready-at-hand model of key commitments. Time boxing limited the actors' commitment to concurrent tasks and imposed additional structure on their meetings, thereby reducing the likelihood of information overload. Information overload is considered a key challenge in mediated communication (Jones et al. 2004). In these situations, actors have more information available than they can assimilate and this leads to loss of perspective and greater tolerance of error (Eppler and Mengis 2004). While such effects could adversely affect the actors' ability to coordinate knowledge, the *Comapping* project's virtual knowledge coordination exploited a simple and shared workspace that helped the actors assign and coordinate work dynamically. These findings motivate that: *The practice of time boxing tasks by negotiating options verbally while continuously updating and sharing commitments through visual representations helps actors avoid organizational breakdowns in virtual meetings.*

Lifeworld breakdowns occurred when virtual meeting participants challenged taken-for-granted constitutive knowledge. Interestingly, these breakdowns were relatively rare (Table 1), and they mostly related to differences in cultural and professional knowledge across sites (Table 5). In the lifeworld breakdown in Quote 4, the actors identify differences in cultural knowledge, but immediately move beyond these differences by agreeing on general product requirements. In a different breakdown, the actors explicitly agreed professional knowledge underlying a specific action did not need sharing. Current research has identified serious difficulties related to knowledge sharing

across sites in virtual settings (Majchrzak et al. 2005) and coined these the mutual knowledge (Cramton 2001) or the situated knowledge problem (Sole and Edmondson 2002). In response, it has been suggested temporarily to relocate participants physically (Sole and Edmondson 2002), to support the communication of differences in context by information technology (Majchrzak et al. 2005), and to hone the skill of grasping local realities across sites (Cramton 2001). Our findings question such a strong emphasis on explicitly sharing cultural and professional knowledge across sites as a substitute for everyday sharing of contextual knowledge in collocated settings. Our findings suggest the *Comapping* managers succeeded to coordinate diverse knowledge during the virtual meetings by offering shared reference points in the mindmap rather than by explicitly sharing cultural and professional knowledge across sites. To be effective, such practices, however, may require significant levels of trust between actors and such conditions are difficult to establish in virtual settings. These findings motivate that: *With a high level of trust between actors, sharing task related reference points through a combination of verbal and visual communication reduces the need for sharing professional and cultural knowledge across sites and helps overcome lifeworld breakdowns in virtual meetings.*

Our study provides preliminary implications for the practical management of virtual team meetings. First, virtual team practitioners who aspire to achieve high knowledge coordination performance should explore how the use of multimodal synchronous information technologies can more effectively support knowledge coordination across sites. Second, specification, prioritization, and time boxing of tasks in combination with visual collaborative modeling can enable knowledge coordination in mediated communication. Virtual team practitioners should therefore consider ways to organize project tasks that support shared models and straightforward knowledge coordination in the project. Finally, relying on trust and shared task related reference points can help team members overcome differences in cultural and professional knowledge across sites without explicitly sharing that knowledge. Virtual team practitioners should therefore critically consider the need for early investments in sharing cultural and professional knowledge across sites based on the project's ability to develop and maintain trust and to share task related reference points through multimodal communication. Our research has also notable limitations that call for caution when transferring the findings to other contexts. First, many software organizations are larger and therefore more complex than *Comapping* and this can make knowledge coordination more difficult. Second, the national culture of the Russian and Danish participants did not appear to obstruct their ability to communicate considerably. While relying on trust and shared task related reference points helped the *Comapping* managers overcome differences in cultural knowledge, it is unclear whether this is transferable to other and more diverse cultural constellations. Third, the established relationship between the two companies most likely affected the quality of their relationship in general and trust in particular (Ranganathan and Alfaro 2011). Thus, our findings cannot be transferred to other settings without consideration of such past relationship.

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