How Social Media-Enabled Communication Awareness Enhances Project Team Performance

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Abstract

Project teams increasingly rely on computer-mediated communication. In this paper, we propose that communication within these teams benefits from a communication-awareness feature that summarizes communication at one common place. We argue that such a feature pays out specifically during action episodes, when team members engage in taskwork. We conducted two studies of 51 and 35 project teams to examine how the amount of communication during action episodes relates to team performance under low versus high communication awareness. In both studies, we technologically designed communication awareness as the availability of a feed, known from social media platforms, that displays all team-internal, computer-mediated communication. The results show that the communication-awareness feature makes communication during action episodes more beneficial, both in term of effectiveness and efficiency. Zooming into the temporal patterns of communication during action episodes further reveals that high-performing teams in the high-communication-awareness condition stick out by early and steady communication. Implications for current and future research on team communication and awareness support are discussed.

Keywords: Team communication, team episodes, awareness systems, communication awareness, social media platforms, team performance.

INTRODUCTION

Project teams are a critical locus of innovation and adaptability in contemporary organizations (Chiocchio & Essiembre, 2009; Hoegl & Parboteeah, 2006). A key issue in project teams is communication. Communication plays an important role not only at the outset of projects, when it serves to define goals and strategies (Fussell et al., 1998; Mathieu & Schulze, 2006), but also during subsequent *action episodes*, i.e., the time periods during which team members perform taskwork (Marks, Mathieu, & Zaccaro, 2001). Communication during action episodes enables a variety of team processes that are critical to performance, such as monitoring progress, asking substantive questions, providing feedback, and coordinating subsequent actions (Humphrey & Aime, 2014; LePine, Piccolo, Jackson, Mathieu, & Saul, 2008; Marks et al., 2001; Salas, Sims, & Burke, 2005). These team processes require teams to engage in steady, rather than one-time, communication in order to keep up with new insights, project progress, and shifts in available resource (Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Massey, Montoya-Weiss, & Hung, 2003). However, establishing a steady stream of team communication during action episodes is often difficult due to multitasking (i.e., different members working on different tasks), part-time involvement (i.e., members devoting only part of their capacity to the project), and asynchronous collaboration (i.e., different members working at different times) (Marks et al., 2001; McGrath, 1991). Under these circumstances, team members may pay too little attention to their team members' communication, which may easily lead to slow response times and progress delays (Cummings, Espinosa, & Pickering, 2009; McGrath, 1991; Ocker, Hiltz, Turoff, & Fjermestad, 1995). In other words, even if team members attempt to communicate a lot, these attempts will be in vain if the team lacks awareness of the communication.

These communication difficulties are further aggravated if teams communicate over information and communication technology (ICT) (Galegher & Kraut, 1994; Schweitzer & Duxbury, 2010). For example, ICT mediation was found to reduce much needed communication (Alge, Wiethoff,

& Klein, 2003; De Guinea, Webster, & Staples, 2012; Hinds & Bailey, 2003), to decrease the team's motivation to engage in important team processes (Andres, 2012; Cramton, 2001), and to lead to dispersion of messages across multiple channels (Buder, 2007; Cramton, 2001). Given these difficulties, it is not surprising that research on ICT-mediated communication has struggled to find positive effects of team communication during action episodes on team performance (Kanawattanachai & Yoo, 2007; Weisband, 2002). Thus, although communication can enable critical team processes during action episodes, empirical evidence from ICT-mediated teams fails to reveal significant associations with team performance.

Our study seeks to contribute to resolving this inconclusive relationship between team communication during action episodes and team performance by integrating research on team communication with that on awareness systems. Awareness systems are ICT designed to increase the visibility of events or states important to the team (Bardram & Hansen, 2010; Gutwin & Greenberg, 2002; Yang, Tong, & Teo, 2015). Specifically, we seek to integrate two findings from research on awareness systems. The first is that awareness systems can help teams to shift attention from individual taskwork to the needs of the team (Dehler, Bodemer, Buder, & Hesse, 2009; Heath, Svensson, Hindmarsh, Luff, & vom Lehn, 2002). Such attention shifting may help establish a steady stream of communication despite multitasking, part-time involvement, and low motivation to engage in team processes. The second finding is that project team members often find communication to be the most useful source of awareness information (Dabbish, Stuart, Tsay, & Herbsleb, 2012; Gutwin, Penner, & Schneider, 2004). Taken together, these two insights suggest that project teams can benefit from *technology-enabled communication awareness (CA)*, i.e., ICT designed to increase the visibility of communication by making messages visible at a single place. Such syndication (Zhang, Venkatesh, & Brown, 2011) of messages is one of the key properties of social media platforms (SMPs), which have rapidly diffused in contemporary organizations (MarketsandMarkets, 2017). SMPs enable CA

by making the communication that is relevant to particular users, or teams, visible in feeds (Leonardi, 2014; Leonardi, Huysman, & Steinfield, 2013). We argue that feeds help teams to maintain an overview over messages. Feeds may thereby stimulate team members to frequently shift their attention to team communication and to establish a steady stream of communication throughout action episodes. As a result, team communication during action episodes may be more effective and efficient.

Our paper examines these ideas by addressing the following research question: *How does technology-enabled CA (implemented through the feed feature as known from SMPs) influence the effectiveness and the efficiency of project team communication?* We report two studies in which small, ICT-supported project teams collaborated on particular tasks over several weeks. In each study, we manipulated CA through ICT design. Teams in the high-CA condition were provided with a feed that tied together team communication at one place, whereas teams in the low-CA condition lacked such a feed. In both studies, we found positive associations between task-oriented communication during action episodes and team performance (effectiveness, efficiency) only for teams provided with the feed. Hence, task-oriented communication during action episodes was beneficial only in concert with technology-enabled CA. To examine why only teams provided with a feed were able to excel through communication, we zoomed into their pacing of communication during action episodes. We found that high-performing teams provided with a feed stood out by early and steady communication, supporting the idea that the feed enables frequent attention shifting throughout action episodes. The key contribution of our study lies in theorizing and empirically demonstrating how technology-enabled CA, a key feature of SMPs, influences the effectiveness and efficiency of project team communication during particular collaboration episodes. In the remainder of this paper, we review the literatures on project team communication and awareness systems, develop hypotheses, describe the two studies, and discuss implications.

BACKGROUND LITERATURE

Communication in Project Teams

Project Teams. A team is a "set of two or more people who interact, dynamically, interdependently, and adaptively toward a common and valued goal" (Salas, Dickinson, Converse, & Tannenbaum, 1992, p. 4). Team research has recognized that "different types of teams … manifest teamwork processes (e.g., communication) differently" (Salas et al., 2005, p. 562). A widely established taxonomy distinguishes *project teams* from work teams and management teams (Cohen & Bailey, 1997). Project teams are teams that (1) are time limited, (2) produce unique output, and (3) progressively elaborate plans and ideas (Chiocchio & Essiembre, 2009, pp. 390-391; Cohen & Bailey, 1997, pp. 242-43). Progressive elaboration is a consequence of time-limitedness and uniqueness, and it has important implications for the dynamics of team processes, as Chiocchio and Essiembre (2009) argue: "It means that at the beginning of the project, there is only a broad understanding of the end result and the process used to achieve it. Work is planned as properly as possible at this stage, but as knowledge grows and the project progresses, both become more explicit and detailed" (p. 391).

Team episodes. Team research has acknowledged this dynamic nature of teams and incorporated the role of time into theories and research designs (Humphrey & Aime, 2014; Ilgen et al., 2005). While some research has incorporated time by bracketing collaborations into two equally spaced time periods (Gersick, 1988, 1989; Kanawattanachai & Yoo, 2007; Maruping, Venkatesh, Thatcher, & Patel, 2015; Mathieu & Schulze, 2006; Weisband, 2002), others have argued against fixed phase durations, submitting that team pacing varies according to task characteristics, multitasking behavior, individual attitudes towards time, and the available technology (Marks et al., 2001; Waller, Conte, Gibson, & Carpenter, 2001; Waller, Zellmer-Bruhn, & Giambatista, 2002). Marks et al. (2001) proposed an alternative framework based on the concept of *episodes*. Episodes are "distinguishable periods of time over which performance

accrues" (p. 359). Important episodes in project teams include strategy formulation and action. Projects typically begin with *strategy formulation*, during which the team discusses expectations, relays task-related information, assigns roles and tasks, orders and times actions, and broadly defines how actions should be executed (Marks et al., 2001, p. 365). Strategy formulation is typically followed by *action episodes*, or "periods of time when teams are engaged in acts that contribute directly to goal accomplishment (i.e. taskwork)" (Marks et al., 2001, p. 360). Importantly, during action episodes, project teams engage not only in individual taskwork (i.e., members not only execute the work assigned to them) but also in team processes that serve to direct, align, and monitor taskwork (Marks et al., 2001, p. 357). Important team processes during action episodes include: monitoring progress (e.g. sharing information about task work progress), systems monitoring (e.g. monitoring the availability of team members), team monitoring and back-up behavior (e.g. providing feedback on a task, helping team members, assuming and completing tasks for them), and coordination (e.g. agreeing on the sequence and timing of subsequent actions) (Marks et al., 2001, p. 363). Although these team processes are, to a large extent, mediated by communication (Humphrey & Aime, 2014; Marks et al., 2001), communication during action episodes is hampered by the *distributed focus of attention* due to multitasking (i.e., different team members working on different tasks). In concert with part-time involvement and asynchronous collaboration, distributed foci of attention may produce serious delays in team communication. As a result, teams may struggle to establish a steady stream of communication that would enable essential team processes to occur precisely when they are most needed.

Communication and Team Performance. In light of these communication difficulties, it comes at little surprise that empirical support for the positive effect of communication on team performance has so far been inconclusive. On the one hand, several studies demonstrated positive effects of communication on performance (e.g. Barrick, Bradley, Kristof-Brown, & Colbert,

2007; Espinosa, Nan, & Carmel, 2015; Keller, 1994). On the other hand, some studies found insignificant effects of communication on the performance of project teams (Espinosa, Cummings, & Pickering, 2012; He, Butler, & King, 2007), or they found significant positive effects only for communication during early collaboration episodes (Kanawattanachai & Yoo, 2007; Mathieu & Schulze, 2006; Pearsall, Ellis, & Bell, 2010; Weisband, 2002). The latter research established that communication during early episodes is important for performance because it allows teams to build shared mental models and communication structures that guide subsequent action (Gersick, 1988; Kanawattanachai & Yoo, 2007; Mathieu & Schulze, 2006; Mintzberg, Raisinghani, & Théorêt, 1976; Pearsall et al., 2010; Weisband, 2002). Two studies explicitly compared communication during early and later episodes (Kanawattanachai & Yoo, 2007; Weisband, 2002). Both studies found that positive associations of communication and team performance disappeared after the midpoint.

At first sight, these findings may appear puzzling. Although there is strong empirical evidence for the critical role of team processes during action episodes (e.g. sharing progress information, helping teammates, coordinating) (LePine et al., 2008), there is little support for the performance benefits of communication during action episodes. In light of these findings, some scholars have argued that communication loses its critical function for team processes during later collaboration episodes (Kanawattanachai & Yoo, 2007, p. 789; Weisband, 2002, p. 324). While this is plausible in routine settings, it is difficult to imagine how project teams can achieve progressive elaboration without communication. A possible alternative explanation is that project teams struggle to communicate effectively given the challenges that project teams face during action episodes (multitasking, part-time involvement, asynchronous collaboration) and in using ICT-mediated communication (reduced communication, low motivation to engage in team processes, dispersion of messages across channels) (Andres, 2012; Cramton, 2001; De Guinea

et al., 2012). Under these conditions, communication is likely to suffer from delays and misunderstandings (Cummings et al., 2009; McGrath, 1991). Thus, teams may be unable to benefit from team communication because they struggle to establish a steady stream of coherent and timely communication, which is essential for team processes to thrive within the limited time of the project. These difficulties may manifest in insignificant correlations between the amount of communication and performance.

Research on communication in teams also points to strategies that may help teams cope with these challenges. There is some evidence that communication can be beneficial if teams are provided with structures, such as fixed milestones, that accelerate the pacing of communication (Massey et al., 2003; Okhuysen & Eisenhardt, 2002). Such structural guidance, however, leaves open the question how teams can enhance their effectiveness and efficiency of communication within action episodes, i.e. episodes flanked by preceding planning episodes and looming deadlines. To address this question, research on awareness systems directs us towards a possible answer.

Awareness Systems

There is a substantial body of research on awareness systems (see Table 1 for an overview of empirical work). Awareness systems are ICTs designed to increase the visibility of states or events (Markopoulos & Mackay, 2009). Such enhanced visibility may support the team members' perception of states or events over time, the comprehension of the meaning of these states or events, and the projection of that information in the near future (Endsley, 1995, p. 36). As Table 1 shows (see column 2), researchers have examined ICT designed to promote awareness of a variety of states or events, such as the team members' activities, workload, communication, location, presence, participation, and knowledge.

Table 1. Empirical Research on Awareness in Teams

(1) Study	(2) Awareness Dimension Enabled by ICT[a]	(3) Collaboration Duration[b]	(4) Collaboration Type	(5) Episodes[c]	(6) ICT Manipulated[d]	(7) Key Findings
Bardram and Hansen (2010)	Activities, location, workload	**Long-term** (18 months)	Synchronous, **asynchronous**	No	No	Activity awareness eases coordination; location awareness eases locating colleagues; workload awareness leads to fewer interruptions.
Biehl, Czerwinski, Smith, and Robertson (2007)	Activities (artifact changes)	**Long-term** (4 days)	Synchronous	No	**Yes**	Activity awareness promotes communication, reduces cognitive load, and eases coordination.
Bradner, Kellogg, and Erickson (1999)	**Communication**, participation, presence	**Long-term** (2 to 18 months)	Synchronous, **asynchronous**	No	No	Communication awareness allows unobtrusive broadcasting and staying in the loop; presence awareness allows waylaying.
Cooper and Haines (2008)	Activities, insight, presence	Short-term	Synchronous	No	**Yes**	Awareness systems improve presence awareness, which enhances behavior awareness, insight awareness, and decision quality, presumably by promoting team interaction.
Dabbish and Kraut (2008)	Workload	Short-term (< 1 hour)	Synchronous	No	**Yes**	Under high team orientation, workload awareness reduces interruptions; abstract information displays yield higher performance than detailed ones.
Dabbish, Stuart, Tsay, and Herbsleb (2013)	Activities (artifact changes), **communication**	**Long-term**	**Asynchronous**	No	No	Activity awareness triggers rich social inference; even with ICT-enabled activity awareness, communication remains important.
Dehler et al. (2009)	Knowledge	Short-term (1 hour)	Synchronous	No	**Yes**	Knowledge awareness leads to a more interactive collaboration style.
Dourish and Bellotti (1992)	Activities (artifact changes)	Short-term (1.5 hours)	Synchronous	**Yes**	No	Teams switch between independent and interactive collaboration; even with ICT-enabled activity awareness, communication remains important.
Espinosa et al. (2000)	Activities (document reading sequences)	Short-term (1 hour)	Synchronous	No	**Yes**	Activity awareness yields quicker but less accurate decision making, presumably due to strong division of labor and, hence, weak common ground.
Gutwin, Greenberg, and Roseman (1996)	Activities (artifact changes), location	Short-term (30 minutes)	Synchronous	No	**Yes**	Abstract (i.e., high-level) awareness displays yield perceptions of high usefulness and promote interaction about the task.
Gutwin et al. (2004)	Activities, **communication**	**Long-term**	**Asynchronous**	No	No	Although there are several sources of information, communication is the primary source of awareness information.

(1) Study	(2) Awareness Dimension Enabled by ICT[a]	(3) Collaboration Duration[b]	(4) Collaboration Type	(5) Episodes[c]	(6) ICT Manipulated[d]	(7) Key Findings
Heath et al. (2002)	Activities	**Long-term**	Synchronous	No	No	People deliberately, subtly, and selectively create awareness of their activities in order to trigger chains of social interaction.
Janssen, Erkens, and Kirschner (2011)	Participation	Short-term (7 hours)	Synchronous	No	No	Longer awareness system use yields higher participation awareness, more process-related communication, and more equal participation.
Kimmerle and Cress (2008)	Participation	Short-term	Synchronous	No	**Yes**	Awareness of individual team members' participation yields higher contributions by those team members that are concerned about self-presentation.
Lowry and Nunamaker (2003)	Activities (artifact changes)	Short-term (4 hours)	Synchronous	No	**Yes**	Activity awareness yields higher amounts of negative and of positive messages, higher effectiveness, and higher efficiency.
Malhotra and Majchrzak (2014)	Activities, presence	**Long-term**	Synchronous, **asynchronous**	No	No	Activity awareness is beneficial for project teams (non-routine tasks); presence awareness is beneficial for teams with many knowledge boundaries.
Omoronyia, Ferguson, Roper, and Wood (2009)	Activities, participation	**Long-term** (6 weeks)	Mostly **asynchronous**	No	No	Awareness information helps direct software developers' attention to the people, tasks, and artifacts that are most relevant to their work.
Sangin, Molinari, Nüssli, and Dillenbourg (2011)	Knowledge	Short-term (1.5 hours)	Synchronous	No	**Yes**	Knowledge awareness yields more elaborative communication, greater sensitivity to knowledge gaps, and stronger learning gains.
Tran, Yang, and Raikundalia (2009)	**Communication**, presence	Short-term (2 hours)	Synchronous	No	**Yes**	Communication awareness yields shorter completion times and fewer turns, presumably due to fewer clarification questions and fewer repeated turns.
Treude and Storey (2010)	Activities	Long-term	**Asynchronous**	No	No	Activity awareness enables task prioritization, facilitates short-term planning, and promotes competition.
Yang et al. (2015)	Knowledge	Unknown	Synchronous	No	No	Knowledge awareness is associated with greater task cohesion and greater satisfaction.

[a] While terminology varies per study, we broadly distinguish awareness of activities (what others do), of communication (what other say), of insight (what others think), of knowledge (what others know), of location (where others are), of participation (how much others contribute), and of presence (whether others are present); [b] short-term if the duration of the collaborations studied was shorter than one day; [c] indicates whether different episodes were distinguished during data analysis; [d] indicates whether technological conditions were manipulated by the researchers; **in bold**: research design characteristics shared with our studies

Two sets of findings of awareness systems research are particularly notable in the context of our study. First, awareness systems can help teams shift attention from individual taskwork to the team and thereby stimulate collective activity (or teamwork) (Dehler et al., 2009; Heath et al., 2002; Schmidt, 2002). For instance, Dehler et al. (2009) found that teams provided with technology-enabled knowledge awareness excelled through an interactive approach, whereas teams without such technology support excelled through an individualistic approach. Biehl et al. (2007) observed higher amounts of communication (i.e., a type of collective activity) when teams were provided with activity awareness. Ethnographic research suggests an explanation for greater collective activity provoked by awareness (Heath et al., 2002; Schmidt, 2002). Under distributed foci of attention, awareness systems enable "appropriate obtrusiveness" (Schmidt, 2002, p. 292), i.e., they help frequently direct the team members' attention from individual task-work to the team. This may help trigger and advance conversations at the right moment, such as when team members need help or when subsequent actions need to be coordinated.

Second, qualitative awareness systems research indicates that people often prefer communication as a source of awareness even if alternative information sources are available (Dabbish et al., 2013; Fussell et al., 1998; Gutwin et al., 2004). For instance, Gutwin et al. (2004) concluded from a qualitative study of distributed software development teams that "[a]lthough there are several sources of information, … awareness is maintained primarily through text-based communication" (Gutwin et al., 2004, p. 72). In a similar setting, Dabbish et al. (2013) found that while in some cases, information from high-level awareness displays was sufficient, "[i]n many cases, [people] needed to directly communicate about a code contribution" because the "project vision" and the "reasoning behind a change or the organization of … code … was not always clear" (p. 40) from the displays. This indicates that team members often prefer rich, communication-based awareness information because it is most informative about "intentions and rationale" (Dabbish et al., 2013, p. 40) behind the team's actions.

These two findings suggest that technology-enabled communication awareness (CA) can help project teams cope with the specific challenges of team communication during action episodes by steadily drawing the team members' attention to the needs of the team and thereby reducing delays and misunderstandings. This may enable a steady stream of communication and may help make communication more beneficial.

However, empirical support for these ideas is lacking because of three gaps in the awareness systems literature. First, although many scholars have examined displays providing activity awareness, relatively few (Bradner et al., 1999; Dabbish et al., 2013; Gutwin et al., 2004; Tran et al., 2009) have examined CA (see column 2). This is unfortunate given the qualitative findings about people's preference for communication-based awareness and given the increasing diffusion of ICT-supported CA through SMPs (Leonardi et al., 2013; MarketsandMarkets, 2017). Second, the literature lacks studies that technologically manipulated awareness in collaborations longer than a day. Some researchers manipulated ICT (see column 6 in Table 1) in short-term collaborations of few hours or less (see column 3). Yet, the difficulties in establishing a steady stream of communication are likely to be much less salient in short-term collaborations than in collaborations where members work on different task at different times over periods of several weeks and where they devote only a fraction of their time and attention to the project (McGrath, Arrow, Gruenfeld, Hollingshead, & O'Connor, 1993). Other researchers studied longer collaborations (see column 3) but did not manipulate ICT (see column 6). Although these studies yielded important qualitative insights into the use of awareness systems, they were not designed to reveal statistically significant differences between distinct ICT conditions. Third, there is a dearth of research on the role of awareness systems during particular collaboration episodes (see column 5). Hence, awareness systems research has not yet explored the idea that technology-enabled awareness may play particular roles during particular collaboration episodes, such as during action episodes.

In sum, our review of the literatures on team episodes, team communication and on awareness systems suggests that CA—enabled through ICT features that increase the visibility of communication—may help project teams cope with the specific challenges of communication during action episodes. However, whether and how such a feature makes communication during action episodes more beneficial remains an open empirical question.

HYPOTHESES

We build on the literatures on team episodes, team communication, and awareness systems to explain how ICT-enabled CA influences the effect of project team communication on team performance during action episodes. Specifically, we propose that the availability of a feed that draws together team communication at a single place makes team communication more effective and efficient. Figure 1 provides an up-front summary of our research model.
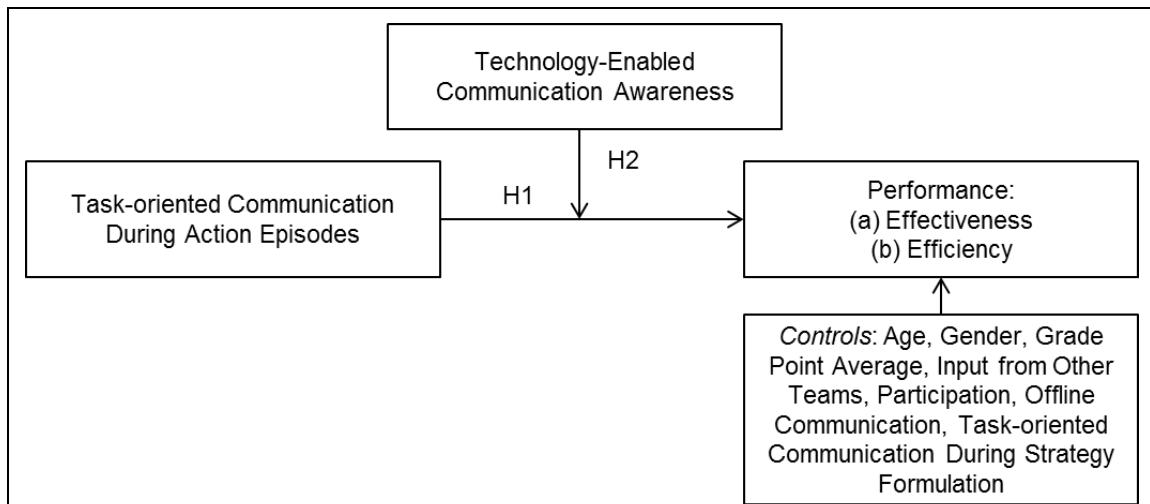

Figure 1. Research Model

Performance

In line with prior team research (Dennis, Wixom, & Vandenberg, 2001; Espinosa et al., 2000; Galegher & Kraut, 1994; Gopal & Gosain, 2010), we define performance in terms of two major dimensions: (1) effectiveness, defined as the degree to which the output delivered by a project

team meets the requirements, and (2) efficiency, defined as the relation of a project team's output to input (i.e., effort) (Law, 2016). We focus on both dimensions because prior studies of ICT in team collaboration often obtained different results for these two performance dimensions (Espinosa et al., 2000; Galegher & Kraut, 1994; Pridmore & Phillips-Wren, 2011).

Task-Oriented Communication During Action Episodes

While the existing literature emphasizes the important role of communication in early team episodes, such as strategy formulation (Gersick, 1988; Kanawattanachai & Yoo, 2007; Mathieu & Schulze, 2006; Mintzberg et al., 1976; Pearsall et al., 2010; Weisband, 2002), we argue that communication also plays a critical role during action episodes. We submit that in particular *task-oriented communication* is critical during action episodes. Task-oriented communication denotes messages that are related to the substance of the task (e.g. substantive questions, feedback on work products) or to the process through which the task is accomplished (e.g. information on own past or current activities, suggestions for coordinating subsequent activities) (Fussell et al., 1998; Kanawattanachai & Yoo, 2007; Marks et al., 2001). Task-oriented communication during action episodes enables a variety of team processes that have been shown to increase team performance, such as monitoring progress, team monitoring and back-up behavior (which includes providing feedback), and coordination (LePine et al., 2008; Marks et al., 2001). We expect that teams that engage in greater amounts of task-oriented communication during action episodes are more *effective* because teams will be more able to leverage the knowledge of their members if they frequently ask substantive questions and provide feedback. Such teams are more likely to identify flaws in the emerging task products and to incorporate insights that team members gained over time, leading to output of higher quality. We also anticipate that it pays out for teams to engage in greater amounts of task-oriented communication in terms of efficiency, because teams are less likely to suffer from duplicated efforts if they frequently share progress information and explicitly coordinate actions. Moreover, team

members who lack knowledge in a particular content domain save efforts if they pose questions to their teammates instead of expending large efforts in unproductive individual taskwork. We hypothesize:

> *H1a/b: The amount of task-oriented communication during action episodes is positively related to (a) effectiveness and (b) efficiency.*

Technology-Enabled Communication Awareness

Although task-oriented communication during action episodes potentially enables a set of critical team processes, it is not granted that communication will actually serve these purposes. Communication will often suffer from serious delays given the challenges that project teams face during action episodes (distributed attention due to multitasking, part-time involvement, asynchronous collaboration) (Marks et al., 2001; McGrath, 1991) and in using ICT-mediated communication (reduced communication, low motivation to engage in team processes, dispersion of messages across channels) (Andres, 2012; Cramton, 2001; De Guinea et al., 2012). Because of these delays, communication may not enable team processes when most needed.

Technology-enabled CA may help alleviate these adverse circumstances. Specifically, we argue that the feed feature known from SMPs enhances CA (Leonardi, 2015; Leonardi et al., 2013). A feed automatically syndicates communication from various channels, such as from discussion boards and personal profiles, at a single spot in form of a summarized text including the publishing date and author (Leonardi et al., 2013; Zhang et al., 2011). Such feed-enabled communication awareness helps to frequently draw team members' attention from their individual taskwork to team communication. This can help establish a steady stream of task-oriented communication, allowing team processes to occur when they are needed, rather than in the last few days, when the looming project deadline directs the team members' attention to the project. As a consequence, task-oriented communication is likely to be more beneficial.

Feed-enabled CA allows for more effective questioning and feedback processes, resulting in output of higher quality (i.e., higher effectiveness). Moreover, with more timely monitoring and coordination processes, teams are also likely to be more efficient, for example by avoiding duplication of effort. These benefits from feeds are, however, contingent on the teams' decisions to engage in task-oriented communication. If a team chooses not to engage in task-oriented communication, the feeds will not display any messages and hence will not draw the members' attention to the needs of the team. Conversely, if a team engages in high amounts of task-oriented communication, the feeds are particularly likely to turn the team members' attention to the varied ways in which members can contribute to ongoing conversations. We hypothesize:

> *H2a/b: The associations between the amount of task-oriented communication and performance (in terms of (a) effectiveness and (b) efficiency) are stronger (i.e. more positive) under high CA (i.e., when the feed feature is available).*

While we hypothesize that feed-enabled CA helps make task-oriented communication during action episodes more effective, we do not expect a main effect of the mere availability of a feed on performance. As argued above, empty feeds are unlikely to turn the team members' attention to any needs of the team. Hence, the availability of the feed is likely to be beneficial only in concert with task-oriented communication during action episodes. This echoes the often articulated idea that particular ICT features create impact in concert with team behaviors that leverage the potential offered by the particular features (DeSanctis et al., 2008, p. 555; Kock & Lynn, 2012; Malhotra & Majchrzak, 2014; Niederman, Briggs, de Vreede, & Kolfschoten, 2008).

METHODS

Research Design

In order to test our hypotheses we conducted two studies with two slightly different contexts, notably with different team tasks and slightly different team size. Such "context-only extension" (Berthon, Pitt, Ewing, & Carr, 2002) "serves to investigate the generalizability of … research findings" (Berthon et al., 2002, p. 419).

Both studies were done with student teams. Notwithstanding the strengths of field research, student teams provided a number of advantages. First, we were able to manipulate the technology through which teams collaborated. Second, teams within the same study worked on the same task, which eased comparability. Third, students mostly lacked joint collaboration history, performed this type of task for the first time, and worked on projects in other courses at the same time. These conditions were consistent with characteristics that are essential or typical for project teams, such as time-limitedness, uniqueness of task for the team, and part-time involvement. Fourth, students are mostly familiar with leisure social media platforms such as Facebook. This reduced the effect of technology assimilation hurdles (Venkatesh, Morris, Davis, & Davis, 2003), which were not the core interest of this study.

Treatments

In each study, we used the same two technological conditions, to which the teams were randomly assigned. Table 2 provides an overview. In the low-CA condition, teams were provided with a collaboration platform that offered the following broad capabilities: (1) communication (team forums, direct messages, document attentions, profile updates); (2) friend relationships (adding other people as friends); (3) artifact editor (integrated Google Docs ® word processor, spreadsheets, and diagrams). These capabilities are common to many contemporary collaboration platforms (Leonardi et al., 2013). In the high-CA condition, teams were provided with a

collaboration platform that offered all capabilities of the low-CA condition and, in addition, CA through team feeds and individual feeds. Appendix A shows the user interfaces of the two platforms. We used two highly similar platforms that differed only in the CA feature to facilitate attributing differences to this particular feature.

Table 2. Technological Conditions			
Capability	**Features**	**Low CA**	**High CA**
Communication	Team forums (accessible to team members only); direct messages to team members, to the team, and to other users; document annotations (i.e. comments function) in word processor; user profiles including photos and user information	Available	
Friend Relationships	Adding users (from the same platform) as friends	Available	
Artifact editor	Concurrent editing of artifacts (Google Docs ® word processor, spreadsheet calculations, drawing components were integrated into the platform.)	Available	
Communication awareness	Team feeds (summaries of a team's communication, visible to the team) and individual feeds (summaries of an individual's communication, visible to the team and to friends); feeds include: - system-generated notifications on forum posts - system-generated notifications on profile updates - user-generated feed posts (updates on artifact actions, status updates)	Not available	Available

Participants and Tasks

Table 3 provides an overview of the participants, teams, and tasks of the two studies. Compared to study 2, study 1 involved slightly larger teams (team size of 4 in study 1 vs. 3 in study 2), more teams (51 vs. 35), a shorter collaboration duration (3 weeks versus 5 weeks), and a different task (solving a business process improvement problem versus a knowledge management problem). We removed three teams from study 1 and three teams from study 2 because of lack of participation (five teams) or technical problems (one team). The appendices B and C provide more information on the task material of the two studies. In both studies, we randomly assigned participants to teams.

Table 3. Participants and Tasks		
	Study 1	**Study 2**
Participants	Students in a compulsory undergraduate course on business process management at a Swiss university	Students in an elective undergraduate course on knowledge management systems at the same university as in study 1
Team size	4	3
Number of teams in final sample	51 (204 participants)	35 (105 participants)
Average age	22	23
% female	37%	41%
% major in business administration	89%	73%
Task	Business process improvement problem (process mapping, cycle time and cost analysis, identifying improvements)	Knowledge management problem (develop recommendations for design and implementation of a knowledge management system)
Artifact editor to be used for task	Word, spreadsheets (for cycle time and cost analysis), drawing (for process mapping)	Word
Duration	3 weeks	5 weeks

Procedures

At the outset, the participants had one week of time to familiarize themselves with the platform. During that period, the participants provided demographic information in a pre-questionnaire, watched a video of a duration of 10 minutes that introduced them to the platform, and then obtained personal credentials to access the platform. Although the participants were informed that they were allowed to meet physically, they were encouraged to use the platform as much as possible, and they were able to access the case material and the shared artifacts through the platform only. Moreover, the participants were informed that they were allowed to exchange information with members from other teams assigned to the same platform. This was supposed to make our study setting more realistic, given that members of real organizations would typically communicate not only within but also across teams through SMPs (Leonardi, 2015).

After the one-week familiarization period, the participants had three weeks in study 1, and five weeks in study 2, to complete the task. The five weeks in study 2 included a 10-days spring break. After these periods, the platform was frozen and the participants were invited to respond to a post-questionnaire. The team deliverables were graded by an assessor who was neither a member of the research team nor the platform administrator. There were different assessors in study 1 and study 2. The grading criteria of study 1 included the correctness and completeness of the process model, of the calculations, and of the process improvement suggestions. The grading criteria of study 2 considered the identification of knowledge management problems from the case, the choice of appropriate theoretical frameworks, the mapping of the framework to case information, and specification of recommendations for actions consistent with the framework.

Measures and Coding Procedure

Our measurement approach combined data from different sources: data extracted from the collaboration platform, the grading scores awarded by assessors, pre- and post-surveys, and grade point average (GPA) scores obtained from the university's internal records. To measure the amount of task-oriented communication during action episodes, we extracted all team-internal messages (i.e., direct messages, forum posts, feed updates, document annotations) from the platform and performed two steps of content analysis (Krippendorff, 2012). First, we coded for each message whether the message was task oriented. A message was coded as task oriented when it referred to the substance of the task (e.g. substantive questions, feedback on work products) or to the process through which the task was accomplished (e.g. information on own past or current activities, suggestions for coordinating subsequent activities). Each message was coded by two coders, who were blind to the hypotheses of the study. Inter-coder agreement was 96% (Cohen's kappa: .74), supporting the reliability of the coding procedure (Landis & Koch, 1977). Second, in order to separate communication during strategy formulation

from communication during action episodes, we coded, for each team, the day on which the team had concluded strategy formulation. This day was determined based on the day of the last message that served to negotiate the team strategy. Each team was coded by two coders blind to the hypotheses. Cronbach's alpha was .94, supporting the reliability of the coding procedure. Appendix D provides coding examples.

Table 4 shows our measures. We examined two performance variables, effectiveness and efficiency. Our effectiveness measure was the grading score that the assessors awarded based on the team deliverables. Efficiency, i.e., "the ability … to produce the maximum output … with the minimum of time, effort, and other inputs" (Law, 2016), was measured as the standardized grading score minus the standardized effort that the team invested into taskwork (i.e., the time spent on actions in the artifact editor). Efficiency was thus highest when teams obtained high scores with low taskwork effort. Similar measurement approaches have been used in other settings in which efficiency is of interest (Paas, Tuovinen, Tabbers, & Van Gerven, 2003). Task-oriented communication during action was measured as the amount of messages that (1) were team internal, (2) were task oriented, and (3) were sent after initial strategy formulation.

We controlled for a number of variables to help rule out alternative explanations (see also Table 4). First, we controlled for task-oriented communication during strategy formulation (i.e., before action episodes) to substantiate our claim that communication only during action episodes benefits from CA. Second, we controlled for a set of individual differences (age, gender, and GPA) that could potentially correlate both with the amount of communication and with performance. Third, since our measures of task-oriented communication referred to communication over the platform only, we controlled for offline communication, i.e., the amount of communication outside the platform, such as through email, phone, and face-to-face meetings. Fourth, we controlled for whether a team received input from other teams. This served to rule out the explanation that teams assigned to different platforms might differ in the degree to which they seek

and obtain help from other teams. Fifth, we controlled for participation, i.e. the degree to which task-oriented communication during action was equally distributed across team members. We controlled for participation because some studies suggest that awareness systems may affect participation (Cooper & Haines, 2008; De Dreu & West, 2001; Janssen et al., 2011).

Table 4. Measures	
Dependent, independent, and moderating variables	
Effectiveness	Grading score (scale: 0 to 100) assigned by assessor of team deliverables
Efficiency	Grading score (standardized) minus taskwork effort (standardized); to measure taskwork effort we extracted the start time and end time of all artifact editing actions from the platform
Communication Awareness	1 if the team was assigned to the high-CA condition (collaboration platform with feeds), else 0 (collaboration platform without feeds)
Task-oriented communication during action	The number of task-oriented team-internal messages that were sent over the platform after initial strategy formulation
Control variables	
Task-oriented communication during strategy formulation	The number of task-oriented team-internal messages that were sent over the platform until the last day of initial strategy formulation
Age	Average age of team members according to pre-questionnaire
Gender	Fraction of female team members according to pre-questionnaire
Grade Point Average	Average GPA of all team members based on the university's records; the GPA excluded the grade obtained on the course in which the study was embedded
Offline Communication	Average of three items from post-questionnaire adapted from Ma and Agarwal (2007) (Cronbach's alpha: .94, items provided in Appendix E)
Input from Other Teams	1 if the team has received input from other teams according to communication records, else 0 (coded based on communication data extracted from platform)
Participation	Herfindahl index of the distribution of task-oriented communication during action over team members; high numbers indicate high concentration and, thus, unequal participation (e.g. one team member making most contributions)

Regression and Post-hoc Analysis

We relied on ordinary least squares (OLS) regression to test our hypotheses, using a three-step hierarchical regression strategy. In the first step (model 1), we included only control variables. In the second step (model 2), we added the main effects of CA and task-oriented communication during action. In the third step (model 3a), we added the hypothesized interaction

of CA and task-oriented communication during action. To substantiate our claim that communication only *during action episodes* benefits from CA, we estimated the alternative model 3b, which included an interaction between CA and task-oriented communication *during strategy formulation*. We ran all models separately for study 1, for study 2, and for the pooled dataset (i.e., for data pooled from study 1 and study 2). In all models, we applied a square root transformation to task-oriented communication during strategy formulation and to task-oriented communication during action in order to eliminate the positive skew of these count data variables. Moreover, we standardized the data before pooling. We performed a number of checks to ascertain that the assumptions of OLS were met (Wooldridge, 2009, pp. 104-105). Histograms and q-q plots showed that the residuals of all models followed normal distributions, indicating that the assumption of normally distributed error terms was met. Variance inflation factors were below 3, suggesting that multicollinearity problems were not salient in the data. Plotting residuals and dependent variables in a scatter plot diagram showed no departure from the assumption of homoscedastic error terms.

After the regression analyses, we performed two post-hoc analyses. The first post-hoc analysis served to shed light on our claim that differences in pacing between technological conditions (i.e., earlier and steadier communication in the high-CA condition) explain differences in the effectiveness and efficiency of task-oriented communication during action. To shed light on pacing, we examined two sets of indicators. First, we divided action episodes by their midpoint and measured the amount and fraction of *communication during the first half*. High amounts and fractions in the first half indicate relatively early communication. To increase robustness, we performed the analysis for two types of midpoints: midpoints by time and midpoints by amounts of messages. Midpoints by time were the average mean day of action episodes. Midpoints by amount of messages were the day by which all teams had sent, on average, at least

half of their task-oriented communication during action[1]. Second, we calculated the *number of days* during action episodes on which messages were sent. High numbers of days indicate relatively steady communication. In the second post-hoc analysis, we examined whether higher taskwork efficiency in the high-CA condition was due to substitution of taskwork effort by communication effort. To examine this explanation, we compared the total length of messages, a proxy for communication efforts, between conditions.

RESULTS

Descriptive Statistics and Regression Results

Table 5 shows descriptive statistics per platform and study. Moreover, the last column shows the means in the pooled data (i.e., the combined dataset of both studies). The only significant differences between technological conditions were un-hypothesized differences in efficiency. In study 1 and in the pooled dataset, teams in the high-CA condition were significantly more efficient than teams in the low-CA condition (t test, $p < .05$). In study 2, teams in the high-CA condition were also more efficient than teams in the low-CA condition, but this difference was not statistically significant. There were no significant differences between platforms along other dimensions, such as in the amount of task-oriented communication during action. Table 6 and Table 7 show bi-variate correlations. Table 8 shows the regression results of the models predicting effectiveness. Table 9 shows the regression results of the models predicting efficiency.

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[1] For instance, in study 1, the average last day of strategy formulation according to our coding was day 10. Hence, the average start day of action episodes was day 11 (10+1). The last full day of collaboration was day 21. The midpoint by time was day 16 ((11+21)/2). Conversely, the midpoint by amount of messages was day 18 because it was only by day 18 that teams had sent at least half of their communication during action (567, or 53%, out of 1077 messages were sent by day 18.).

Table 5. Descriptive Statistics

Variable	Study 1[a]		Study 2[a]		Pooled Data[b]	
	Low CA	High CA	Low CA	High CA	Low CA	High CA
Effectiveness	71.3 (11.1)	71.8 (13.3)	58.9 (15.3)	63.2 (15.5)	-.07	.07
Efficiency	**-.30* (1.12)**	**.34* (1.03)**	-.24 (1.15)	.23 (1.20)	**-.25***	**.25***
Age	22.3 (1.1)	22.3 (.9)	23.5 (2.21)	23.7 (2.3)	-.03	.03
Gender	.38 (.28)	.34 (.19)	.43 (.28)	.36 (.27)	.10	-.10
GPA	4.70 (.20)	4.66 (.24)	4.56 (.26)	4.74 (.26)	-.08	.08
Input from Other Teams	.81 (.40)	.80 (.41)	.65 (.49)	.67 (.49)	.00	.00
Offline Communication	3.92 (1.79)	4.27 (1.63)	3.67 (1.66)	3.64 (1.73)	-.06	.06
Participation	.34 (.08)	.32 (.05)	.37 (.15)	.46 (.17)	-.02	.02
ToC During Stat. Formul.	14.1 (7.7)	13.0 (4.7)	9.5 (6.8)	11.2 (4.0)	-.06	.06
ToC During Action	18.7 (11.2)	22.6 (14.6)	17.9 (14.2)	14.6 (9.9)	-.05	.05
n	26	25	17	18	43	43

(ToC: Task-oriented Communication; [a] study 1, study 2: figures show means and standard deviations; [b] pooled data: figures means that have been standardized for each study; *difference between low and high CA significant at $p < .05$)

Table 6. Correlations (Study 1)

	Effec-tiven.	Effi-ciency	Age	Gen-der	GPA	Input	Offl.	Part.	ToC SF	CA	ToC Act.
Effectiveness	1.00										
Efficiency	.55*	1.00									
Age	.34*	.01	1.00								
Gender	.00	-.28*	.22	1.00							
GPA	.27	.19	-.08	-.14	1.00						
Input	-.01	-.08	-.02	.07	.14	1.00					
Offline Com.	-.23	-.27	.04	.11	-.26	.04	1.00				
Participation	-.20	-.27	-.01	.12	-.16	.05	.18	1.00			
ToC SF	-.16	-.12	.08	.40*	.01	.09	-.01	.15	1.00		
CA	.02	.29*	.01	-.07	-.09	-.01	.10	-.15	-.05	1.00	
ToC Action	.40*	.05	.05	.10	.02	.20	.00	-.15	-.17	.15	1.00

(ToC SF: Task-oriented Communication During Strategy Formulation, CA: Communication Awareness, ToC Action: Task-oriented Communication During Action, * $p < .05$)

Table 7. Correlations (Study 2)											
	Effec-tiven.	Effi-ciency	Age	Gen-der	GPA	Input	Offl.	Part.	ToC SF	CA	ToC Act.
Effectiveness	1.00										
Efficiency	.59*	1.00									
Age	.27	.28	1.00								
Gender	.38*	.26	.33	1.00							
GPA	-.16	-.03	-.39*	-.34*	1.00						
Input	-.15	-.26	.15	.17	-.45*	1.00					
Offline Com.	.15	.06	.12	.28	.06	-.10	1.00				
Participation	-.09	-.06	-.43*	-.32	.34*	-.28	-.09	1.00			
ToC SF	.18	-.20	-.18	-.05	.19	.19	.24	.18	1.00		
CA	.14	.20	.05	-.13	.32	.02	-.01	.28	.22	1.00	
ToC Action	.22	-.06	-.04	.16	.00	-.16	-.08	.04	-.15	-.08	1.00

(ToC SF: Task-oriented Communication During Strategy Formulation, CA: Communication Awareness, ToC Action: Task-oriented Communication During Action, * p < .05)

H1a/b predicted positive associations between task-oriented communication during action and the two performance dimensions, effectiveness (a) and efficiency (b). We refer to model 2 in testing these hypotheses. Table 8 shows significant positive associations between task-oriented communication during action and *effectiveness* in study 1 (β = .37, p < .01), in the pooled dataset (β = .31, p < .01), but not in study 2 (β = .18, p > .05). Thus, H1a is partially supported. Table 9 fails to show significant associations between task-oriented communication during action and *efficiency* in study 1 (β = .02, p > .05), in study 2 (β = -.16, p > .05), or in the pooled dataset (β = -.04, p > .05). Hence, H1b is not supported.

H2a/b predicted a positive interaction effect of CA on the association between task-oriented communication during action and performance. We refer to model 3a in testing these hypotheses. Table 8 shows significant positive interaction effects relative to *effectiveness* in study 1 (β = .40, p < .05), in study 2 (β = .52, p < .05), and in the pooled dataset (β = .34, p < .05). Table 9 shows significant positive interaction effects relative to *efficiency* in study 1 (β = .46, p < .01), in study 2 (β = .59, p < .05), and in the pooled dataset (β = .41, p < .01). Thus, H2a and H2b are supported in both studies.

Table 8. Regression Results: Effectiveness

Variables	Study 1				Study 2				Pooled Data			
	Model 1	Model 2	Model 3a[a]	Model 3b[a]	Model 1	Model 2	Model 3a[a]	Model 3b[a]	Model 1	Model 2	Model 3a[a]	Model 3b[a]
Intercept	.00 (.13)	.00 (.12)	.00 (.12)	.00 (.12)	.00 (.15)	.00 (.15)	.00 (.14)	.00 (.15)	.00 (.10)	.00 (.10)	.00 (.10)	.00 (.10)
Age	**.36** (.13)**	**.36** (.12)**	**.41** (.12)**	**.35** (.13)**	.21 (.19)	.14 (.19)	.07 (.18)	.14 (.19)	**.30** (.11)**	**.31** (.11)**	**.32** (.10)**	**.30** (.11)**
Gender	.07 (.15)	-.01 (.14)	.05 (.14)	-.01 (.14)	.35 (.18)	.31 (.18)	.33 (.17)	.29 (.19)	.14 (.11)	.08 (.11)	.11 (.11)	.08 (.11)
GPA	.25 (.14)	.25 (.13)	**.26* (.12)**	.24 (.13)	-.21 (.20)	-.31 (.21)	-.41 (.20)	-.29 (.21)	.17 (.11)	.15 (.11)	.16 (.10)	.14 (.10)
Input Other Teams	-.02 (.13)	-.10 (.13)	-.08 (.12)	-.10 (.13)	**-.42* (.19)**	**-.44* (.20)**	**-.63** (.21)**	-.41 (.20)	-.09 (.11)	-.11 (.10)	-.15 (.10)	-.10 (.10)
Offline Comm.	-.17 (.14)	-.16 (.13)	-.13 (.12)	-.16 (.13)	-.09 (.18)	-.06 (.17)	-.18 (.17)	-.05 (.18)	-.09 (.11)	-.08 (.10)	-.11 (.10)	-.08 (.10)
Participation	-.11 (.14)	-.05 (.13)	-.10 (.13)	-.07 (.13)	-.01 (.19)	-.10 (.19)	.06 (.19)	-.11 (.19)	-.10 (.11)	-.09 (.10)	-.05 (.10)	-.11 (.10)
ToC SF	-.20 (.14)	-.11 (.14)	-.10 (.13)	-.06 (.16)	**.38* (.18)**	.37 (.18)	**.41* (.17)**	**.44* (.20)**	-.03 (.11)	.04 (.11)	.05 (.11)	.13 (.13)
CA	-	-.01 (.13)	-.01 (.12)	-.02 (.13)	-	.25 (.18)	.24 (.17)	.26 (.18)	-	.05 (.10)	.05 (.10)	.05 (.10)
ToC Action	-	**.37** (.13)**	.06 (.19)	**.35* (.14)**	-	.18 (.16)	-.18 (.23)	.18 (.16)	-	**.31** (.10)**	.08 (.14)	**.28** (.10)**
ToC Action × CA	-	-	**.40* (.18)**	-	-	-	**.52* (.24)**	-	-	-	**.34* (.13)**	-
ToC SF × CA	-	-	-	-.10 (.15)	-	-	-	-.16 (.19)	-	-	-	-.18 (.12)
Adjusted R²	.17	.27	.33	.26	.17	.20	.30	.19	.08	.17	.22	.18
R²	.28	.40	.46	.41	.34	.41	.50	.43	.16	.25	.31	.28
ΔR²	.28	.12	.06	.01	.34	.07	.09	.02	.16	.09	.06	.02
F	**2.41***	**3.06****	**3.47****	**2.76***	1.98	1.92	**2.43***	1.78	2.11	**2.87****	**3.42****	**2.86****
F Change	**2.41***	**4.11***	**4.69***	.41	1.98	1.47	**4.55***	.68	2.11	**4.80***	**6.47***	2.35

(ToC SF: Task-Oriented Communication During Strategy Formulation; CA: Communication Awareness; ToC Action: Task-Oriented Communication During Action; standardized coefficients shown; standard errors in parentheses, [a] model comparisons contrast model 3a to model 2 and model 3b to model 2, *p < .05, **p < .01, *** p < .001)

	Study 1				Study 2				Pooled Data			
Table 9. Regression Results: Efficiency												
Variables	**Model 1**	**Model 2**	**Model 3a**[a]	**Model 3b**[a]	**Model 1**	**Model 2**	**Model 3a**[a]	**Model 3b**[a]	**Model 1**	**Model 2**	**Model 3a**[a]	**Model 3b**[a]
Intercept	.00 (.14)	.00 (.13)	.00 (.13)	.00 (.13)	.00 (.17)	.00 (.16)	.00 (.15)	.00 (.17)	.00 (.11)	.00 (.10)	.00 (.10)	.00 (.10)
Age	.08 (.14)	.07 (.14)	.13 (.13)	.07 (.14)	.26 (.20)	.14 (.21)	.07 (.19)	.14 (.21)	.14 (.11)	.12 (.11)	.13 (.11)	.11 (.11)
Gender	-.24 (.16)	-.22 (.15)	-.15 (.15)	-.22 (.16)	.26 (.20)	.30 (.20)	.33 (.18)	.30 (.20)	-.03 (.12)	.01 (.12)	.05 (.11)	.01 (.12)
GPA	.09 (.15)	.12 (.14)	.13 (.14)	.12 (.15)	.02 (.22)	-.11 (.23)	-.23 (.22)	-.11 (.23)	.11 (.11)	.09 (.11)	.1 (.11)	.09 (.11)
Input Other Teams	-.06 (.14)	-.07 (.14)	-.05 (.13)	-.07 (.14)	-.30 (.21)	-.40 (.21)	**-.62** (.22)	-.39 (.22)	-.15 (.11)	-.15 (.11)	-.19 (.10)	-.15 (.11)
Offline Comm.	-.19 (.15)	-.22 (.14)	-.19 (.14)	-.22 (.14)	-.05 (.19)	-.05 (.19)	-.19 (.18)	-.05 (.19)	-.11 (.11)	-.13 (.11)	-.16 (.10)	-.13 (.11)
Participation	-.19 (.14)	-.13 (.14)	-.18 (.14)	-.13 (.15)	.06 (.20)	-.03 (.21)	.15 (.21)	-.04 (.21)	-.15 (.11)	-.15 (.11)	-.11 (.10)	-.16 (.11)
ToC SF	.00 (.15)	.01 (.15)	.02 (.15)	.00 (.18)	-.09 (.20)	-.13 (.19)	-.09 (.18)	-.10 (.22)	-.09 (.11)	-.12 (.11)	-.10 (.11)	-.08 (.13)
CA	-	**.28*** (.14)	**.28*** (.13)	.28 (.14)	-	.30 (.19)	.30 (.18)	.31 (.20)	-	**.27*** (.11)	**.27*** (.10)	.27 (.11)
ToC Action	-	.02 (.14)	-.34 (.21)	.02 (.15)	-	-.16 (.17)	**-.57*** (.24)	-.16 (.18)	-	-.04 (.11)	**-.31*** (.14)	-.05 (.11)
ToC Action × CA	-	-	**.46*** (.20)	-	-	-	**.59*** (26)	-	-	-	**.41**** (.14)	-
ToC SF × CA	-	-	-	.00 (.17)	-	-	-	-.07 (.21)	-	-	-	-.08 (.13)
Adjusted R²	.06	.11	.19	.09	.02	.07	.21	.04	.03	.08	.16	.07
R²	.19	.27	.35	.27	.23	.32	.44	.32	.11	.18	.26	.18
ΔR²	.19	.08	.08	.00	.23	.09	.12	.00	.11	.07	.08	.00
F	1.46	1.68	**2.18***	1.47	1.12	1.30	1.89	1.14	1.35	1.81	**2.64****	1.65
F Change	1.46	2.16	**5.17***	.00	1.12	1.71	**5.25***	.10	1.34	**3.16***	**8.57****	.42

(ToC SF: Task-Oriented Communication During Strategy Formulation; CA: Communication Awareness; ToC Action : Task-Oriented Communication During Action Episodes; standardized coefficients shown; standard errors in parentheses, [a] model comparisons contrast model 3a to model 2 and model 3b to model 2, *p < .05, **p < .01, *** p < .001)
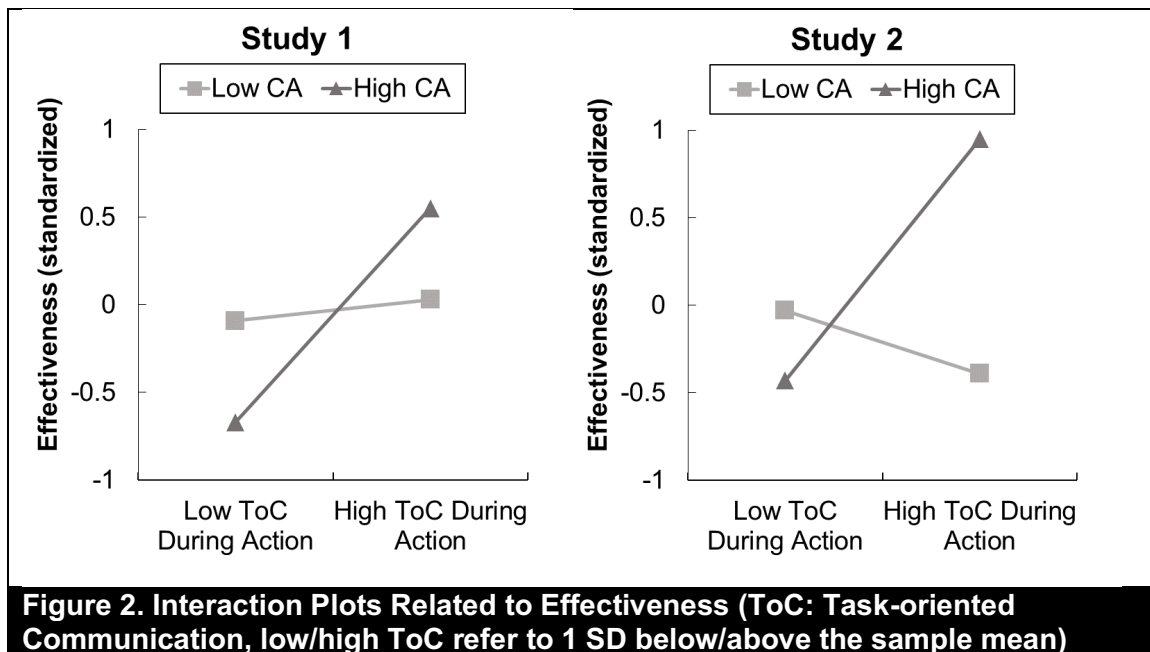
Two sets of results deserve further attention. First, across both studies and both dependent variables, model fit was highest in model 3a—the model that includes the interaction of CA and task-related communication *during action* (effectiveness: R^2 of .46 in study 1 and of .50 in study 2; efficiency: R^2 of .35 in study 1, and of .44 in study 2). Moreover, the differences in model fit between model 2 and model 3a were statistically significant (F test, $p < .05$ for both studies and both dependent variables) and substantial (effectiveness: ΔR^2 of .06 in study 1 and of .09 in study 2; efficiency: ΔR^2 of .08 in study 1 and of .12 in study 2). Conversely, adding a term for the interaction of task-oriented communication *during strategy formulation* and performance from model 2 to model 3b did *not* yield significant increases in model fit relative to model 2 in any study. Hence, the regression results demonstrate substantial positive interaction effects of CA with task-oriented communication during action but not with task-oriented communication during strategy formulation. Second, the regression results show a significant main effect of CA on efficiency in study 1 ($\beta = .28$, $p < .05$) and in the pooled dataset ($\beta = .27$, $p < .05$). Hence, overall, teams assigned to the high-CA condition achieved a given level of output quality with lower taskwork effort than teams assigned to the low-CA condition.

Interaction Plots

Figure 2 and Figure 3 illustrate the regression results through interaction plots. Figure 2 shows the relationship of task-oriented communication during action and *effectiveness* for teams assigned to different conditions (low CA vs. high CA). The plots show relatively flat slopes for teams assigned to the low-CA condition (see the lines marked by squares). The slope was marginally positive in study 1 (left-hand side of Figure 2) and marginally negative in study 2 (right-hand side of Figure 2). The relatively flat slopes indicate that the effectiveness of teams in the low-CA condition hardly depended on their amount of task-oriented communication during action episodes. Conversely, the plots show steep positive slopes for teams assigned to the high-CA condition (see the lines marked by triangles), both in study 1 and in study 2. This

suggests that, in both studies, only teams assigned to the high-CA condition were able to achieve high effectiveness with high amounts of task-oriented communication during action.

Figure 3 shows the relationships of task-oriented communication during action and efficiency. The plots show negative slopes for teams assigned to the low-CA condition (see the lines marked by squares) both in study 1 (left-hand side) and in study 2 (right-hand side). Hence, the more teams in the low-CA condition engaged in task-oriented communication during action, the less efficient they were. Conversely, the lines marked by triangles show positive slopes for teams assigned to the high-CA condition. Hence, teams in the high-CA condition were more efficient when they engaged in greater amounts of task-oriented communication during action. Interestingly, the Figure 3 shows that teams with low amounts of task-oriented communication during action were about similarly efficient on both platforms. The overall difference in efficiency between technological conditions stemmed, hence, from teams that engaged in high amounts of task-oriented communication. These teams were by far more efficient when they were assigned to the high-CA condition.

Figure 2. Interaction Plots Related to Effectiveness (ToC: Task-oriented Communication, low/high ToC refer to 1 SD below/above the sample mean)

Figure 3. Interaction Plots Related to Efficiency (ToC: Task-oriented Communication)
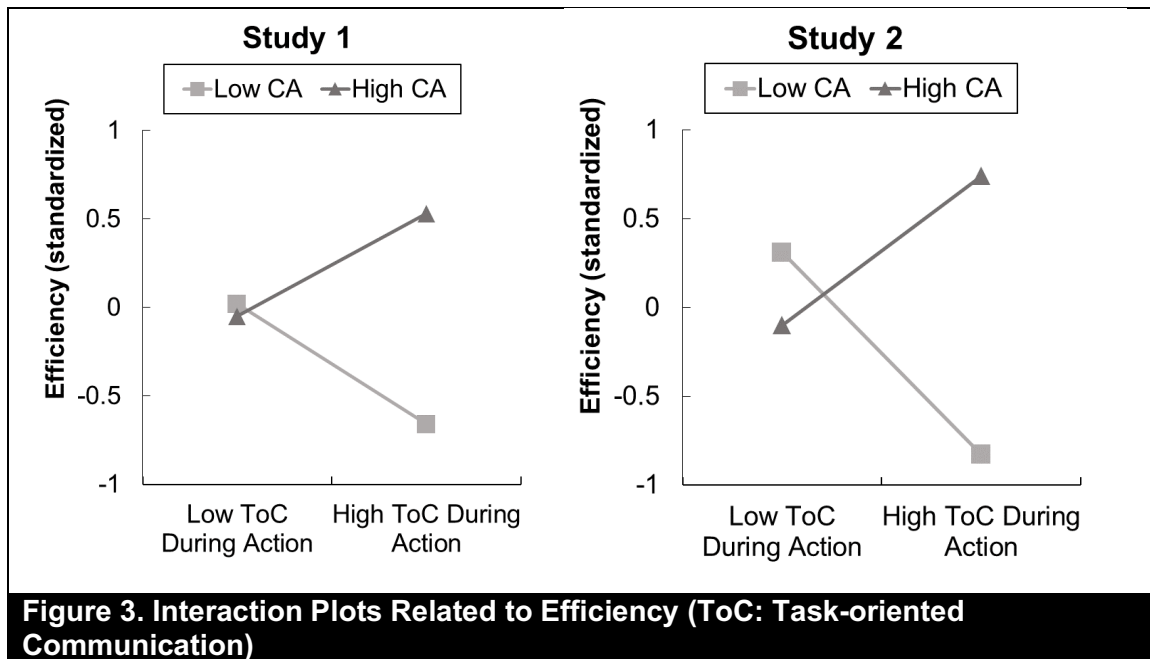
Post-hoc Analysis: Pacing of Task-oriented Communication During Action

The preceding analysis suggests that only teams in the high-CA condition were able to achieve high performance through task-oriented communication. We performed a first post-hoc analysis to examine how their task-oriented communication during action was distinctive from that of other teams. Because our theorizing points to the role of pacing, we compared a set of pacing indicators between different technological conditions and different performance levels. We divided the sample into low-performing and high-performing teams, where high-performing teams were teams with effectiveness greater than the median of each study.

Table 10 presents the results for study 1 (top segment of the table), study 2 (mid segment of the table), and the pooled data (bottom segment of the table). In each segment, the first row shows the overall amount of messages that referred to task-oriented communication during action. There were no significant differences in this overall amount of messages between technological conditions within each performance group. In contrast, we noted several significant

differences in the subsequent rows, which focus on the pacing of communication. The significant differences all referred to high-performing teams.

A number of indicators show that high-performing teams in the high-CA condition engaged in *earlier* task-oriented communication during action than high-performing teams in the low-CA condition. Specifically, high-performing teams in the high-CA condition sent greater *absolute* amounts of messages in the first half of the collaboration than high-performing teams in the low-CA condition (see the second and third row in each segment). For instance, in study 1, high-performing teams in the high-CA condition sent 11.9 messages until the midpoint by time, whereas high-performing teams in the low-CA condition sent only 4.7 messages within this period. The differences in amount of messages in the first half were statistically significant for study 1 and the pooled data ($p < .05$, Mann-Whitney Test). In study 2, high-performing teams in the high-CA condition sent more messages in the first half than high-performing teams in the low-CA condition, but the differences were not significant. High-performing teams in the high-CA condition also sent greater *relative* amounts of messages in the first half of the collaboration than high-performing teams in the low-CA condition (see the fourth and fifth row in each segment). For example, in study 1, high-performing teams in the high-CA condition sent, on average, 42% of their task-oriented communication during action until the midpoint by time, whereas high-performing teams in the low-CA condition sent only 19% within in this period. These differences were statistically significant for midpoints by time in study 1, and for midpoints by time and by amount of messages in the pooled data ($p < .05$, Mann-Whitney Test).

| Table 10. Pacing Indicators for Teams of High versus Low Effectiveness									
	Low-Performing Teams (Low Effectiveness)			**High-Performing Teams (High Effectiveness)**			**All Teams**		
Indicator	**Low CA**	**High CA**	**Δ**	**Low CA**	**High CA**	**Δ**	**Low CA**	**High CA**	**Δ**
Study 1	*n=14*	*n=12*		*n=12*	*n=13*		*n=26*	*n=25*	
ToC during action (no. of messages)	18.0	16.1	-1.9	19.6	28.5	9.0	18.7	22.6	3.8
ToC during action (no. of messages) until action episode midpoint by time	6.1	5.7	-0.5	**4.7**	**11.9**	**7.2***	5.5	8.9	3.5
ToC during action (no. of mess.) until action episode midpoint by amount of messages	9.1	9.0	-0.1	**8.3**	**17.3**	**9.0***	8.8	13.3	4.6
Fraction of ToC during action until action episode midpoint by time	46%	35%	-11%	**19%**	**42%**	**23%***	33%	38%	5%
Fraction of ToC during action until action episode midpoint by amount of messages	62%	55%	-7%	35%	60%	25%	50%	57%	7%
Number of days with ToC during action	6.3	5.6	-0.7	**5.3**	**7.0**	**1.7***	5.8	6.3	.5
Study 2	*n=10*	*n=9*		*n=7*	*n=9*		*n=17*	*n=18*	
ToC during action (no. of messages)	7.3	6.1	-1.2	9.4	7.5	-1.9	8.2	6.8	-1.3
ToC during action (no. of messages) until action episode midpoint by time	5.2	3.2	-2.0	6.7	7.7	1.0	5.8	5.4	-.4
ToC during action (no. of mess.) until action episode midpoint by amount of messages	6.2	5.7	-.5	10.7	13.4	2.7	8.1	9.6	1.5
Fraction of ToC during action until action episode midpoint by time	40%	17%	-23%	31%	37%	6%	37%	27%	-9%
Fraction of ToC during action until action episode midpoint by amount of messages	48%	35%	-13%	60%	73%	13%	53%	54%	2%
Number of days with ToC during action	4.5	3.9	-.6	4.1	6.6	2.4	4.4	5.2	.9
Pooled data (standardized values expect for percentages)	*n=24*	*n=21*		*n=19*	*n=22*		*n=43*	*n=43*	
ToC during action (standardized no. of messages)	-.12	-.39	-.27	.08	.43	.35	-.03	.03	.06
ToC during action (standardized no. of messages) until action episode midpoint by time	-.10	-.25	-.15	**-.14**	**.47**	**.61***	-.12	.12	.23
ToC during action (standardized no. of messages) until action episode midpoint by amount of messages	-.24	-.28	-.04	**-.09**	**.61**	**.70***	-.18	.18	.35
Fraction of ToC during action until action episode midpoint by time	44%	27%	-17%	**23%**	**40%**	**17%***	35%	34%	-1%
Fraction of ToC during action until action episode midpoint by amount of messages	56%	47%	-9%	**44%**	**65%**	**21%***	51%	56%	5%
Number of days with ToC during action	.01	-.25	-.26	**-.28**	**.48**	**.76***	-.12	.12	.24

(ToC: Task-oriented communication, Δ: High-CA teams minus low-CA teams, *difference between high-CA and low-CA teams statistically significant at p < .05)

The figures also show that high-performing teams in the high-CA condition engaged in *steadier* task-oriented communication during action than high-performing teams in the low-CA condition, as indicated by the number of days on which messages were sent (see the last row in each segment). For example, in study 1, high-performing teams in the high-CA condition sent messages on 7.0 distinct days, whereas high-performing teams in the low-CA condition sent messages on only 5.3 distinct days. These differences were statistically significant in study 1 and in the pooled data ($p < .05$, Mann-Whitney Test). In study 2, high-performing teams in the high-CA condition also sent messages on more days (6.6 versus 4.1) than high-performing teams in the low-CA condition, although the difference was not statistically significant.

Table 10 shows no significant differences between technological conditions among low-performing teams (see the columns on the left-hand side) and in the overall sample (i.e., teams that are not separated by performance, see columns on the right-hand side).

Although the preceding analysis compared teams of different effectiveness levels, the analysis of teams of different efficiency levels yielded qualitatively similar results. These results are shown in Appendix F.

The results from this post-hoc analysis provide a refined perspective on the role of pacing. Teams in the high-CA condition did not universally engage in earlier or steadier task-oriented communication during action than teams in the low-CA condition. Instead, it appears that teams in the high-CA condition were more able to benefit from early and timely communication than teams in the low-CA condition. Only in the high-CA condition was a pattern of early and steady task-oriented communication associated with high performance. This suggests the refinement of our research model shown in Figure 4. Technology-enabled CA makes task-oriented communication during action episodes more beneficial only if the pacing of this communication is characterized by *earliness* and *steadiness*.

Figure 4. Refined Research Model
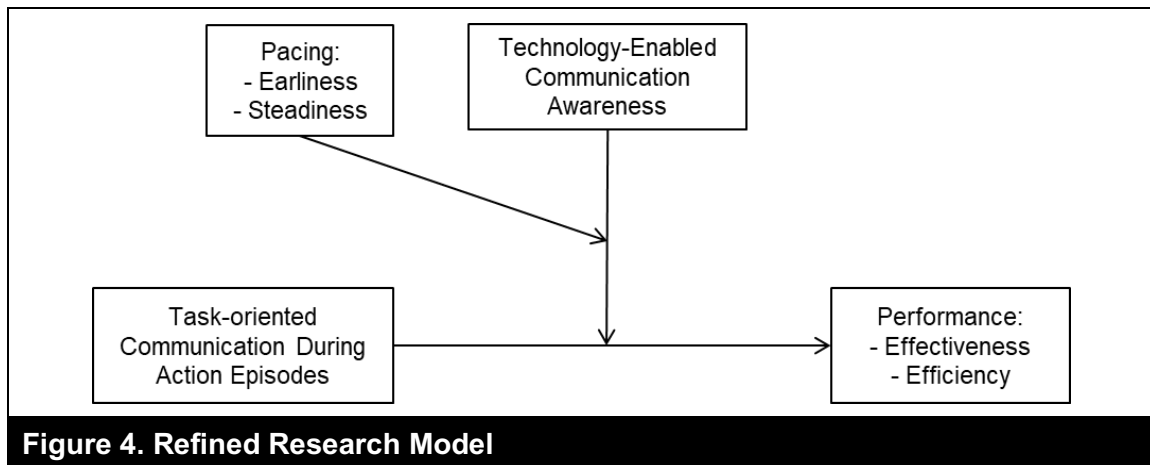
Post-hoc Analysis: Effort

An unexpected finding was that teams in the high-CA condition were overall more efficient than teams in the low-CA condition, a difference that was significant in study 1 and in the pooled data. We performed a second post-hoc analysis to scrutinize this finding. We examined whether teams in the high-CA condition had merely substituted taskwork effort (i.e., effort for editing shared artifacts), which was the focus of our efficiency measure, by communication effort (i.e., effort for sending task-oriented communication during action), which was not captured by our efficiency measure. The total number of characters of all task-oriented communication messages during action is a reasonable proxy for this communication effort. The higher the overall number of characters, the more time does it take team members to write and read these messages. Table 11 shows taskwork effort and communication effort (measured through the proxy of number of characters) for different performance groups and studies. The results were highly consistent across performance groups and studies. Indicators of communication effort were lower, not higher, in the high-CA condition. For instance, in study 1, teams in the high-CA condition spent not only lower taskwork efforts than teams in the low-CA condition (19.2 instead of 25.4 hours) but also somewhat lower communication efforts as indicated by the total length of messages (5,450 instead of 5,928 characters). These numbers corroborate our assertion that

teams in the high-CA condition were overall more efficient than teams in the low-CA condition. Importantly, although teams in the high-CA condition reaped greater benefits from task-oriented communication during action than teams in the low-CA condition, they did not appear to spend greater efforts on it.

Table 11. Effort Indicators for Teams of High versus Low Effectiveness									
	Low-Performing Teams (Low Effectiveness)			High-Performing Teams (High Effectiveness)			All Teams		
Indicator	Low CA	High CA	Δ	Low CA	High CA	Δ	Low CA	High CA	Δ
Study 1	*n=14*	*n=12*		*n=12*	*n=13*		*n=26*	*n=25*	
Taskwork effort (artifact editing in hours)	23.1	15.4	-7.8	28.0	22.8	-5.2	**25.4**	**19.2**	**-6.2***
Communication effort (no. of characters of ToC during action)	4659	4083	-576	7409	6713	-696	5928	5450	-478
Study 2	*n=10*	*n=9*		*n=7*	*n=9*		*n=17*	*n=18*	
Taskwork effort (artifact editing in hours)	7.3	6.1	-1.2	9.4	7.5	-1.9	8.2	6.8	-1.3
Communication effort (no. of characters of ToC during action)	5272	3082	-2190	6422	5141	-1281	5745	4112	-1633
Pooled data	*n=24*	*n=21*		*n=19*	*n=22*		*n=43*	*n=43*	
Taskwork effort (artifact editing in hours, standardized)	.03	-.47	-.50	.44	.03	-.41	**.21**	**-.21**	**-.43***
Communication effort (no. of characters of ToC during action, std.)	-.09	-.40	-.30	.38	.16	-.22	.11	-.11	-.23

(ToC: Task-oriented communication, Δ: High-CA teams minus low-CA teams, * difference between high-CA and low-CA teams statistically significant at p < .05)

DISCUSSION

In this research, we set out to study how technology-enabled communication awareness (CA) influences the effectiveness and efficiency of project team communication during action episodes. Two underlying motivations were: (1) the ambiguity of empirical results regarding the association between the amount of team communication during action episodes and team performance and (2) the lack of research that examines how technology-enabled CA affects collaboration during particular episodes of projects longer than few hours. To gain insight into these issues, we drew on research on team episodes, team communication, and awareness

systems. The results of two studies yielded two sets of key findings. First, technology-enabled CA strengthens the relationships between task-oriented communication during action episodes and team performance (effectiveness, efficiency). Second, high-performing teams in the high-CA conditions stand out by early and steady task-oriented communication during action. We discuss the implications of these findings for research on team communication and on awareness systems.

Theoretical Implications

Research on Team Communication

Although there is reason to believe that frequent communication during action episodes (e.g. in form of helping and coordinating each other) is critical for team performance (LePine et al., 2008), studies have failed to find significant associations between communication during later collaboration episodes and team performance (Kanawattanachai & Yoo, 2007; Weisband, 2002). This raises the question of why the performance of project teams should not depend on their communication during action episodes. Project teams rely on the progressive elaboration of ideas and plans over time (Chiocchio & Essiembre, 2009); thus why should more communication after initial planning not pay out? In this paper, we advance the idea that beyond the sheer amount of team communication during action episodes, it is the awareness of this communication that matters. Specifically, we argue that as far as communication in teams is increasingly computer mediated, it is technology-enabled communication awareness that matters. The results from our two studies provide support for this idea. We found only partial support for a positive relationship between task-oriented communication during action and team performance that would hold irrespective of technological conditions (see our mixed results on H1a/b). However, we were able to demonstrate strong positive associations between task-oriented communication during action and team performance in those teams that were equipped

with technology-enabled communication awareness (see our results on H2a/b and the interaction plots). Extending common views in the communication literature (Kanawattanachai & Yoo, 2007; Weisband, 2002), this suggests that teams *can* strongly benefit from task-oriented communication during later collaboration periods if they use ICT that addresses the needs of the collaboration episode, in particular a feed that helps teams cope with the distributed foci of attention characteristic of action episodes. More broadly, our results suggest that findings on team communication that were obtained under a single ICT-supported condition (Espinosa et al., 2015; Kanawattanachai & Yoo, 2007; Weisband, 2002) need not necessarily transfer to alternative ICT conditions, even if the differences between the ICT conditions are subtle, such as the availability of a feed. We therefore join a recent call by Malhotra and Majchrzak (2014) to incorporate greater variance in the *type* of ICT support into research on team communication.

Research on Awareness Systems

Our paper also contributes to awareness systems research by addressing three critical gaps in this literature. First and foremost, our study is among the first to demonstrate statistically significant support for the key idea of the attention-drawing perspective that technology-enabled awareness facilitates collective action by turning individuals' attention to the team (Dabbish et al., 2013; Dehler et al., 2009; Heath et al., 2002; Schmidt, 2002).

In both of our two studies, we found that teams were able to excel through task-oriented communication (i.e., a collective activity, being constituted by the interaction of members) only if provided with technology-enabled awareness. This collective avenue to high effectiveness in the high-CA condition contrasts with a rather individualistic avenue to high effectiveness in the low-CA condition. Although teams in the low-CA condition were also able to achieve high effectiveness, they achieved this not by leveraging team communication but by spending substantially higher efforts on taskwork (see our results on efficiency and Table 11). In contrast to

communication, taskwork is individual activity. It "describes functions that *individuals* must perform to accomplish the team's task, whereas teamwork describes the *interaction* of team members" (Mathieu, Maynard, Rapp, & Gilson, 2008, p. 420, emphasis added). We argue that teams in the low-CA condition relied on this individualistic approach because they lacked the ICT support required to leverage a collective (teamwork-based) approach. The attention-drawing perspective is further informed by our analysis of pacing. We found that high-performing teams in the high-CA condition stood out by early and steady communication. Endorsing an attention-drawing perspective, we argue that technology-enabled awareness frequently directs the attention of these individuals to their team, inviting them to ongoingly trigger and respond to conversations (Heath et al., 2002; Schmidt, 2002). In line with these ideas, those teams that leveraged the action potential for early and steady communication offered by the platform (i.e., teams that were in the high-CA condition and engaged in early and frequent communication) were precisely those teams that benefited most from task-oriented communication (high-performing teams in the high-CA condition, see our first post-hoc analysis). In conclusion, our findings provide support for the so far untested assertion that awareness systems help transform individualistic into more collective activity.

A second gap in the awareness systems literature is its scant attention to CA, notably at a time when technology-enabled CA is rapidly diffusing in contemporary organizations through SMPs. Our paper is among the first to provide statistically significant evidence of the specific ways in which technology-enabled CA shapes asynchronous project team collaboration. We show that technology-enabled CA enhances the effectiveness and efficiency of project team communication. Moreover, it allows teams to benefit from a rhythm of early and steady communication. These findings are somewhat related to Bradner and colleagues' qualitative observation that CA allows unobtrusive broadcasting and staying in the loop (Bradner et al., 1999; Erickson & Kellogg, 2000). Our findings add that although technology-enabled CA may be less intrusive

than, for instance, phone calls, it may enable "appropriate obtrusiveness" (Schmidt, 2002, p. 292). It draws others' attention to conversations and stimulates them to participate. In this sense, technology-enabled CA is more than an unobtrusive means for broadcasting and staying informed; it is a means subtly attracting team members' attention and for triggering and advancing conversations with them at the right moment.

Last but not least, a third gap in awareness systems research is its scant attention to the needs associated with particular collaboration episodes. Indeed, it is difficult to find awareness systems research that theorized or empirically examined distinct collaboration episodes. Our study is a first step in this direction. By drawing on research on team episodes, we argue that action episodes with their *distributed foci of attention* and multitasking pose challenges that are distinct from, for instance, those of strategy formulation, where teams have a shared focus on developing one team strategy. We argue that technology-enabled CA, which draws individuals' attention to the team, helps teams cope with these specific challenges of action episodes. Our studies provide support for these ideas. We found strong interaction effects of technology-enabled CA with task-oriented communication during action (see our results on model 3a) but not with task-oriented communication during strategy formulation (see our results on model 3b). Our study contributes thus to a more fine-grained understanding of what types of awareness support are beneficial to teams at what stage.

Finally, we believe that our unique study design was instrumental to these three contributions. While awareness systems researchers have rarely manipulated technological conditions in collaborations longer than a day, we conducted two studies of multi-week collaborations in which we manipulated awareness features and were able to replicate key findings.

Limitations and Directions for Future Research

We acknowledge several limitations, which provide opportunities for future research. First, we did not implement dependencies between team members such as by providing single members with exclusive information (Okhuysen & Eisenhardt, 2002). As a result, team members might have been able to circumvent the need for communication. This may explain why teams in the low-CA condition were also able to achieve high effectiveness through other means than communication, such as by individually expending high amounts of taskwork effort. Future research could gain additional insights into how teams cope with communication challenges by implementing conditions of high task interdependence, under which team processes are more critical (LePine et al., 2008). Yet, while more extreme conditions may bring additional insights, we showed important differences between technological conditions even in absence of strong dependencies. Second, although we manipulated CA and found more effective task-oriented communication during action, enhanced collective activity (such as more effective communication) has also been observed when other types of awareness were manipulated (although not at statistically significant levels) (Dehler et al., 2009). Future research could combine various types of awareness manipulations in one study to examine to what extent the specific types of awareness support (e.g. CA, participation awareness) affect specific types of collective activity (e.g. more effective communication, more equal participation). Third, while our paper focuses on positive consequences of SMP use, there is an increasing body of research on the negative consequences of SMP use. Researchers have argued or shown that SMP use yields cognitive overload (Freyne, Berkovsky, Daly, & Geyer, 2010), technostress (Maier, Laumer, Weinert, & Weitzel, 2015), and envy (Krasnova, Widjaja, Buxmann, Wenninger, & Benbasat, 2015). These consequences may not have been very salient in our setting, where teams used the SMP to work on one project only. However, negative consequences, such as overload and technostress, may be more salient in real organizational settings where feeds show messages from many teams and individuals working on a variety of topics. Important questions are whether

feeds are also beneficial in these conditions, how SMPs should pre-select the information to be displayed in feeds to avoid overloading individuals, and how positive and negative consequences of SMP use interact. Although these are important questions, using a relatively controlled setting in our studies was instrumental in demonstrating the potential effects of technology-enabled CA. Fourth, our paper does not focus on implementation strategies. Future research could examine structuring attempts such as collaboration scripts or real-time interventions, as scholars do in a collaboration engineering paradigm (de Vreede, Briggs, & Massey, 2009; Massey et al., 2003). Such structuring attempts are likely to shape team processes and the resultant outcomes (Niederman et al., 2008). For instance, future work could draw on our findings on pacing and examine how scripts for temporal coordination (Massey et al., 2003) affect team communication on SMPs and the resulting outcomes. Future research could also examine how interventions described in SMP research (Laumer, Shami, Muller, & Geyer, 2017) affect team communication.

Practical Implications

Much of the innovativeness and adaptability of contemporary organizations emanates from project teams. A key challenge for project teams is to progressively elaborate plans and ideas while new insights crystallize, work progresses, and external conditions change. Our paper shows that ICT can play an important role in this mission. Especially in settings where asynchronous multitasking prevails, project teams should consider leveraging technology-enabled communication awareness, such by collaborating over social media platforms. Social media platforms are likely to enable project teams to maintain a coherent stream of timely and steady communication after responsibilities are defined and tasks are distributed. Those teams that use the social media platform to frequently communicate may achieve superior outcomes with reduced efforts. Organizations should not only make social media platforms available to their

project teams, they should also encourage early and frequently communication over the platform while members work on their tasks. Organizations may incorporate these recommendations in project management trainings and communication guidelines.

CONCLUSION

Teams are not collections of taskworkers; they are collectives that interact to create something that is beyond the reach of individuals (Salas et al., 1992). Our article shows that technology-enabled CA can help enable this distinctive interactive quality of teams. Results from two studies demonstrate that technology-enabled CA allows teams to benefit from team communication in episodes in which individuals devote their attention to their individual taskwork. In this sense, technology-enabled CA helps teams to leverage teams.

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APPENDIX A: SCREENSHOTS

Low-Communication Awareness Condition

The following figures illustrate the user interface and capabilities of the platform in the low-CA condition. The figures show mock-ups that we created with a design tool. We used mock-ups to improve the readability of the screenshots, to translate text into English, and to protect the privacy of the study participants. The figures are schematic, but accurate representations of the actual tool. They include actual communication that has been translated into English. The names of the participants are pseudonyms.

Figure 5 shows the team page. Call-outs show how users could trigger tool capabilities by clicking on elements of the team page. These capabilities include:

(1) Communicating by (1a) clicking the envelope to view or send direct message (see Figure 6), by (1b) clicking forum topic to view or make forum posts (see Figure 7), and by (1c) viewing or updating user profiles (see Figure 8)

(2) Relationship building by viewing and modifying friend relationships (see Figure 8)

(3) Concurrent artifact editing by clicking artifacts (such as "Answer document") in order to be redirected to Google Docs
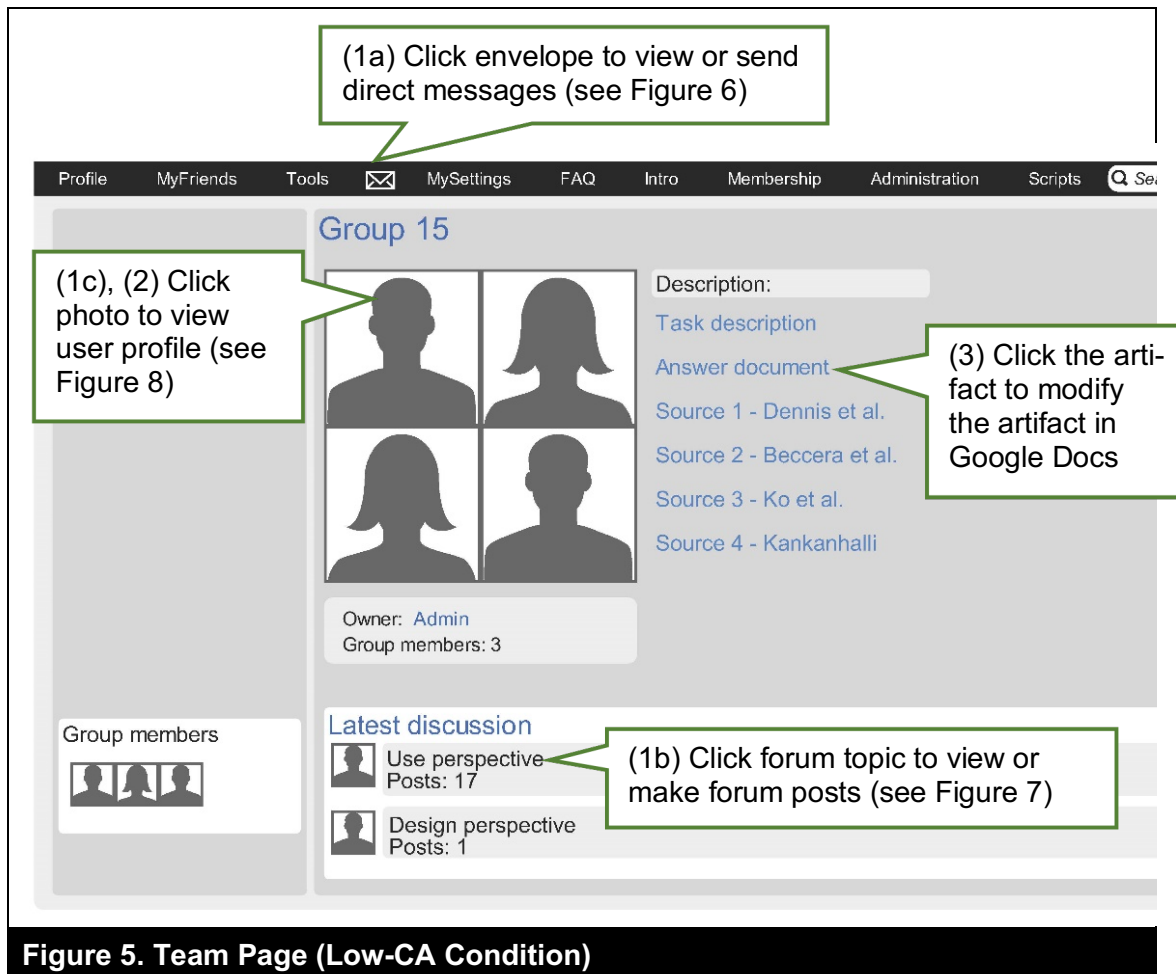
Figure 5. Team Page (Low-CA Condition)
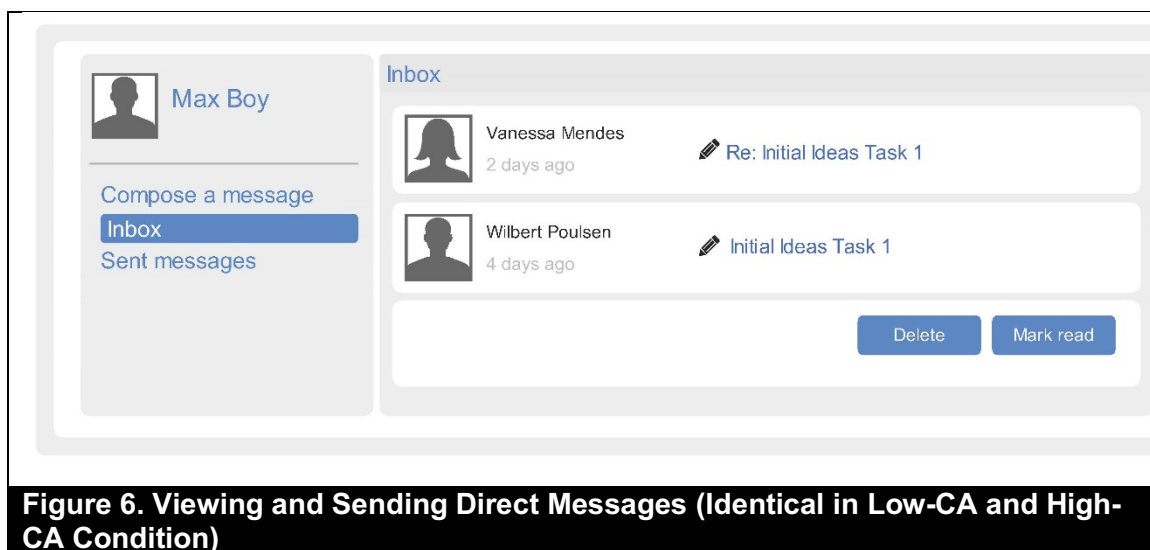
Figure 6. Viewing and Sending Direct Messages (Identical in Low-CA and High-CA Condition)

Use Perspective

	Svenja Ruge	Hi Girls!
	3 days	I'm Svenja, and I guess we are going to do the group work together.
		How are we going to do it?
		Svenja

Delete Edit

	Lisa Seubert	Hi you,
	2 days	Im not sure how to submit the group work - I connot find any information...?
		I'm planing to work on it in the end of this week and next week.
		I haven't done anything yet.
		Do you want to meet? I don't really have a lot of time. I could do Monday morning or
		Thursday afternoon. Maybe it's possible to do the whole thing online.
		Greetings,

	Astrid Drexl	Hi everyone!
	2 days	I'm working a lot and I'm not that often at university. I'm free on Wednesday and
		Thursday afternoon.
		It makes no difference to me how we organize it.... Anyway I think it could work out
		online.
		I guess we have to submit it on 17/18 of May.
		Cheers,
		Astrid

Post a comment

Post

Figure 7. Viewing and Making Forum Posts (Identical in Low-CA and High-CA Condition)
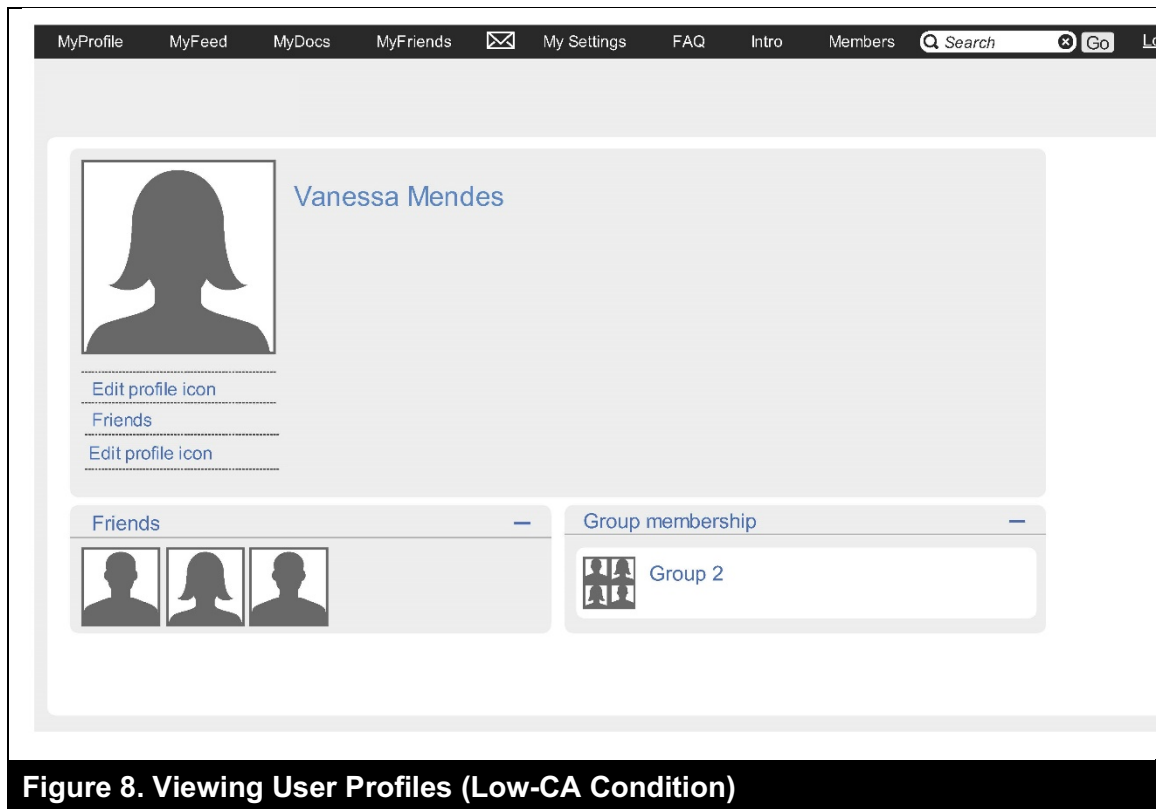
Figure 8. Viewing User Profiles (Low-CA Condition)

High-CA Condition

The following figures illustrate the user interface and capabilities of the enhanced platform. Figure 9 shows the team page of the enhanced platform. Call-outs show how users could trigger tool capabilities by clicking on elements of the team page. These capabilities include all capabilities of the basic platform and the following:

(4) Communication awareness: Viewing all communication at one place by (4a) clicking "MyFeed" to view the team feed (see Figure 10) or by (4b) viewing the user profile page, which included an individual feed (see Figure 11).

Figure 9. Team Page (High-CA Condition)

MyProfile   MyFeed   MyDocs   MyFriends   ✉   My Settings   FAQ   Intro   Members   Search: Name

Hi Anita Tran
What are you doing?

System-gener-
ated notification
on a forum post

All   Mine

Max Boy Has posted a new comment on this discussion topic   Design Perspective

I think it's ok that way. What do you think? Should we leave it like that or rework it?

Elisa Danner Has posted a new comment on this discussion topic   Design Perspective

Hi Max. Thank you for your addition. I'm working today. I just added my confirmation.
I haven't read it yet. Could you please also add yours...

Vanessa Staub Has posted a new comment on this discussion topic   Response Document

Well, I just tried something. I hope for improvements :)

User-generated feed
post (update on an arti-
fact action)

4 days ago · Comment · Like

Jessica Meier Thanks for your effort.
It looks really nice...

Max Boy says: I have now read all the papers!

User generated feed
post (status update)

6 days ago · Comment · Like

Write a comment...

Elisa Danner updated their profile

System-generated notifica-
tion on a profile update

Vanessa Staub says: I'm reading the text by Alan R. Dennis, Indiana University

8 days ago · Comment · Like

Jessica Meier I'm reading the text by Beccera about the
design perspective.
330 days ago

Write a comment...

Jessica Meier updated their profile icon

Figure 10. Viewing a Team Feed (High-CA Condition)

Figure 11. Viewing User Profiles (High-CA Condition)

APPENDIX B: TASK MATERIAL OF STUDY 1

The following text is a translated and shortened summary of the task material of study 1.

Process improvement is a top priority of the XYZ bank. The board asked the managers of the local subsidiaries to make suggestions for process improvement to the board. The board also asked a consultancy to analyze the processes. The task of the consultants is to identify potential for process improvement in the two local subsidiaries A and B.

You are a member of the team of consultants. Please familiarize with the information provided on the credit request approval process in the attached documents. Work on the following tasks related to the credit request approval process:

(1) Map the credit request approval process for subsidiaries A and B using an appropriate process mapping technique. The process model should include information on time and resources.

(2a) How can subsidiary A reduce the cycle time of the credit request approval process?

(2b) What type and amount of costs can subsidiary A save if they follow your suggestions?

(2c) If the bank decided to delegate the process step credit check of the credit request approval process to a shared service center, how will the process model, cycle times, and costs change?

(2d) If a new groupware allowed the bank to simultaneously perform credit check and property check, who would that affect the credit approval process mapped in task 1?

The following tasks refer to the bank XYZ as a whole rather than to the process approval process only. Please familiarize with the attached document that shows the results of a process analysis of the XYZ bank conducted by the consultancy company.

(3a) Please compare cycle times, salary classes, and costs across subsidiaries.

(3b) What should XYZ do improve cycle times and costs?

(3c) What type and amount of costs can the XYZ save if they follow your suggestions?

(3d) What context factors should the bank account for when they implement the suggested actions?

(4) The bank considers outsourcing the credit request approval process to service provider SP. Please provide a recommendation for whether and how the bank should outsource particular steps of the credit request approval process.

APPENDIX C: TASK MATERIAL OF STUDY 2

You are member of a team at a consultancy for knowledge management systems. Sebastian Kalinke, head of the department "Nuclear Safeguards" at the International Nuclear Energy Agency (INEA) approached you for help. After the Fokushima disaster, the United Nations asked Kalinke's department to develop safety standards for different types of nuclear reactors and to communicate these specifications to the power plant operators.

Defining nuclear safety standards is a highly complex task. A number of risk factors need to be identified, analyzed, and evaluated to define appropriate measures. Kalinke's department employs several risk experts. Risk experts are intimately familiar with mathematical approaches for calculating risks. Yet, insight from the Fokushima disaster suggests that these calculations were based on unrealistic assumptions. To improve the specification of the risk estimation models, risk experts need to collaborate with experts in nuclear physics. Moreover, Kalinke's team needs to collaborate with external actors, such as the electric engineers working in the businesses responsible for the cooling equipment for nuclear power plants. Finally, construction engineers need to be involved to provide knowledge on possible constructional changes in the power plants. Kalinke has been asked to balance the safety gains from additional measures with the profit interests of power plant operators. Please familiarize with the information provided in the attached documents.

a) Suggest a knowledge management system that helps Kalinke's team develop safety standards. Base your suggestions on an article by Dennis & Vessey or on an article by Becerra-Ferndandez & Sabherwal or on both.

b) Suggest specific actions to ensure that employees make beneficial use of the knowledge management system.

APPENDIX D: CODING EXAMPLES

Table 12 provides examples for the coding of task-oriented communication. A message was coded as task-oriented if it referred to the process or the substance of the task. The last column provides a brief rationale for each coding decision. The messages are taken from different teams.

Table 12. Coding Examples: Task-oriented communciation		
Message	**Code: Task-Ori-ented**	**Coding Rationale**
Hello hello how should we go about the task? Should every-one do everything and we define until when this should be done? Or should everyone simply take over one task (which is a bit difficult because of the different effort)? Kind regards	Yes	Process (how the team will go about organizing the work on the task)
I will finish task 2 over the weekend. I have not yet had time to do that … =/	Yes	Process (what the sender has done so far and what the sender is planning to do next)
Hi Marc, I basically like your process model. There are two possibilities for modelling delays [in Petrinets]: 1) You put the delay next to the place, then it is interpreted as idle time, i.e. the team that a tokan has to wait in a place until the token can move to the next place or 2) you put the delay next to the transition, then it is interpreted as transition time, i.e. time un-til the token arrives at the next place. Since the firing of tran-sitions does not take time, the two options mean the same thing. Perhaps you may want to put the delays next to the places, then everything is fine. Kind regards	Yes	Substance (how delays are incorporated into Petrinets)
Does anyone of you know what I shall do with the different salary levels?	Yes	Substance (the sender is asking a question related to the content of the task)
I am finished with task 2. Please tell me if anything looks strange. What I noted on task 1: Should we perhaps divide the credit check into "if creditworthiness is ok" and "if credit-worthiness is not ok" (and the credit request is rejected)? What do you think?	Yes	Process (what the sender has done) and substance (feedback on task 1)
All the best for the exams to everyone!!	No	Neither substance nor pro-cess
Hello ;-)	No	
This is going to be real fun ;-) haha	No	
Do you all understand Swiss German?	No	
This [artifact editor] is really a pain. I would be faster if I had to carve everything in stone.	No	

Table 13 illustrates the coding of episodes. The table shows the first 15 messages of one team. Through the messages 1 to 13, the team defined how they planned to accomplish the task. Message 13 on day 4 ("Right, Peter :-), let's do it like this") was the last message that was coded as initial strategy formulation. Hence, day 4 was coded as the last day of initial strategy formulation of this team. Consequently, all messages that this team sent after day 4 (i.e., all messages from #14 onwards) were considered to belong to action episodes.

Table 13. Task-oriented communication of Team 39			
#	Sender	Message	Day
1	Max	Hi, how should we go about this work?	2
2	Jenny	Good question … how should we divide the tasks?	3
3	Max	First, it would be nice if everyone could post a message here.	3
4	Peter	Hi. I just found my way into [the collaboration platform]. I like process mapping, but I guess this is the post popular part of this work. So I am happy to submit myself to the group. Do you have any preferences?	3
5	Jenny	I do not absolutely have to do process mapping ;-) So, Peter, it is ok for me if you do that part of the work.	3
6	Laurent	Hi everyone. Sorry for my late reply. Let me propose the following division of work (under the assumption that the distribution of points per tasks correlates with effort): If Peter does the process mapping, he will do task 1 (15%). I would like to do task 2 and task 4 (25%). Thus, I would do 25%. I prefer this because I would then work on my own. .. Then Jenny and Max could do Task 3. With this division of tasks, Peter would do 15%, Jenny and Max 30% and I 25%. Peter could help Jenny and Max on task 3 to make everything fairer. What do you think? :-)	4
7	Peter	Hi Laurent. Thank you for this very concrete post. I am fine with it but I would wait for Max' and Jenny's answer. I am happy to help on task 3. Finally, that's what [the collaboration platform] is for. :-)	4
8	Max	I am also fine with the suggestion. Since Peter would have only 15% of the work. He could also work on task 4 and he would have 25%. Provided that Peter and Jenny are fine with this.	4
9	Jenny	Ok, I am fine with this suggestion	4
10	Peter	I think it is not important whether I do task 4 and Laurent has 15% or vice-versa, I just propose that whoever has only 15% should provide help on task 3 on demand. I would also be happy with doing task 4. Laurent, what would you prefer?	4
11	Max	Sorry, I had not read your messages well, my fault ;-). Yes, ok, Peter, you would help on task 3, that's ok. Sorry ;-)	4

12	Peter	No problem ;-) I think we now have agreed on a way to proceed. Laurent had made the proposal, so for sure he will also agree. Since I am currently in the mid of the work on a seminar thesis, I will have time to start the process mapping task only next week. Is there anyone who depends on task 1 (process mapping)?	4
13	Laurent	Right, Peter :-), let's do it like this. My task 2 is quite strongly dependent on your process mapping task. I plan to work on my task next week on Thursday and Friday. On Thursday I will only revise the theory. So it would be great if you could finish your process mapping until Friday. Would you be fine with this, Peter? If this timeline is too tight, we would find another way.	4
14	Peter	Please do not move any [Petrinet] symbols, please only copy them. Task 1 is more effortful than expected! I will try to finish it by tomorrow. Kind regards, Peter	9
15	Peter	@Laurent: I finished the process mapping task … Some things are not yet complete. I will check that based on the theory, if possible until Sunday. But I think that you can start working with the current version of the process model. The model includes all relevant information. By the way, I tried to avoid mistakes, but there may still be some. Please write me if you note any issues. I think it is not ideal if anyone did just directly modify the process model. Please write me and I change the model.	11
…			

APPENDIX E: SURVEY ITEMS FOR OFFLINE COMMUNICATION

(1) I often communicated with my team members outside of the environment (e.g., via phone, email, personal meetings)

(2) Our team met multiple times.

(3) I often had offline contact with my team members.

APPENDIX F: PACING OF TASK-ORIENTED COMMUNICATION FOR DIFFERENT LEVELS OF EFFICIENCY

Table 14. Pacing Indicators for Teams of High versus Low Efficiency						
	Low-Performing (Low Efficiency)			**High-Performing (High Efficiency)**		
Indicator	**Low CA**	**High CA**	**Δ**	**Low CA**	**High CA**	**Δ**
Study 1	*n=17*	*n=9*		*n=9*	*n=16*	
ToC during action (no. of messages)	20.3	17.6	-2.7	15.8	25.4	9.6
ToC during action (no. of messages) until action episode mid-point by time	6.6	7.8	1.1	**3.2**	**9.6**	**6.3***
ToC during action (no. of messages) until action episode mid-point by amount of messages	10.7	11.4	0.7	**5.1**	**14.4**	**9.3***
Fraction of ToC during action until action episode midpoint by time	40%	46%	6%	21%	34%	13%
Fraction of ToC during action until action episode midpoint by amount of messages	59%	67%	7%	33%	52%	20%
Number of days with ToC during action	6.1	5.6	-0.6	5.3	6.8	1.4
Study 2	*n=9*	*n=9*		*n=8*	*n=9*	
ToC during action (no. of messages)	21.3	13.9	-7.4	14.1	15.2	1.1
ToC during action (no. of messages) until action episode mid-point by time	7.6	6.3	-1.2	3.9	4.6	0.7
ToC during action (no. of messages) until action episode mid-point by amount of messages	8.9	9.4	0.6	7.1	9.7	2.5
Fraction of ToC during action until action episode midpoint by time	45%	27%	-18%	25%	27%	2%
Fraction of ToC during action until action episode midpoint by amount of messages	51%	47%	-4%	54%	61%	6%
Number of days with ToC during action	5.2	5.0	-0.2	3.4	5.4	2.1
Pooled data	*n=26*	*n=18*		*n=17*	*n=25*	
ToC during action (no. of messages, standardized)	-.12	-.39	-.27	.08	.43	.35
ToC during action (no. of messages, standardized) until action episode midpoint by time	.05	.09	.03	**-.38**	**.14**	**.51***
ToC during action (no. of messages, standardized) until action episode midpoint by amount of messages	-.02	.06	.08	**-.42**	**.26**	**.68***
Fraction of ToC during action until midpoint by time	42%	36%	-5%	23%	32%	9%
Fraction of ToC during action until midpoint by amount of messages	56%	57%	1%	42%	55%	13%
Number of days with ToC during action (standardized)	.06	-.08	-.14	**-.40**	**.26**	**.66***

(ToC: Task-oriented communication, Δ: High-CA teams minus low-CA teams, * difference between high-CA and low-CA teams statistically significant at $p < .05$, Mann-Whitney Test)