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Team member proximity and teamwork in innovative projects

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Abstract

Innovation teams vary in terms of team members' proximity, i.e., the degree to which all team members are in direct vicinity over the duration of the project. The proximity of team members, however, has potentially important implications for the collaborative working of teams. In this paper, we develop and test hypotheses relating team members' proximity to the performance-relevant team collaborative processes included in Hoegl and Gemuenden's [Organization Science 12 (4) (2001) 435] teamwork quality framework, i.e., communication, coordination, balance of member contributions, mutual support, effort, and cohesion. Using data from 430 team members and team leaders of 145 software development teams, the results of the regression models show that team members' proximity is significantly related to teamwork quality. However, the magnitude of the relationship between proximity and teamwork quality varies among the six facets of teamwork quality. Theoretical and practical implications are discussed.

Keywords: Proximity; Teamwork; Innovation

Research inquiry into teams remains strong given the importance of cross-functional collaborative processes to organizations' ability to efficiently develop new products (Brown and Eisenhardt, 1995; Lovelace et al., 2001; Keller, 2001). A number of studies have demonstrated the link between the mere existence of a team-based organization and innovative performance (Hise et al., 1990; Cooper and Kleinschmidt, 1995; Gupta and Wilemon, 1996). Moreover, recent research (Hoegl and Gemuenden, 2001) has addressed earlier calls (Denison et al., 1996) for more sophisticated concepts and measures of teamwork, thereby contributing to a better understanding of the multifaceted nature of the collaborative functioning of teams and illustrating how this relates to various aspects of the success of innovative projects.

Prior research on collaborative team processes in innovative projects, however, has not adequately

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recognized that new product development teams regularly have members that are not co-located. The cross-functional and multi-disciplinary nature of such teams (Lovelace et al., 2001; Keller, 2001) often entails that team members spend time away from the team's main location (e.g., a central project office or laboratory) such as at their functional department's location (e.g., in a different building on the same premises or at different premises) or at the site of a supplier or customer organization. Hence, innovation teams vary in terms of team members' proximity, i.e., the degree to which all team members are in direct vicinity over the duration of the project. The proximity of team members, however, has potentially important implications for the collaborative working of teams. In this paper, we investigate how the degree of team members' proximity affects performance-relevant team collaborative processes.

Given this focus, the present research offers several contributions to the extant literature on teams with innovative projects. First, while there is a host of studies pertaining to *virtual* teams, such research has typically regarded geographical dispersion as a definitional feature of such teams (Jarvenpaa and Leidner, 1999; Maznevski and Chudoba, 2000; Montoya-Weiss et al., 2001), with a number of studies comparing virtual teams to *co-located* teams, the latter of which were implicitly assumed to be fully co-located (Markus, 1994; Kahn and McDonough, 1997; DeSanctis and Monge, 1999; McDonough et al., 2001; Schmidt et al., 2001; Billing, 2003). In this investigation, however, we focus on the *degree* to which team members are in geographical proximity (or dispersion) and identify how this affects the quality of teamwork performed. As such, we consider team members' proximity as a continuous variable, rather than as a definitional element for discretely distinguishing between virtual and co-located teams (Keller, 1986; Pinto et al., 1993; Sethi and Nicholson, 2001).

Second, while the seminal research by Allen (1971) on communication processes in R&D laboratories has produced encouraging results (i.e., with reduced proximity drops the probability of communication; 80% reduction at an average distance of 80 ft.), scholars have not built on these conceptual and empirical foundations to gain a more detailed understanding of how physical proximity of team members affects different social and task-related elements of a team's collaborative processes. Our study addresses this gap in the literature by relating team members' proximity to six performance-relevant facets of the team's collaborative process, i.e., open sharing of information, task coordination, balance of member contributions to problem solving, mutual support, cohesion, and effort. As such, this research extends prior work relating physical proximity to unitary team process variables such as "cross-functional cooperation" (Pinto et al., 1993) and "charged team behavior" (Sethi and Nicholson, 2001). Moreover, prior research has also established links between geographic groupings of companies (e.g., regional clusters such as Silicon Valley) and patterns of success in many industries (Tallman et al., 2004). Such research streams, however, remain largely at the inter-organizational level of analysis, whereas our study focuses on intra-organizational innovation projects.

Third, given today's comparatively advanced information and communication technologies relative to the time of Allen's study in the late 1960s, an inquiry into the effects of decreasing proximity of team members on critical team collaboration processes seems particularly timely, as recent evidence from a laboratory study (Schmidt et al., 2001) suggests that virtual teams may even produce superior performance on innovative tasks (e.g., new product development decision-making) when compared to teams with high geographical proximity. Our study investigates the influences of team members' proximity on the collaboration of software development teams, operating as IT professionals with advanced technology such as Computer Aided Software Engineering (CASE) tools (Faraj and Sproull, 2000). Furthermore, the nature of software development as producing software code rather than a physical product seemingly lends itself particularly well to geographically dispersed collaboration of team members. As such, we conceptually argue and empirically test how variances in team members' proximity affect the collaborative working of teams in the highly computer-supported and potentially "easy-to-virtualize" software development industry.

The possible direct relationship between team member proximity and team performance, however, is not subject of this research. Instead, this manuscript investigates the relationship of team member proximity (as a team characteristic) with different aspects of the collaborative work process of teams, building on earlier analyses (Hoegl and Gemuenden, 2001; Hoegl et al., 2003) positively relating these elements of the collaborative work process to team performance. Thus, putting this study into the context of widely recognized input-process-output models of team effectiveness (Gladstein, 1984; Hackman, 1987), this research addresses the possible links between inputs (i.e., team member proximity as a team characteristic) and processes (i.e., the six facets of teamwork quality), while earlier work has conceptually and empirically demonstrated the process-output link.

The detailed discussion of our conceptual arguments begins with specifying teamwork quality and its six facets as the dependent variables for this research, followed by the independent construct of team members' proximity as well as its proposed relationship with the six teamwork quality facets. The hypotheses are tested using data from 430 team members and team leaders of 145 software development teams.

1. Constructs and hypotheses

1.1. Team collaborative processes

In this research, we consider as our dependent constructs the process variables specified by Hoegl and Gemuenden's (2001) concept of teamwork quality. In order to capture the complex nature of team members working together, Hoegl and Gemuenden conceptualize and empirically validate teamwork quality as a higher order construct with six facets, i.e., communication, coordination, balance of member contributions, mutual support, effort, and cohesion (for a later validation of the teamwork quality construct in a study on the usage of collaborative technology see Easley et al., 2003). The six teamwork quality facets embrace elements of both task-related and social interaction within teams (Cummings, 1978). The underlying proposition of this latent construct is that highly collaborative teams display behaviors related to all six teamwork quality facets. In teams with high teamwork quality, team members openly communicate relevant information (Katz and Allen, 1988), coordinate their individual activities (Adler, 1995; Faraj and Sproull, 2000), ensure that all team members can contribute their knowledge to their full potential (Seers, 1989), mutually support each other in team discussion and individual task work (Tjosvold, 1984; Cooke and Szumal, 1994), establish and maintain work norms of high effort (Hackman, 1987; Weingart, 1992), and foster an adequate level of team cohesion where team members maintain the group (Mullen and Copper, 1994; Gully et al., 1995).

The following arguments in support of our hypotheses will relate to the six teamwork quality facets in illustrating the relationships between team member proximity and intra-team collaboration in innovative projects. Analogous to the socio-technical approach (Cummings, 1978; Manz and Sims, 1987), we divide the six elements of teamwork quality into more 'technically' and more 'socially' oriented clusters, and draw on both theoretical bases in our arguments. The 'technical' cluster includes open sharing of information, task coordination, and balance of member contributions to problem solving, as all three focus chiefly on task-related processes of team-internal collaboration in cross-functional innovation teams. The 'socio' cluster includes mutual support, cohesion, and effort, which relate primarily to norms and values held in the team as a social unit.

1.2. Proximity of team members and team collaborative processes

Allen (1971), in his seminal work, relates the concept of proximity to that of "physical distance", measured in terms of feet or meters. The measure considered by Allen is dyadic, in that it refers to pairs of individuals or, better, to pairs of physical locations that do not vary in reciprocal distance over time. Furthermore, the outcomes measured by Allen are limited to communication frequency (as already stated in this paper, reduced proximity leads to a drop in communication probability: 80% reduction at an average distance of 80 ft.).

In this paper we focus on the team level, rather than the dyadic level, necessitating a team-level concept of proximity. Prior work has emphasized mean geographical distance between team members (Keller, 1986; Pinto et al., 1993). Such average proximity of team members, however, is not attributable only to the simple physical distance between offices or desks. Team members tend to meet in different locations or facilities as required in a specific stage of the project or as imposed by the company's physical layout. As such, we consider a team's proximity as high if team members are easily reachable on foot, if all or most team members work directly in the vicinity of each other, and if it is unproblematic to call spontaneous face-to-face meetings (e.g., for solving problems or taking decisions).

1.2.1. Team member proximity and task-related team processes

The task-related elements of team-internal collaboration in innovation teams include open sharing of information, task coordination, and balance of member contributions to problem solving. We argue that with increasing team member proximity, these three team process variables increase as well.

Team-internal communication is likely facilitated by the close proximity of team members (Allen, 1971). There are multiple reasons to account for this. First, with team members in close vicinity, for instance on the same floor of a building, initiating communication requires less effort as compared to circumstances where team members are dispersed over different sites. Second, decreasing proximity decreases the possibility of spontaneous and/or informal face-to-face communication. For example, with team members dispersed over different physical premises, so-called hallway or kitchen talks are largely unavailable as vehicles of communication. Third, decreasing proximity of team members is likely to entail a decrease in face-to-face communication within the team. Non face-to-face communication (e.g., telephone, e-mail, etc.), however, is unlikely to provide the same level of "richness" (Daft and Lengel, 1986) because of the lack of non-verbal cues.

Innovative tasks, such as the design and development of new software, are characterized by high levels of ambiguity, uncertainty, and equivocality (Daft and Lengel, 1986; Sicotte and Langley, 2000) necessitating an ongoing coordination of task activities as pre-programming of task sequences is largely not possible. Such ongoing structuring and synchronizing of task activities of team members, however, may be more easily accomplished if team members are in close proximity to each other. Close proximity of team members allows for the first-hand and "real-time" observation of team members' progress on their work. Subsequently, team members are in a better position to initiate any restructuring of work sequences and contents as new information becomes available. If team members are located at some distance from one another, coordinative activities are more likely to take place in dyadic discussions (e.g., individual team members coordinating their activities via phone or e-mail with other individual team members), leaving other team members largely unaware of the information being shared. This, however, can be problematic as such dyadic coordination may create so-called gaps or overlaps, with some work being done multiple times by different team members, or not done at all.

The teamwork quality facet of balance of member contributions, i.e., the ability of the team to utilize every members' potential to the fullest, is also likely positively related to team member proximity. Having team members in the vicinity increases the likelihood of team members being aware of each others knowledge, skills, and experiences, as team members engage in richer and frequently more informal interaction. Such awareness, in turn, enables the team to draw on the individual team members' specific strengths.

Given all of the above, we hypothesize:

- Hypothesis 1: Proximity of team members is positively related to communication.
- Hypothesis 2: Proximity of team members is positively related to coordination.
- Hypothesis 3: Proximity of team members is positively related to balance of member contributions.

1.2.2. Team member proximity and social team processes

We also argue that team member proximity is positively associated with the more social aspects of the collaborative work process, such as mutual support, effort, and cohesion. For instance, mutual support within the team is more likely to occur if team members are physically close to one another. For one, team members are likely to find it easier to observe situations where their assistance may be needed or beneficial. Likewise, team members may find it easier to call upon one another for providing support and guidance. While there is no specific literature relating proximity to mutual support, it is widely accepted that social phenomena are related to the co-presence of people (Schachter et al., 1951) and that small and frequently interacting groups produce more satisfaction in team members and more identification (Hare, 1976; Shaw, 1981), leading to a more conscious perception of others' task problems.

Moreover, we argue that close physical proximity of team members is also instrumental for the development of team cohesion and work norms of strong effort. If team members are in close vicinity, stronger social integration is likely (O'Reilly et al., 1989) as team members are more easily accessible for both task-related and also personal interaction. Team members in close proximity, by the higher likelihood of informal and spontaneous communication (Allen, 1971), will tend to interact not only on task-related matters, but also on social and personal matters, strengthening ties among team members leading to stronger team cohesion. Support for this notion comes from the strong and positive relationship between interaction frequency and interpersonal attraction, an important component of cohesion (Zaccaro and Lowe, 1988). Also, Shaw (1981) describes a positive relation between physical proximity and the existence of cohesive groups.

Proximity is likely to create stronger social norms regarding work effort as individual contributions to the team tasks can more readily be observed and are thus more identifiable in the team, reducing tendencies of social loafing (Latané et al., 1979). Furthermore, team members in proximity are more likely to develop a stronger sense of group identity (Scott, 1997), creating a commitment to the team and its goals (Hoegl and Parboteeah, 2003), and leading to increased effort on the common task (Locke and Latham, 1990).

Given all of the above, we hypothesize:

- Hypothesis 4: Proximity of team members is positively related to mutual support.
- Hypothesis 5: Proximity of team members is positively related to effort.
- Hypothesis 6: Proximity of team members is positively related to cohesion.

2. Methods

2.1. Sample and data collection

A total of 145 software development teams from four German software development laboratories participated in this research. All four laboratories were part of larger organizations, with two of them being independent operations of the same US parent company. The other two laboratories belonged to organizations headquartered in Germany. Each laboratory employed between 100 and 500 software developers. All four laboratories had largely comparable information and communication technology resources (including e-mail, file-sharing, online forums, chat, videoconferencing, telephone, telefax, etc.) available for all project teams to utilize at their discretion.

The laboratories provided lists of projects including names and contact information of team members while the employees of the software laboratories were informed that a study about team management was to be conducted. All team leaders as well as randomly chosen team members were contacted for individual data collection appointments. Respondents' participation in this study was strictly voluntary. All contacted respondents participated in the study. Data were gathered through individual data collection sessions using a fully standardized questionnaire (five-point answer scale). All data collection sessions were conducted on site in dedicated rooms assuring similar conditions for every respondent.

The individual data collection sessions followed a very structured pattern. First, team membership as stated on the list was confirmed with the respondent to ensure that he or she was indeed a member of the team in question and to ascertain that all respondents of one team were referring to the same set of individuals as the team. Then the respondent was instructed to read and complete the questionnaire on his/her own. This way, possible interviewer effects were minimized, while there was still a researcher present to clarify questions if any occurred. Each data collection session lasted about 45 min.

2.2. Multiple informants

The database for our analyses consists of 145 team leader and 285 team member responses pertaining to 145 software development teams. In order to ensure content validity and to avoid a possible common source bias, data from different respondents were used to measure the different variables. Teamwork quality was measured using aggregated responses from multiple team members (excluding team leaders). Proximity of team members was measured using responses from the team leaders. Prior to the hypotheses testing analyses, we calculated interrater agreement for this variable based on both team leader and team member data

Table 1
Means, standard deviations, and correlations

		Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	Proximity of team members	4.44	0.82								
(2)	Teamwork quality	4.04	0.45	0.26							
(3)	Communication[a]	4.20	0.44	0.26	0.86						
(4)	Coordination[a]	4.04	0.59	0.20	0.74	0.58					
(5)	Balance of member contribution[a]	4.08	0.50	0.16	0.87	0.73	0.54				
(6)	Mutual support[a]	4.13	0.55	0.19	0.88	0.80	0.55	0.75			
(7)	Effort[a]	3.91	0.59	0.24	0.83	0.61	0.52	0.65	0.62		
(8)	Cohesion[a]	3.89	0.56	0.26	0.88	0.69	0.49	0.74	0.75	0.78	
(9)	Team size	6.34	2.88	−0.03	−0.19	−0.19	−0.05	−0.24	−0.14	−0.18	−0.18

[a] Teamwork quality facet. $N = 145$ teams.

available. Using the multiple item estimator for within-group interrater reliability as proposed by James et al. (1984), we found generally strong agreement between the raters (team leader and team members) across all teams (0.90). This offers support for using the team leaders as reliable key informants for this variable. All further analyses are conducted on the team leader responses for proximity of team members.

2.3. Measures

All constructs considered in this investigation refer to the team as the unit of analysis. Accordingly, all measures were specified on the team level. The questionnaire was administered in German language. The German language measurement scales were generated for the present study based on descriptions and measures of related constructs in the literature (Keller, 1986; Pinto et al., 1993). All items for our measures were generated based on a thorough literature review. A pretest was conducted including 23 members of product development teams at a machine tool manufacturing company. Following this pretest, the wording of some items was refined for later use in the present study (Table 1).

Building on Keller (1986) and Pinto et al. (1993), proximity of team members was measured using four items pertaining to the share of team members working directly in the vicinity of each other, whether team members were easily reachable on foot, and whether it was problematic to call spontaneous face-to-face meetings (Cronbach's alpha = 0.80). Translations of the items used are included in Appendix A.

The teamwork quality construct was measured using between three and ten items per teamwork quality facet, with a total of 38 items for all six facets. The measurement scales for teamwork quality are documented in full by Hoegl and Gemuenden (2001), however, representative items for these scales are included in Appendix B. The detailed analyses by Hoegl and Gemuenden (2001) on the basis of this data demonstrate that all six teamwork quality facets pertain to the same latent construct (i.e., are strongly loading on one factor). Their analyses further document strong interrater agreement among team members' assessments of teamwork quality in the same team (James et al., 1984).

2.4. Control variables

We included team size as a control variable in our analysis. Team size was reported to us by the laboratories and confirmed by the team leaders. The size of a project team is an important structural variable with potential influences on the quality of a team's collaborative task process and project success (Gladstein, 1984; Hackman, 1987; Campion et al., 1993). Large team sizes make it more difficult for team members to interact with all other team members given the dramatic increase of (possible) individual links between team members as team size grows (Steiner, 1966). Moreover, with team size increases the possibility that team members are located apart from each other.

In addition, we included a dummy variable to differentiate between new software projects and upgrade projects. This categorization was based on the team leaders' assessments of whether their projects involved primarily the design and development of new software solutions (more innovative), or primarily the upgrade or customization of existing software solutions (less innovative).

Table 2
Regression analysis

Independent variables	Dependent variables (standard coefficient)						
	Teamwork quality	Communication	Coordination	Balance of member contributions	Mutual support	Effort	Cohesion
Laboratory 1	0.08	0.10	−0.04	0.17	0.01	0.04	0.14
Laboratory 2	0.06	0.04	−0.03	0.16	0.00	0.11	0.04
Laboratory 3	0.05	0.16	0.00	0.11	−0.01	0.02	−0.01
Project type (new vs. upgrade)	0.04	−0.03	0.05	0.02	0.01	0.07	0.06
Team size	−0.19[a]	−0.19[a]	−0.03	−0.26[b]	−0.14	−0.17[a]	−0.20[a]
Proximity of team members	0.23[a]	0.21[a]	0.21[a]	0.11	0.19[a]	0.22[a]	0.25[b]
R^2	0.10	0.12	0.05	0.10	0.05	0.10	0.12
F	2.68[a]	3.01[b]	1.12	2.52[a]	1.33	2.53[a]	3.12[b]

N = 145 teams.
[a] Significant at the 0.05 level.
[b] Significant at the 0.01 level.

Given that this study includes data from four different software development laboratories, we are controlling for possible organizational effects (i.e., dependencies between observations from one laboratory) in our analysis by including dummy variables for laboratory in the regression analyses. This effectively controls for all constant and unmeasured differences across the laboratories that may explain differences in the variables and relationships investigated. As such, controlling for laboratory also accounts for any differences there might be in laboratory specific information and communication technologies available (as stated above, the information and communication technology resources were largely comparable across all laboratories) as well as laboratory specific physical layouts of premises or policies regarding travel and relocation.

3. Results

To test our hypotheses, we have conducted multiple regression analyses using laboratory, project type, and team size as control variables, proximity of team members as the main effect variable, and teamwork quality and its six elements as dependent variables. Table 2 reports the results of the regression analyses.

The results of the regression models provide support for the general thesis of our research: proximity among team members is positively associated with the quality of teamwork among them (standard coefficient = 0.23). Furthermore, five of the six facets of teamwork quality show the same relationship with team members' proximity. While communication, coordination, mutual support, effort, and cohesion are positively related to the proximity of team members (with standard coefficient between 0.19 and 0.25), the balance of member contributions is not. These results provide support for hypotheses 1, 2, 4–6, but fail to support hypothesis 3.

It should also be noted that, of the control variables, only team size shows significant relationships with teamwork quality and its facets, while neither project type (new versus software upgrade/customization projects) nor laboratory show significant regression coefficients. This underscores the particular importance attributed to team size as a structural variable affecting team processes.

4. Discussion

Departing from the assumption of complete co-location of team members, we recognize that geographic proximity is a matter of degree, rather than a dichotomous distinction between so-called co-located and virtual teams. This research shows that the proximity of team members is related to various aspects of the collaborative working of teams.

4.1. Theoretical implications

We show a tangible impact of the degree of members' proximity on the teamwork quality construct. Our results widen the scope of Allen's (1971) work. Not only the likelihood of communication is facilitated by proximity, but also other task-related and social processes within teams are related to physical distance. In the following we will comment on each of the six teamwork quality facets, integrating and contrasting our findings with related prior research.

As found by Allen (1971), our results show that team-internal communication is facilitated by the close proximity of team members. In the communication literature, the process view of communication has overcome the signaling metaphor (Shannon and Weaver, 1949) and its view of communication as a linear and non-costly act. Following previous studies, we know that communication is a complex, long, and costly process in which people try to converge on a common sense (Rogers and Kincaid, 1981). From this point of view, it is plausible that the (geographically) closer the persons involved in the process, the less the effort required to achieve such convergence as the higher number of spontaneous and/or informal moments of contacts ensure a higher level of richness of the information transferred.

In a similar way, proximity supports another complex and costly process, the coordination of tasks and contributions from individual members. If people are close to one another, the coordination process will be supported by direct observation and the mutual, day-to-day adjustments among people (two of the most relevant coordination tools described by Lawrence and Lorsch, 1967).

Contrary to our expectation, the balance of member contributions, i.e., the ability of the team to utilize every member's potential to the fullest, is not affected by team member proximity. We can only speculate as to possible reasons for this surprising finding and would like to offer the following explanations that essentially posit a compensating effect that may partly offset the predicted relationship. Our results document a significant negative relationship between team size and the balance of member contributions. As such, this result may indicate that this element of the collaborative team process is more affected by structural features of team design such as size (Steiner, 1966) or role and goal clarity (Gladstein, 1984).

As we expected, team member proximity is positively associated to all three more socially oriented aspects of the teamwork quality construct, i.e., mutual support, work norms of high effort, and cohesion. The findings from this research underscore the validity of more fundamental and general theories relating the social phenomena to the co-presence of people (Schachter et al., 1951). Co-presence produces affective phenomena and isomorphic/imitative behaviors (Rafaeli and Worline, 2000; Thomas et al., 1993). Affectivity and cohesion are determined by visual imagery, tact, smells, and other similar factors. Existing literature stresses that physical proximity produces and reinforces a sense of group identity (Gioia et al., 2000) and team spirit.

4.2. Practical implications

Though outside the scope of this research, we see different "coping strategies" to counter the negative effects of decreasing proximity highlighted in this research. Possible answers to collaborative work through geographical distance are team members' temporary re-location or travel (Moyle and Parkes, 1999), which can be quite costly and time-consuming for the project as well as fatiguing for the team members travelling. Furthermore, teams can use computer mediated communication technologies (Fulk and DeSanctis, 1995; Zmud et al., 1990; Büchel, 2001 for a review) to deal with a lack of geographic proximity. While it is possible to argue that computer mediated communication technologies can help solve communication and coordination problems associated with decreasing proximity, the burgeoning literature on this topic is often controversial and hence unable to provide a clear indication of the effectiveness of distant communication and coordination. On the one hand, McGrath (1991) suggests that a team with no past history and engaged in a dispersed task has a lower possibility to be as effective as a fully co-located team. Similarly, Daft and Lengel (1986) argue that computer-mediation can hinder communication effectiveness through the cut of non-verbal cues and other relevant information. On the other hand, a number of studies have demonstrated that communication effectiveness is more a function of the context (environment) than of the media (Zack, 1993; Markus, 1994). Similar findings are highlighted by Fjermestad and Hiltz (1999) in their meta-analysis of the effectiveness and efficiency of group support systems. Moreover, computer mediated communication technologies such as e-mail, forums, chat, and videoconferencing are widely diffused in companies today and are therefore more a constant than a variable across many organizations in the US, Europe, and Asia.

Given this context, our study offers several practical implications. First, considering the high mean values for the proximity of team members (4.44 out of 5.00), our findings suggest that even low levels of geographic dispersion (e.g., on the same premises or within the same building) can have detrimental effects on important team processes. This is amplified when considering that software development by its immaterial nature (i.e., software code, rather than a physical product is developed) and the general information technology abilities of software engineers that could be thought of as providing a rather favorable setting for dispersed teamwork. Consequently, product development teams must be aware that even relatively low levels of geographic dispersion come at a cost to vital team processes.

Second, specific attention must be devoted to fostering social elements of the team process such as mutual support, cohesion, and work norms of high effort. Similarly, communication and coordination need to be more actively managed as team member proximity is reduced. As such, decreases in team member proximity amplify the importance of teamwork-related skills (e.g., social and project management skills) along with technical skills when selecting applicants to join a team-based innovative organization, when assigning individuals to work in teams, and when crafting training and development schemes.

Third, as already indicated, software development is clearly a privileged environment for effective dispersed coordination. Immateriality of the product and encapsulation of software objects (meaning that every object composing the software architecture can be developed separately) is a strong advantage if the choice is a team with a low degree of proximity, perhaps because the necessary technical expertise for a given project is situated with individuals in different locations. We assume that the development of physical products would be more affected by decreases in proximity and this should be considered by managers. In case of low proximity we propose to reinforce team collaborative processes through different and more pervasive tools such as advanced information and communication technologies or travel/temporary relocation (see our discussion of coping mechanisms above). Unfortunately the media richness of current information and communication tools is clearly not enough to ensure a complete resolution of the low proximity issue. Thus, in low proximity groups, the more social aspects of teamwork should be initiated by a face-to-face kickoff meeting and reinforced by frequent and scheduled meetings (Maznevski and Chudoba, 2000).

4.3. Contributions, limitations, and future research

In this paper we view geographic proximity of members as a continuous variable, rather than the basis for a dichotomous distinction between co-located and so-called virtual teams. We propose that proximity of team members is positively related to teamwork quality in general and its six facets in particular. The results confirm that five of six teamwork quality facets are significantly related. As such, this study contributes to the literature by providing a comprehensive analysis of the relationship between even relatively small decreases in proximity and several performance-relevant team processes.

On a methodological note, our research draws on data from 430 members and leaders of 145 software development teams with responses from different informants used to measure the different constructs. Employing this elaborate research methodology, any inflation of results due to common source bias was avoided while the most credible respondents were surveyed to provide information on the variables of interest.

A few limitations of this study along with questions for future research should be noted. First, the data for this research are cross-sectional rather than longitudinal. As this study demonstrates associations between variables, it cannot fully establish causality. A longitudinal research design using multiple informants would further our knowledge towards both causality of relationships as well as the development of team member proximity and team collaboration perceptions over time. For instance, it may be possible to find that negative effects of dispersion are greatest in early phases of team development and less detrimental as teams establish working routines and social ties. Second, the scope of the empirical data gathered for this research allows generalization of the results obtained chiefly to the domain of teams with innovative tasks such as R&D teams, new venture teams, etc. Third, the present study was conducted in software development laboratories in Germany, raising the question of transferability of results to other cultures such as those of North America or Asia. While this study is not internationally comparative in nature and therefore cannot offer any answers to this question, the theoretical considerations presented in this paper as well as the industry for this study (software) are not country-specific, but rather our arguments are based on international scholarly work and empirical findings. Further research in other countries is encouraged in order to increase our understanding of the possible influences of country contexts on the relationships investigated here. Fourth, although our hypothesized relations held with the wider concept of teamwork quality, balance of member contributions did not show the predicted positive relationship with team member proximity. Future research should investigate this specific relationship, building on and testing the possible explanation offered above. Fifth, while we found significant relationships between the proximity of team members and teamwork quality as well as five of its six facets, the variance explained remains between 5 and 12%. This, however, is not surprising given that other variables such as individual characteristics (e.g., social and project management skills; Stevens and Campion, 1994), team characteristics (e.g., role and goal clarity; Gladstein, 1984) and organization-level characteristics (e.g., cooperative climate; Mohrman et al., 1995) are also likely to influence the quality of teamwork. Finally, this research recognizes that the vast majority of teams are neither perfectly co-located nor perfectly virtual. There are many shades of gray in between these two extremes, and various team, task, and contextual characteristics may have an effect on how decreases (however small) in geographical proximity affect the process and performance of teams. We encourage future research to address these questions aimed at providing managers with recommendations for dispersed teamwork. The conceptual arguments and empirical results from this study may provide a starting point for such further inquiry.

Appendix A. Measurement scale for proximity of team members

Variable	Items
Proximity of team members	Most members of my team worked directly in the vicinity, so that they could visit each other without much effort. Team members were located too far from one another to move the project along expeditiously.[R] Only a few team members were easily reachable on foot.[R] It was at times problematic to get the team members together in one place for spontaneous meetings (e.g., for discussions and decisions).[R] Four items, Cronbach's alpha = 0.80.

[R] Reverse coded item. *Note*: These are translations of the original German items used in the study.

Appendix B. Representative items for teamwork quality

Variables	Representative items
Teamwork quality	*Communication*: The team members communicated mostly directly and personally with each other. Project-relevant information was shared openly by all team members. The team members were happy with the usefulness of the information received from other team members. Ten items, Cronbach's alpha = 0.94. *Coordination*: The work done on sub-tasks within the project was closely harmonized. There were clear and fully comprehended goals for sub-tasks within our team. Four items, Cronbach's alpha = 0.85.

Variables	Representative items
	Balance of member contributions: The team recognized the specific potentials (strengths and weaknesses) of individual team members. The team members were contributing to the achievement of the team's goals in accordance to their specific potentials. Three items; Cronbach's alpha = 0.72.
	Mutual support: The team members helped and supported each other as best they could. Discussions and controversies were conducted constructively. Suggestions and contributions of team members were discussed and further developed. Seven items, Cronbach's alpha = 0.93.
	Effort: Every team member fully pushed the project. Every team member made the project highest priority. Four items, Cronbach's alpha = 0.94.
	Cohesion: It was important to the members of our team to be part of this project. All members were fully integrated in our team. Our team was sticking together. Ten items, Cronbach's alpha = 0.97.

Note: These are translations of the original German items used in the study.

References

Adler, P.S., 1995. Interdepartmental interdependence and coordination: the case of the design/manufacturing interface. Organization Science 6 (2), 147–167.

Allen, T.J., 1971. Communication networks in R&D laboratories. R&D Management 1, 14–21.

Billing, F., 2003. Koordination in radikalen Innovationsvorhaben. Deutscher Universitaetsverlag, Wiesbaden.

Brown, S.L., Eisenhardt, K.M., 1995. Product development: past research, present findings, and future directions. Academy of Management Review 20 (2), 343–378.

Büchel, B.S.T., 2001. Using Communication Technology. Palgrave, New York.

Campion, M.A., Medsker, G.J., Higgs, A.C., 1993. Relations between work group characteristics and effectiveness: implications for designing effective work groups. Personnel Psychology 46 (1), 823–850.

Cooke, R.A., Szumal, J.L., 1994. The impact of group interaction styles on problem-solving effectiveness. Journal of Applied Behavioral Science 30 (4), 415–437.

Cooper, R.G., Kleinschmidt, E.J., 1995. Benchmarking for firm's critical success factors in new product development. Journal of Product Innovation Management 12, 374–391.

Cummings, T., 1978. Self-regulating work groups: a socio-technical synthesis. Academy of Management Review 3, 625–634.

Daft, R.L., Lengel, R.H., 1986. Organizational information requirements, media richness and structural design. Management Science 32 (5), 554–571.

Denison, D.R., Hart, S.L., Kahn, J.A., 1996. From chimneys to cross-functional teams: developing and validating a diagnostic model. Academy of Management Journal 39 (4), 1005–1023.

DeSanctis, Gerardine, Monge, Peter, 1999. Communication processes for virtual organizations. Organization Science 10, 693–703.

Easley, R.F., Devaraj, S., Crant, M., 2003. Relating collaborative technology use to teamwork quality and performance: an empirical analysis. Journal of Management Information Systems 19 (4), 247–268.

Faraj, S., Sproull, L., 2000. Coordinating expertise in software development teams. Management Science 46 (12), 1554–1568.

Fjermestad, J., Hiltz, S.R., 1999. An assessment of group support systems experiment research: methodology and results. Journal of Management Information Systems 15, 7–149.

Fulk, J., DeSanctis, G., 1995. Electronic communication and changing organizational forms. Organization Science 6, 337–349.

Gioia, D.A., Schultz, M., Corley, K., 2000. Organizational identity, image and adaptive instability. Academy of Management Review 25, 63–82.

Gladstein, D.L., 1984. Groups in context: a model of task group effectiveness. Administrative Science Quarterly 29, 499–517.

Gully, S.M., Devine, D.J., Whitney, D.J., 1995. A meta-analysis of cohesion and performance: effects of level of analysis and task interdependence. Small Group Research 26 (4), 497–520.

Gupta, A.K., Wilemon, D., 1996. Changing patterns in industrial R&D management. Journal of Product Innovation Management 13, 497–511.

Hackman, J.R., 1987. The design of work teams. In: Lorsch, J.W. (Ed.), Handbook of Organizational Behavior. Prentice-Hall, Englewood Cliffs, NJ, pp. 315–342.

Hare, A. Paul, 1976. Handbook of Small Group Research. Academic Press, New York.

Hise, R.T., O'Neal, L., Parasuraman, A., McNeal, J.U., 1990. Marketing/R&D interaction in new product development: implications for new product success. Journal of Product Innovation Management 7, 142–155.

Hoegl, M., Gemuenden, H.G., 2001. Teamwork quality and the success of innovative projects: a theoretical concept and empirical evidence. Organization Science 12 (4), 435–449.

Hoegl, M., Parboteeah, K.P., 2003. Goal setting and team performance in innovative projects: on the moderating role of teamwork quality. Small Group Research 34 (1), 3–19.

Hoegl, M., Parboteeah, K.P., Gemuenden, H.G., 2003. When teamwork really matters: task innovativeness as a moderator of the teamwork-performance relationship in software development projects. Journal of Engineering and Technology Management 20, 281–302.

James, L.R., Demaree, R.G., Wolf, G., 1984. Estimating within-group interrater reliability with and without response bias. Journal of Applied Psychology 69 (1), 85–98.

Jarvenpaa, S.L., Leidner, D.E., 1999. Communication and trust in global virtual teams. Organization Science 10 (6), 791–815.

Kahn, K.B., McDonough III, E.F., 1997. An empirical study of the relationships among co-location, integration, performance, and satisfaction. Journal of Product Innovation Management 14 (3), 161–178.

Katz, R., Allen, T.J., 1988. Investigating the not invented here (NIH) syndrome: a look at the performance, tenure, and communication patterns of 50 R&D project groups. In: Tushman, M.L., Moore, W.L. (Eds.), Readings in the Management of Innovations. Ballinger Publishing Company, Cambridge, MA, pp. 293–309.

Keller, R.T., 1986. Predictors of the performance of project groups in R&D organisations. Academy of Management Journal 29 (4), 715–726.

Keller, R.T., 2001. Cross-functional project groups in research and new product development: diversity, communications, job stress, and outcomes. Academy of Management Journal 44 (3), 547–555.

Latané, B., Williams, K., Harkins, S., 1979. Many hands make light the work: the causes and consequences of social loafing. Journal of Personality and Social Psychology 37 (6), 822–832.

Lawrence, P.R., Lorsch, J.W., 1967. Differentiation and integration in complex organisations. Administrative Science Quarterly 12, 1–47.

Locke, E.A., Latham, G.P., 1990. A Theory of Goal Setting and Task Performance. Prentice-Hall, Englewood Cliffs, NJ.

Lovelace, K., Shapiro, D.L., Weingart, L.R., 2001. Maximizing cross-functional new product teams' innovativeness and constraint adherence: a conflict communications perspective. Academy of Management Journal 44 (4), 779–793.

Manz, C.C., Sims, H.P., 1987. Leading workers to lead themselves: the external leadership of self-managing work teams. Administrative Science Quarterly 32, 106–128.

Markus, M.L., 1994. Electronic mail as the medium of managerial choice. Organization Science 5, 502–527.

Maznevski, M.L., Chudoba, K.M., 2000. Bridging space over time: global virtual team dynamics and effectiveness. Organization Science 11 (5), 473–492.

McDonough III, E.F., Kahn, K.B., Barczak, G., 2001. An investigation of the use of global, virtual, and colocated new product development teams. Journal of Product Innovation Management 18 (2), 110–120.

McGrath, J.E., 1991. Time, interaction and performance (TIP): a theory of groups. Small Group Research 22 (2), 147–174.

Mohrman, S.A., Cohen, S.G., Mohrman, A.M., 1995. Designing Team-based Organizations: New Forms for Knowledge Work. Jossey-Bass, San Francisco, CA.

Montoya-Weiss, M.M., Massey, A.P., Song, M., 2001. Getting it together: temporal coordination and conflict management in global virtual teams. Academy of Management Journal 44 (6), 1251–1262.

Moyle, P., Parkes, K., 1999. The effects of transition stress: a relocation study. Journal of Organizational Behavior 20, 625–646.

Mullen, B., Copper, C., 1994. The relation between group cohesiveness and performance: an integration. Psychological Bulletin 115 (2), 210–227.

O'Reilly, C.A., Caldwell, D.F., Barnett, W.P., 1989. Work group demography, social integration, and turnover. Administrative Science Quarterly 34, 21–37.

Pinto, M.B., Pinto, J.K., Prescott, J.E., 1993. Antecedents and consequences of project team cross-functional cooperation. Management Science 39 (10), 1281–1297.

Rafaeli, A., Worline, M., 2000. Symbols in organizational culture. In: Ashkanasy, N.M., Wilderon, C.P.M., Peterson, M.F. (Eds.), Handbook of Organizational Culture and Climate. Sage, Thousand Oaks, CA, pp. 71–84.

Rogers, E.M., Kincaid, D.L., 1981. Communication Networks: Toward a New Paradigm for Research. Free Press, Collier Macmillan, New York, London.

Schachter, S., Ellerston, N., Mc Bride, D., Gregory, D., 1951. An experimental study of cohesiveness and productivity. Human Relations 4, 229–238.

Schmidt, J.B., Montoya-Weiss, M.M., Massey, A.P., 2001. New product development decision-making effectiveness: comparing individuals, face-to-face teams, and virtual teams. Decision Sciences 32 (4), 575–600.

Scott, S.G., 1997. Social identification effects in product and process development teams. Journal of Engineering and Technology Management 14 (2), 97–127.

Seers, A., 1989. Team-member exchange quality: a new construct for role-making research. Organizational Behavior and Human Decision Process 43, 118–135.

Sethi, R., Nicholson, C.Y., 2001. Structural and contextual correlates of charged behavior in product development teams. Journal of Product Innovation Management 18, 154–168.

Shannon, C.E., Weaver, W., 1949. The Mathematical Theory of Communication. University of Illinois Press, Chicago, IL.

Shaw, M.E., 1981. Group Dynamics: The Psychology of Small Groups' Behaviour. McGraw-Hill, New York.

Sicotte, H., Langley, A., 2000. Integration mechanisms and R&D project performance. Journal of Engineering and Technology Management 17, 1–37.

Steiner, I.D., 1966. Models for inferring relationships between group size and potential group productivity. Behavioral Science 11, 273–283.

Stevens, M.J., Campion, M.A., 1994. The knowledge, skill, and ability requirements for teamwork: implications for human resource management. Journal of Management 20 (2), 503–530.

Tallman, S., Jenkins, M., Henry, N., Pinch, S., 2004. Knowledge, clusters, and competitive advantage. Academy of Management Review 29, 258–271.

Thomas, J.B., Clark, S.M., Gioia, D.A., 1993. Strategic sensemaking and organizational performance: linkages among scanning, interpretation, action, and outcomes. Academy of Management Journal 36, 239–270.

Tjosvold, D., 1984. Cooperation theory and organizations. Human Relations 37 (9), 743–767.

Weingart, L.R., 1992. Impact of group goals, task component complexity, effort, and planning on group performance. Journal of Applied Psychology 77 (5), 682–693.

Zaccaro, S.J., Lowe, C.A., 1988. Cohesiveness and performance on an additive task: evidence for multidimensionality. The Journal of Social Psychology 128, 547–558.

Zack, M.H., 1993. Interactivity and communication mode choice in ongoing management groups. Information Systems Research 4, 207–239.

Zmud, R., Lind, M., Young, F., 1990. An attribute space for organizational communication channels. Information Systems Research 1, 440–457.