7 THE INFLUENCE OF SUBGROUP DYNAMICS ON KNOWLEDGE COORDINATION IN DISTRIBUTED SOFTWARE DEVELOPMENT TEAMS: A Transactive Memory System and Group Faultline Perspective

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Abstract *With the globalization of the software industry, distributed software teams (DSTs) have become increasingly common. Among the various social aspects that are essential to the success of distributed software projects, the focus of this research is the impact of inter-subgroup dynamics on knowledge coordination. To address this research question, we extend and apply theory from two primary sources: transactive memory systems theory and the faultline model. We describe a field survey study that is in progress. The findings from this study will inform managers on how DSTs develop capabilities to perform successfully across temporal, geographic and cultural boundaries.*

Keywords Distributed software team, inter-subgroup dynamics, knowledge coordination, transactive memory systems, faultline

1 INTRODUCTION

With the globalization of the software industry, distributed software teams (DSTs) have become increasingly common (Carmel and Agarwal 2002; Herbsleb and Mockus

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2003; Kotlarsky and Oshri 2005; Sarker and Sahay 2004). For distributed software development projects to be successful, managers need to focus not only on technical aspects but also social factors (e.g., trust, social ties, formal and informal communication, etc.) that are crucial to these projects (Kotlarsky and Oshri 2005; Orlikowski 2002). Among the various social aspects that are essential to the success of dispersed software projects, the focus of this research is the impact of *inter-subgroup dynamics on knowledge coordination*. Specifically, we investigate

RQ1: Do subgroup dynamics affect team members' knowledge coordination?
RQ2: Does knowledge coordination benefit team performance and member satisfaction?

There are four reasons why this is an important area of research. First, software development is an excellent example of service work that is both highly paid and responsible for rapid growth in the economies of many developing countries. Second, software project failures occur due to coordination problems (Bohem 1981; Kraut and Streeter 1995), especially when projects are large (Brooks 1995) and members are geographically distributed (Herbsleb and Grinter 1999). Coordination is a crucial process in software development that ensures knowledge is properly acquired, shared, and integrated among various members, teams, and organizations. Third, while DSTs utilize a wide range of communication tools such as groupware and codified KMS, coordination breakdowns still occur (Kotlarsky and Oshri 2005). This suggests that teams need to develop *distributed organizing*[1] capabilities to complement existing technical solutions, in order to deal effectively with knowledge coordination challenges in dispersed environments (Orlikowski 2002). Finally, inter-subgroup dynamics—the relationships among subgroups within the overall project team—affect distributed teams' ability to share knowledge, because subgroups often emerge within larger groups (i.e., the notion of group faultlines), which can have negative consequences on member trust, information sharing, and overall coordination. This has been widely shown in laboratory experiments of members charged with performing a task requiring overall group coordination (Li and Hambrick 2005).

2 THEORY BUILDING AND HYPOTHESES DEVELOPMENT

2.1 Knowledge Coordination in Distributed Environments

Prior studies have identified many factors contributing to collaborative work, such as social ties, formal and informal communication, trust, and rapport (Kotlarsky and Oshri 2005). Among them, research on traditional colocated software teams has found that expertise coordination plays a significant role in software teams' performance, above

[1]Distributed organizing is defined as "the capability of operating effectively across the temporal, geographic, political, and cultural boundaries routinely encountered in global operations" (Orlikowski 2002, p. 249).

and beyond the mere presence of expertise, professional experience, and software methods employed (Faraj and Sproull 2000). However, knowledge coordination is never an easy task, especially when teams operate across temporal, geographic, and cultural boundaries (Herbsleb and Moitra 2001; Kotlarsky and Oshri 2005; Orlikowski 2002). Among other challenges, the problem of *where to locate project knowledge when needed* is a major challenge (Herbsleb and Mockus 2003). When knowledge is distributed among various stakeholders (Curtis et al. 1988), each member needs to know where to look for information before he or she is able to find and apply that knowledge. Field studies found that problems and questions that require timely solution often occur in software teams (Paasivaara and Lassenius 2003), and are particularly common in distributed projects (Carmel and Agarwal 2001). But few projects are proactive in planning for this kind of knowledge-sharing ahead of time, causing project members to spend much time just trying to find someone with the necessary knowledge, wasting both time and energy (Paasivaara and Lassenius 2003). In DSTs, geographical distance, time-zone differences, and organizational or national culture differences make it even more challenging to coordinate knowledge. Research shows that software developers find it much more difficult to identify distant colleagues with needed expertise and to communicate with them effectively, compared to when all members are local (Herbsleb and Mockus 2003). Herbsleb et al. (2000, p.3) described how one global project team faced this challenge of identifying who knows what, so that "difficulties of knowing who to contact about what, of initiating contact, and of communicating effectively across sites, led to a number of serious coordination problems."

2.2 Transactive Memory and TMS in DSTs

This social aspect of "knowing who knows what" is also labeled *transactive memory*, the knowledge that a person has about what *another* person knows. A transactive memory system (TMS) is a group-level concept, referring to "the operation of the memory systems of the individuals and the processes of communication that occur within the group" (Wegner 1987, p. 191). It describes the active use of members' transactive memories to complete a group task cooperatively. According to TMS literature, researchers generally agree on three facets that reflect the presence of TMS (Lewis 2003; Liang et al. 1995; Moreland and Myaskovsky 2000): *specialization* (the existence of specialized team knowledge), *credibility* (members' trust and reliance on each other's knowledge), and *coordination* (coordinated task processes). By convention, TMS researchers also agree that the higher the levels of these three facets of TMS, the more developed is the group's TMS—and the more value this TMS has for effective knowledge coordination.

Both laboratory and field studies have been conducted to specify the antecedents and consequences of TMS. Table 1 lists the antecedents of TMS development both in traditional, colocated teams and in distributed teams, while Table 2 summarizes research on the consequences of TMS.

Of the studies listed in these tables, only one quantitatively examined the levels of TMS and their antecedents in distributed teams (Kanawattanachai and Yoo 2007). Results suggest that the three TMS dimensions have different effects on distributed team performance. *Specialization* and *credibility* (these dimensions are labeled as *expertise*

Table 1. Antecedents of TMS Development

Factors Facililitate (+) or Hinder (–) TMS Development	Prior Literature
In Traditional Colocated Teams	
Group training (+)	Liang et al. 1995; Moreland 1999; Moreland et al. 1996, 1998; Moreland and Myaskovsky 2000
Performance feedback about one anothers' training performance (+)	Moreland and Myaskovsky 2000
Membership change (–)	Lewis et al. 2007; Moreland and Argote 2003
Distributed expertise (also moderated by *member familiarity*) (during project planning phase) (+)	Lewis 2004
Face-to-face communication (during project implementation phase) (+)	Lewis 2004
Non-face-to-face communicatoin (moderated by TMS developed in planning phase) (during project implementation phase) (+)	Lewis 2004
In Distributed Teams	
Task-oriented communication (e-mail, message, etc.) (early project stage) (+)	Kanawattanachai and Yoo 2007

Table 2. Consequences of TMS in Teams

TMS's Impact on Teams	Prior Literature
Individual-level learning	Lewis et al. 2003
Team-level learning	Lewis et al. 2003
Viability	Austin 2003; lewis 2004; Liang et al. 1995; Moreland and Myaskovsky 2000; Yoo and Kanawattanachai 2001
Team performance	Austin 2003; Kanawattanachai and Yoo 2007; Lewis 2004, 2005; Liang et al. 1995; Moreland 1999; Moreland et al. 1996, 1998; Moreland and Myaskovsky 2000
Successful collaboration	Kotlarsky and Oshri 2005

location and *cognition-based trust* in this research) have no direct impact on performance; instead, their effect is mediated by *coordination*. In addition, the latter effect occurred only in the final stages of the project, once members had learned to work together (Kanawattanachai and Yoo 2007).

Another quantitative study by Faraj and Sproull (2000) did not explicitly mention TMS; however, it introduced the concept of *expertise coordination*, which overlaps with

TMS to a large extent.[2] These authors studied traditional, colocated software teams, finding that *expertise coordination* had a positive effect on team performance. Members' ability to coordinate expertise exerted a strong effect on performance, above and beyond the mere *presence* of member expertise. A case study of two globally distributed system projects by Kotlarsky and Oshri (2005) found that TMS is a key contributor to successful collaboration. Based on these prior results, we propose that

> *Hypothesis 1*: The level of a team's TMS will be positively related to performance in DSTs; however, the only direct effect is through the *coordination* dimension of TMS.

2.3 Gaps in Transactive Memory Systems Literature

2.3.1 Additional Outcome Variable for TMS's Impact on Team

In addition to the conventional outcome variables that have been studied in TMS research (team performance, individual- and team-level learning, etc.), research on groups suggests that team members' psychological well-being is also an important outcome to consider. Thus, we include *member satisfaction* with the team as a second outcome variable. Studies of virtual teams suggest that teams who overcome coordination barriers are more likely to be satisfied with each other (Maznevski and Chudoba 2000; Piccoli et al. 2004). Thus, we posit that

> *Hypothesis 2*: TMS will be positively related to member satisfaction in DSTs; however, the only direct effect on satisfaction is through the coordination dimension of TMS.

2.3.2 Lack of Research on Subgroup Dynamics' Influences on TMS

While providing insightful perspectives of TMS development in teams, the prior TMS studies have the limitation that they focus on teams (either face-to-face teams or virtual teams) that treat each member as an "independent actor" (Li and Hambrick 2005) contributing his/her profile to the overall team diversity. From a group diversity perspective, prior TMS research has examined member heterogeneity and homogeneity among *individuals*, but has not addressed how patterns of difference between *subgroups within a larger group* might influence TMS development. In DSTs, however, dissimilarity between subgroups based on location, culture, and possibly language will have stronger negative effects on knowledge sharing and member behavior than overall member heterogeneity (Li and Hambrick 2005).

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[2]Compared to the three facets of TMS (specialization, credibility, and coordination), two dimensions of Faraj and Sproull's expertise coordination construct (knowing the location of expertise and recognizing the need for expertise) map to the specialization facet of TMS; their third expertise coordination dimension (bringing expertise to bear) maps to the coordination facet of TMS. Faraj and Sproull do not consider any construct analogous to credibility.

For example, it is not uncommon to see a student project team splitting into one subgroup with international students versus another comprised of domestic students. In a distributed team environment, location differences become salient as the team engages in its task. In turn, these salient location differences can affect team dynamics such as trust, conflict, and communication patterns. For instance, one field study found that hybrid teams composed of two or three subgroups of colocated members experienced more conflict and less trust than fully-distributed teams.[3] Polzer et al. (2006) compared hybrid teams where some members were colocated to fully distributed teams. While the latter had to rely on listservs for information sharing, those teams with some colocated members were able to substitute face-to-face communication for some messages that would otherwise have been sent via listserv to all members. While this had obvious benefits (i.e., in terms of saving time), it also had the undesirable consequence that co-located members started behaving as a faction, making statements such as "the three of us would like to" and "we at [Australian university] decided to take some action" (Polzer et al. 2006, p. 688). This led to a reduction in the level of information sharing across all team members; ultimately, communication was reduced to communication between the subgroups. Panteli and Davison (2005) observed this phenomenon in their virtual student teams where the volume of communication that reached *all* member was lowest in the teams with strong, colocated subgroups.

Thus, when obvious subgroups emerge within a given team (due to locational or other factors, such as gender, race or ethnicity), this has negative effects on team performance and other outcomes (Li and Hambrick 2005). While this effect has been labeled group *faultlines* and widely studied in the groups literature, the notion of subgroup dynamics and group faultlines has not explicitly been linked to the research stream on TMS. To make this link explicit, and to explore its implications for DSTs, we leverage the notion of faultlines to theorize about how such faultlines that emerge in distributed teams can impair overall team performance and satisfaction via reductions in the level of TMS.

2.4 Group Faultlines: Subgroup Dynamics in DSTs

2.4.1 Concept of Group Faultlines

Faultlines are "hypothetical dividing lines that may split a group into subgroups based on one or more attributes" (Lau and Murnighan 1998, p. 328). In organization studies research, the focus has usually been on demographic factors that distinguish team members from each other. For example, a group comprised of two Asians in their 20s and two Caucasians in their 50s (Group 1 in Figure 1) has the potential to split into subgroups consisting of young Asian versus mid-age Caucasian members. Group 1 is defined as a group where strong faultlines occur; in contrast, faultlines are weaker in completely heterogeneous groups (Group 4) or in completely homogeneous groups (Group 3). By definition, the latter groups have weak faultlines. The stronger the faultlines, the more likely the team will split into factions, leading to the potential for inter-

[3]Polzer et al. (2006) defined fully distributed teams as those where each individual member worked in a separate location.

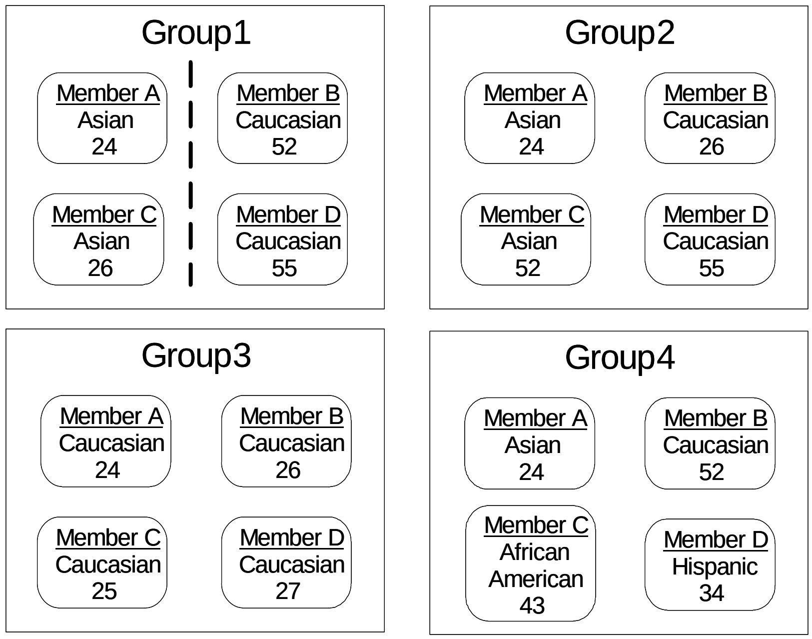

Figure 1. Groups with Different Faultline Strength Levels

Table 3. Direct Impacts of Strong Faultlines

Prior Literature	Faultline Base[†]	Direct Effect of Strong Faultines (+ = positive impact; – = negative impact)	
Earley & Moskowski 2000 (study 2)[‡]	Nationality	–	Worse proceses (team identity, group efficacy, role expectations, intrateam communication) Worse outcomes (team performance, satisfaction with team's performance
Lau & Murnighan 2005	Ethnicity and sex	+	Less relationship conflict Better group outcomes (psychological safety, group satisfaction)
Molleman 2005	Gender, age, and having a part-time job	–	Lower group cohesion Higher team conflict
Li & Hambrick 2005	Age, tenure, gender, and ethnicity	–	Higher emotional conflict Higher task conflict
Polzer et al. 2006	Geographic location	–	Higher conflict Lower trust
Rico et al. 2007	Educational background and conscientiousness	–	Worse performance Lower level of social integration

[†]We define the attribute or set of attributes based on which group faultlines are formed as the faultline base.
[‡]This paper reported results from three studies that examined the relationship between team and nationality heterogeneity and effectiveness performance. The faultline concept was reflected well only in Study 2's operationalization of heterogeneity.

group conflict (Jehn 1995) and the risk that members will share information within their subgroups rather than with all team members (Lau and Murnighan 1998). Empirical studies of group faultlines generally report that strong faultlines harm group processes and outcomes (see Table 3) (with the exception of Lau and Murnighan 2005).[4]

Some limitations of the faultlines literature have recently been identified, including the criticism that so-called "objective" faultlines (e.g., based on demographic attributes) don't necessarily mean that team members will perceive a true faultline in practice (Jehn and Bezrukova 2006). It is only when objective faultlines *do* manifest themselves as a divide among members that teams are likely to experience inter-subgroup conflict (Greer and Jehn 2007), coalition formation, and group conflict (Jehn and Bezrukova 2006). We believe it is critical to distinguish the notion of *perceived* (or actual) faultlines[5] from *objective* faultlines (Greer and Jehn 2007; Jehn and Bezrukova 2006), because objective faultlines (e.g., race, age, or gender differences) are not a sufficient condition for an actual, *perceived* faultlines to occur—that is, perceived by members as causing a rift or divide. Of course, faultlines may have nothing at all to do with visible demographic factors—but may emerge due to location, time-zone, or even cognitive style differences among team members.

The stronger the perceived faultline in a team, the more likely it will split into discrete subgroups, which leads to the potential for intergroup conflict (Jehn and Bezrukova 2006) and the likelihood that members will communicate and share information only within their subgroups rather than with all team members (Lau and Murnighan 1998).

2.4.2 Impacts of Perceived Faultlines on DSTs

In distributed environments, location differences become salient as the team engages in its task. Such location differences may, in turn, shape team dynamics and outcomes, including trust, conflict, and communication patterns. In field settings, researchers also observed that subgroups tend to withhold information from each other (Cramton 2001) or share knowledge only within their subgroups, with rare collaboration with other subgroups (Gratton et al. 2007). These studies suggest that strong perceived faultlines cause the team to disintegrate into subgroups, with members communicating and sharing knowledge only within their subgroups (Cramton 2001). This leads to the existence of uniquely held information among one or a few members of the team. Such uniquely held information is less likely to be salient to other members, causing knowledge gaps and misunderstanding (Stasser and Titus 1985).

Thus, failure of information exchange due to perceived faultlines has two negative consequences: first, it contributes to the existence of uniquely held information in distributed teams, which becomes a source of confusion and misunderstanding; second,

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[4]Some authors reject a simple linear relationship between faultlines and group outcomes. For example, Gibson and Vermeulen (2003) and Thatcher et al. (2003) report a curvilinear relationship between the faultline strength and various outcomes.

[5]Jehn and Bezrukova (2006, p. 6) define perceived faultlines in groups "when members actually perceive these divisions and the group behaviorally splits into two subgroups based on the alignment of two or more demographic attributes."

even when all members of a team have the same information regarding certain areas of the project, the problem of salience may still occur due to lack of information in other project aspects. In other words, people may be aware of the existence of project-related knowledge distributed in the team, but they do not realize the usefulness or importance of this knowledge because of their different schema (resulting from uniquely held information), thus they don't use that information or they use it in a way that creates misunderstanding or confusion. For example, research on product development teams found that members who lack a shared understanding of their domain activities often fail to take advantage of each others' knowledge due to differences in skills and experience (Dougherty 1992). Due to these differences, members often lack cues that can help them judge the credibility and quality of knowledge from their remote colleagues, which in turn leads them to ignore or misunderstand that knowledge (Carlile 2002; Dougherty 1992).

The knowledge management literature recognizes that effective coordination through electronic media depends on having a common understanding about the problems at hand, clear norms of behavior, and a context for interpreting knowledge (Davenport and Prusak 1997; Dougherty 1992; Krauss and Fussell 1990). When members of distributed teams have different information, they are more likely to filter out or misconstrue information held by others. Based on this logic, we anticipate a negative relationship between perceived fautlines and the coordination dimension of TMS:

> *Hypothesis 3*: Perceived fautlines will be inversely related to the coordination dimension of TMS in DSTs.

Perceived faultlines may also damage members' attitudes toward each other. Groups with strong faultlines have higher levels of conflict, which causes members to avoid communicating and sharing information with other subgroup members. According to attribution theory, when people lack situational information due to failure of information exchange, they tend to explain others' behavior as resulting from individual disposition, rather than due to the situation (Nisbett et al. 1973). This causes people to reach negative conclusions about others, particularly members of other subgroups. Based on this logic, we suspect that groups with strong faultlines will be less likely to have high levels of member credibility, compared to teams with no perceived faultlines (or only weak ones).

> *Hypothesis 4*: Perceived fautlines will be inversely related to the credibility dimension of TMS in DSTs.

Figure 2 shows our overall research model.

3 RESEARCH METHOD

We plan to survey of DSTs in multiple organizations. Data will be collected from team members and aggregated to the project team level. Where possible, validated measures from prior studies will be adapted. Table 4 summarizes measures that we are currently pilot testing with distributed student teams.

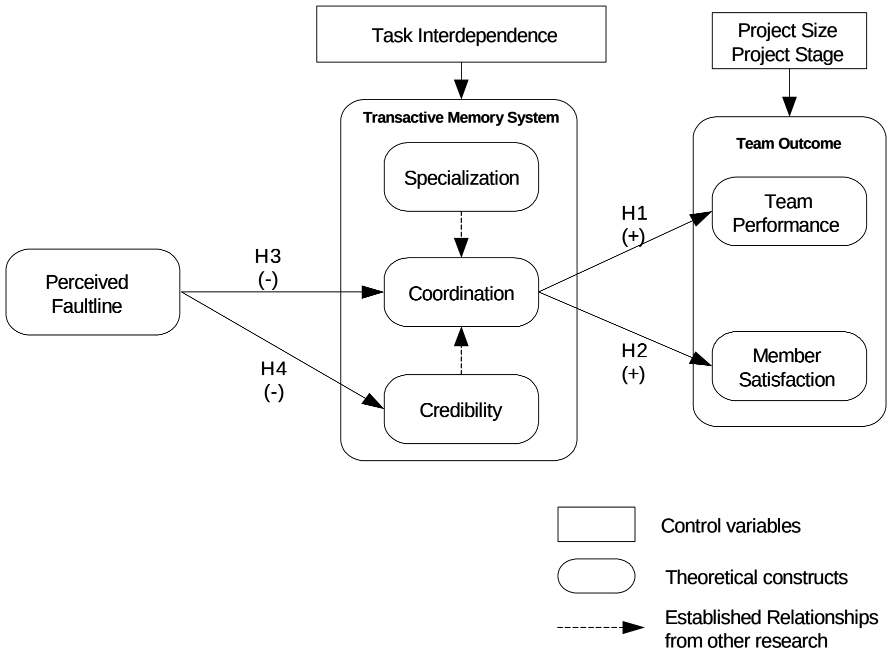

Figure 2. Research Model

Table 4. Measurement Items Used for Each Construct

Constructs and Measurement Items	References
Model Variables	
Perceived Faultlines	Original measures
Transactive Memory System	Lewis 2003
Team Performance	Henderson and Lee 1992
Member Satisfaction	Piccoli, Powell, and Ives 2004
Control Variables	
Project Stage	Original measures
Team size	Piccoli, Powell, and Ives 2004
Work Interdependence	Pearce and Gregersen 1991

4 EXPECTED CONTRIBUTION

4.1 Theoretical Contributions

Our study contributes to theory by examining how groups develop a TMS, taking into account subgroup dynamics based on faultlines triggered by demographic, location, or other differences. Moreover, we will focus on those faultlines that are *perceived* by group members (Greer and Jehn 2007; Jehn and Bezrukova 2006), rather than just the presence of objective faultlines (i.e., those assumed to occur based on demographic attributes). Prior research suggests that groups with strong faultlines have higher levels of conflict, which make members *intentionally* withhold information from other members. Our study will emphasize other by-products of faultlines (i.e., lack of effective coordination, reduced performance, and member satisfaction). Second, by measuring TMS as a consequence of group faultlines, we will provide insights into why such problems in developing an effective TMS occur, thus opening the "black box" that prior researchers have posited between objective faultlines and performance. By measuring the level of group TMS as a downstream result of actual, perceived faultlines, we hope to show how perceived faultlines impair team performance and member satisfaction.

4.2 Contribution to Practitioners

Our results will emphasize that managers should pay attention to subgroup dynamics that emerge within their teams. Especially in DSTs, faultlines can easily emerge due to salient location or culture differences. Second, the results from our study may encourage managers to take steps to increase the level of TMS among team members, especially members from subgroups who differ in terms of cultural or locational attributes.

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