The Moderating Effect of Cognitive Capability on Task Conflict: A Longitudinal Study of Task Conflict and Team Performance in Student Software Development Teams

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The Moderating Effect of Cognitive Capability on Task Conflict: A Longitudinal Study of Task Conflict and Team Performance in Student Software Development Teams

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Abstract

For software development teams to achieve development success, task conflict needs to be managed skillfully to counteract its undesirable consequences to team performance. Conflict is dynamic in nature, and its effect on team performance varies during software development lifecycle. Based on information processing theory and team cognition theory, this study proposes cognitive capability as an important moderator on the task conflict – team performance relationship. A longitudinal study was conducted in 70 student software development teams and multi-level model of change was applied to analyze the data collected at different time points. Results supported the proposition that while task conflict interferes with team performance, its detrimental effects get more severe over time; and cognitive capability, which develops along with the maturing of team cognition as team members work together on the focal project, helps restrain and convert the undesirable effect of task conflict on team performance toward beneficial and constructive.

Keyword: task conflict, software development teams, cognitive capability, longitudinal study
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Introduction

Modern organizations are increasingly adopting the team approach as a way of accomplishing tasks which surpass the capabilities of single individuals (Glassop, 2002). In addition to issues of time and resource coordination, teams are often created with the expectation that they will enable organizations to “better utilize expertise, minimize the impact of increasing workload on one individual, and maximize the use of increasingly more sophisticated technology” (Smith-Jentsch et al., 2001; p. 179).

Software development teams are an important example of this trend (Faraj and Sproull, 2000). Software projects are typically complex, dynamic, and involve unstructured tasks (Kraut and Streeter, 1995; Brodbeck, 2001). When a project exceeds the capacity of a single software developer, a team is convened and social processes interact with cognitive and motivational processes in performing technical work (Curtis et al. 1988). Effective teamwork featured by coordination among the various efforts is critical to successful software development (Kraut and Streeter 1995, Nidumolu 1995, Wholey et al. 1996). But the teamwork effort could be offset by conflict, or disagreements and tensions among team members, by impeding
the integration of different knowledge, expertise, viewpoints, and resources. Being able to handle conflict and overcome coordination breakdown is argued to be an element for successful software development (Curtis et al. 1988).

Conflict is dynamic in nature (Jehn and Mannix 2001), and its effect on team performance varies during software development lifecycle (Robey et al. 1989). However, most studies addressing the conflict – team performance relationship focus on the static levels of conflict, and time effect is rarely examined by their research models. To fill this gap, this study conducted a longitudinal investigation of conflict in 70 student software development teams, and applied multi-level model of change to analyze data collected at different time points. Based on information processing theory and team cognition theory, this study proposed and tested cognitive capability as an important moderator that affect the conflict – team performance relationship during software development lifecycle.

Conceptual Background and Hypotheses

Conflict and Team Performance

Early study of conflict focused primarily on its negative consequences such as reduced productivity, poor decision quality, and low team morale and member satisfaction (Jehn 1997; De Dreu and Weingart 2003). Recent development in this field considered the pursuit of effective conflict management toward constructive outcomes as a more meaningful research inquiry. Two approaches – instrumental approach and structural approach – represent the switch of research focus to the pursuit of productivity benefits of conflict.

Instrumental Approach

The instrumental approach views conflict as a driver, rather than an impeder, for successful software development process. This approach describes conflicts by their consequences as functional vs. dysfunctional or constructive vs. destructive. Conflicts that help enhance decision quality (functional conflict (Amason 1996)) and solve complex problems (constructive conflict (Deutsch 1969)) are considered desirable situations for software development. The ways how high-performing teams handle conflict during the software development process are investigated; common practices are summarized; and strategies are suggested to guide future software development practices. “The objective is not to avoid conflict, but rather to use the group setting to confront differences and to resolve them” (Robey et al. 1989; p. 1173).

The premise underlying instrumental approach is that when managed skillfully or resolved successfully, conflict can be beneficial to teams (Schweiger et al., 1986; Jehn, 1995; Amason, 1996; Simons and Peterson, 2000). Conflict resolution is
suggested as an important mechanism to bring constructive outcomes to software development (Robey and Farrow 1982; Robey et al. 1989, 1993). The undesirable conflicts (dysfunctional or unconstructive) that produce tension, antagonism, and distract team members from performing the task are also discussed mainly for a purpose of highlighting the importance of conflict management.

By analyzing their consequences, the instrumental approach also provide some insight on the special makeup of conflict that leads to different outcomes. For example, Amason (1996) argued that functional conflict is generally task oriented and focused on judgmental differences about how best to achieve common objectives, while dysfunctional conflict tends to be emotional and focused on personal incompatibilities or disputes.

**Structural Approach**

The structural approach views conflict as multidimensional (Jehn 1995; Simons and Peterson 2000). It is possible that one dimension of conflict enhances the quality of decisions made by a team, while another dimension attenuates satisfaction and affective acceptance of the decisions. Two types of conflict have been widely studied in the literature: task conflict and relationship conflict. Task conflict is a perception of disagreements among team members about the content of their decisions and involves differences in viewpoints, ideas, and opinions. Relationship conflict is a perception of interpersonal incompatibility and typically includes tension, annoyance, and animosity among team members.

Task conflict is cognitive in nature, and involves the expression of different viewpoints and opinions among team members pertaining to a team task. As thus, task conflict is beneficial to performance ends by: (1) encouraging greater cognitive understanding of the issue being discussed, and (2) improving affective acceptance of group decisions. In contrast, relationship conflict is affective in nature, involves interpersonal negative emotions such as dislike among team members, or feelings such as annoyance, frustration, irritation, and angry. Team interactions based on these emotional factors tend to distract from the focal task and waste time and resources on irrelevant issues. As thus, negative consequences to team performance can hardly be prevented. Member satisfaction also suffers as the result of increased tension among team members.

Both the instrumental approach and the structural approach of conflict support the positive potential of task conflict to team performance. The arguments bring task conflict to the focus of much research in a pursuit of enhanced team performance. However, empirical studies did not support the expected benefits of task conflict. A recent meta-analysis (De Dreu and Weingart 2003) revealed a strong and negative correlation between task conflict and team performance, even after

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1 Jehn (1997) proposed a third type of conflict, process conflict, to depict an awareness of controversies about aspects of how task accomplishment will proceed. Process conflict is not well examined in the literature (Jehn and Mannix 2001), and its conceptual difference from task conflict may not be distinct in that the two concepts are both cognitive in nature. So this study selected to avoid discussing process conflict.
counting the moderating roles of task types, and the associations between task and relationship conflict. De Dreu and Weingart adopted an information processing perspective to explain the results, arguing that conflict impedes team performance by taking “needed resources (cognitive resources and time) away from the performance of complex task” (p. 747).

The results from De Dreu and Weingart (2003) and other empirical findings suggest that the effect of task conflict is likely determined by the way a team processes information (e.g., using different communication modes (Hinds and Mortensen 2005)) and the team’s cognitive capability to handle the information processing. This study focuses on the moderating effect of cognitive capability on the task conflict – team performance relationship.

**Task Conflict And Cognitive Capability**

Based on information processing theory and team cognition theory, I propose cognitive capability as an important moderator for the task conflict - team performance relationship.

**Information Processing Theory**

The positive potential of conflict to team performance can find theoretical roots in the information processing theory. First proposed by March and Simon (1958), information processing theory has been a predominant framework to studying organizational behavior (Levitt et al. 1999). According to the theory, organizations and their subunits are viewed as open social systems to cope with uncertainty - the difference between information possessed and information required to complete a task. To achieve quality performance, organizations and their subunits need to design and implement certain structures to deal with information requirements faced during task execution. The structural conditions, including the organismic-mechanistic nature of a subunit’s structure and the nature of coordination and control mechanisms, affect the subunit’s ability to attend to and deal with uncertainty (Tushman and Nadler, 1978).

Applying the information processing perspective, software development teams are viewed as cognitive systems to process information. The instrumental approach views conflict as “a universal social process through which disagreements between people are addressed” (Robey et al. 1989, p. 1173). Disagreements (different views, opinions, perspectives, etc) are considered as valuable information and conflict is considered as the process to articulate the information. Conflict will be functional or constructive when these disagreements are resolved and consensus is reached among team members. In contrast, the structural approach views task conflict as the information input that need to be processed. Intensified task conflict is considered equivalent to a large amount of information of different viewpoints, ideas, or approaches on handling a focal task. Being effectively processed, such task-relevant information will benefit team performance.
Treating conflict either as a process (the instrumental approach) or as an input (the structural approach), the information processing theory suggests an important constrained factor – cognitive capability – for teams to process the information successfully. Cognitive capability is discussed in the literature as the ability of a team to interpret its information environment in an efficient and meaningful fashion.

In IS research, cognitive capability and related concepts are often used to explain the undesirable consequences of excessive information to the extent of exceeding the system processing capacity. For example, Grise and Gallupe (2000) investigated the productivity of face-to-face electronic meeting with an emphasis on the effects of information overload. They argued that too much information increases mental workload to an extent of exceeding the limitation of human information processor, resulting in poor performance. In another study, Patrashkova-Volzdoska and colleagues (2003) investigated communication effects in cross-functional IS project teams. They postulated a curvilinear relationship between communication frequency and team performance, hypothesizing that both low and high communication frequency would inhibit team performance. While acknowledging communication as a main medium for information exchange and sharing, they argued that “Too much information sharing and processing within a team, however, can overload members’ processing capabilities and, thereby, inhibit their performance” (p. 263).

Although commonly discussed as a determining factor for teams information-processing capability, the concept of cognitive capability on team performance is often suggested in general discussion by common wisdoms and logic reasoning. There is a lack of quantitative assessment of its exact makeup, not to mention empirical examination of how cognitive capability shapes team effectiveness on information processing. Recent development of team cognition theory may provide a theoretical lens as well as measurement support to studying the impact of cognitive capability in software development teams.

**Team Cognition Theory**

Team cognition refers to the mental models collectively held by a group of individuals which enable them to accomplish tasks by acting as a coordinated unit. Rather than studying the activities among team members, team cognition addresses the underlying mental models that guide team behavior. As Walsh (1995) pointed out, team cognition functions as mental templates which are imposed on information environments to give them form and meaning, providing a cognitive foundation for action.

The concept of team cognition has been proposed as a powerful explanatory mechanism for understanding interactions in effective teams (Cannon-Bowers et al., 1993; Cooke et al., 2000; Klimoski and Mohammed, 1994). For a team to exchange and process information and knowledge among team members, team interaction requires both time and cognitive
resources (MacMillan et al., 2004). Team cognition enables members to formulate accurate teamwork and taskwork predictions (Cannon-Bowers et al., 1993; Katz and Tushman, 1979), adapt their activities and behaviors in a collaborative way, and thereby increase overall team effectiveness (Cannon-Bowers and Salas, 2001; Lewis, 2004). Without well-formed team cognition, team members will not be able to efficiently share knowledge and information, coordinate each other’s activities, resolve conflicts, or negotiate agreed-upon solutions (Cannon-Bowers and Salas, 2001; Jackson et al., 1995; Walsh, 1995).

From an information processing perspective, the performance of a team is constrained by its cognitive capability. Given the same amount of information, the teams with high level of cognitive capability are able to process information more effectively to achieve quality performance. By providing a mental template to guide team behavior, team cognition is equivalent to cognitive capability on shaping teams’ effectiveness of information processing. Viewing task conflict as a significant source of task information, team cognition can serve as a surrogate measure for cognitive capability to moderate the task conflict – team performance relationship.

Team cognition is also viewed as a dynamic consequence which is resulted from team interactions, and in turn, affects team interactions. The process view of team cognition suggests the construct as a mediating mechanism to predict team performance (Cooke et al., 2000). In contrast, cognitive capability focuses on the ability of a team as information processor rather than the wellness of team process. Theoretically, cognitive capability has no direct effects on team performance. In other words, team cognition has theoretically direct impact on team performance while cognitive capability has not. As to the moderating effect on the effectiveness of team processing (e.g., the task conflict – team performance relationship), the two concepts are not fundamentally different.

*Hypothesis 1:* Task conflict has a negatively effect on team performance.

*Hypothesis 2:* Cognitive capability moderates the task conflict – team performance relationship in a way that the detrimental effect of conflict on team performance is less severe for teams with high level of cognitive capability than for teams with low level of cognitive capability.

**The Dynamic Nature of Task Conflict and Cognitive Capability**

Conflict is dynamic in nature. Both the patterns of conflict (Jehn and Mannix 2001) and effects of conflict (Robey et al. 1989) change over time. The observations have guided the development of stage models for successful teamwork. Productive teams are said to move through different stages over time. As teams progress the degree and nature of conflict change markedly. There are abundant observations that conflicts happened in late stages are more detrimental to team performance than conflicts happened in early stages, so special attentions to reduce conflicts need to be placed in early stages.
rather than in late stages. A pioneer stage model was proposed by Tuckman (1965). Of its four stages of “forming”,
“storming,” “norming,” and “performing,” “storming” is designated specially for conflict management. In another work,
Wheelan (1994) synthesized a large body of team development work and proposed a five stage model, of which conflict is
expected to increase dramatically in the second stage (counterdependency and fight) when individuals begin to jockey for
position within the team. Teams are suggested to effectively reduce conflict such that they can be productive in the later work
stage (stage 4).

So, the qualitative literature suggests clearly that conflict must subside over time if teams are to become productive.
In other words, the negative effect conflict will be more detrimental over time. However, empirical research investigates
conflict mainly on static levels, leaving a gap in the qualitative literature regarding the powerful influence of time (Jehn and
Mannix 2001).

Understanding the dynamic nature of conflict is particularly important for managing task conflict in software
development teams. Software development involves different stages to handle different sub-tasks (Edström 1977), and
information requirements that guide developing activities often fluctuate dramatically through the development lifecycle
(McKeen et al. 1994). As thus, the disagreements among developers can hardly be the same through the dynamic
development process. As both the amount and the content of task conflict changes over time, so is expected for the effects of
task conflict on team performance.

_Hypothesis 3a: The negative effect of task conflict on team performance increases over time._

Cognitive capability is not static during the software development lifecycle. Similar to team cognition, which
evolves to higher levels as team members work together on the same task (Mathieu et al. 2000; Levesque et al. 2001), teams’
cognitive capability to process task information increases over time as members develop more understanding of the focal task
as well as other members’ knowledge, skills, and abilities. As a direct reflection of the maturing team cognition, cognitive
capability develops along with teams’ progress.

The dynamic nature of task conflict and cognitive capability and their interplay with time during software
development lifecycle lead to a three-way-interaction of time-conflict-cognitive capability on affecting team performance.
Because in the literature there is a lack of longitudinal study of conflict, the three-way interaction is proposed to be
significant, but its effect is not specified as positive or negative.

_Hypothesis 3b: A three-way interaction of time-conflict-cognitive capability is significant in affecting team
performance._

The hypotheses are graphically summarized in the research model shown in Figure 1. Signs indicate that the
associated effects have been hypothesized to be positive or negative.
Methods

Procedures

In this study, I designed a synthetic task of software development to test the research model. Synthetic tasks are “research tasks constructed by systematic abstraction from a corresponding real-world task” (Martin et al. 1998, p. 123). Performance on a synthetic task should exercise some of the same behavioral and cognitive skills associated with the real-world task, while avoiding the complexity (i.e., the existence of various confounding factors that may lower the opportunity of observing significant effects of the investigated factors) encountered in an uncontrolled field study on real tasks.

The synthetic task employed in this study was to develop a relational database system using Microsoft Access. The subjects were students. Except for team formation and task deadline, students were free to set their own schedules and procedures to carry out their tasks, simulating the software development process in a realistic manner.

212 undergraduates from two middle-eastern public universities participated in this study. The students enrolled in a similar information systems course and had a similar course requirement of collaboratively developing a relational database system over a 5-week or 4-week period. The students were juniors (about 24%), seniors (about 65%), and fifth-year business majors (about 11%). When the project was assigned, students were instructed to form three-member teams and were allowed to make their own teammate selections. Some students selected acquaintances as teammates, while others chose students who happened to be seated nearby. Seventy teams were formed with some variances in sizes (ranging from 2 to 5, with 3 as the dominant team size). The demographics of participants are reported in Table 1. The characteristics of teams are reported in table 2.

Table 1. Demographics of Participants

<table>
<thead>
<tr>
<th>Gender</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>88</td>
</tr>
<tr>
<td>Male</td>
<td>124</td>
</tr>
<tr>
<td>Total</td>
<td>212</td>
</tr>
</tbody>
</table>
Measures

This study investigates the moderating effects of time and cognitive capability on the task conflict – team performance relationship. Three constructs were measured to test the hypotheses.

Task Conflict

Task conflict was measured with 3 items adopted from Robey et al. (1989). Students were asked to use a 1-5 scale to rate the extent to which conflict, disagreement, and debate happened in their teams on task issues. The instrument is consistent with Jehn’s (1995) measures of task conflict. After aggregation analysis individual responses were averaged to construct the final measure of conflict.

Cognitive Capability

In the literature there is no explicit measure for cognitive capability. I used 8 items borrowed from the team cognition literature to measure the level of cognitive capability in the participated student teams. As discussed before, team cognition is theoretically equivalent to cognitive capability on moderating the task conflict – team performance relationship.

The 8 items includes 4 items adopted from Faraj and Sproull (2000) regarding the shared awareness of expertise location (knowing who knows what) in the team, and 4 items adopted from Kraut and Streeter’s (1995) notion of shared task understanding (having a shared view of the software development project). The two sub-constructs were considered as two
important elements of team cognition especially for software development teams (He et al. 2007). The average of the two-constructs was used as an indicator for the level cognitive capability later in the hypothesis testing.

**Team Performance**

Team performance has been discussed in the literature as multidimensional, including within-team coordination, effectiveness, and efficiency dimensions of team performance. The focus of this research was on the dynamic effect of task conflict, and the complicated nature of team performance is beyond the scope of the study. So I selected a 5-item instrument adapted from Robey et al.’s (1993). Students were asked to use a 1-5 scale to rate the extent to which their teams operated efficiently, met the schedule, produced products with appropriate quantity and quality, and interacted effectively with people inside and outside the teams. After aggregation analysis individual responses were averaged to construct the final measure of team performance.

**Data Collection, Analysis, and Results**

**Data Collection**

During the software development process, students were asked to answer an online survey regarding their participation and team performance every week over a five or four week period. The first survey was conducted one week after the start of the project. Although encouraged by the course instructor, participating in the survey was voluntary. Students were told that the survey responses would not influence grades in any way. Some students failed to answer the survey on time, and some submitted incomplete answers. This resulted in 618 usable sets of individual data for analysis, or an 89.6% effective response rate. To assure the data integrity of team-level representation, 44 team data were dropped because of less than 50% member participation. This resulted in 201 effective team-level data points for further analysis. Team-level participation percentages were reported in Table 3.

**Table 3. Team-Level Survey Participation**

<table>
<thead>
<tr>
<th>Survey Participation Percentage</th>
<th>Team Data Points</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;33.3%</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>33.3%</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>66.7%</td>
<td>34</td>
<td>44 in total, dropped from further analysis</td>
</tr>
<tr>
<td>75%</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>152</td>
<td>201 in total, used for further analysis</td>
</tr>
<tr>
<td>Total</td>
<td>245</td>
<td></td>
</tr>
</tbody>
</table>
Aggregation Analysis

Before aggregating individual responses to the team level, it is necessary to confirm response homogeneity or agreement within each team. I selected two classes of statistic tests for the aggregation analysis: Inter-Rater Agreement (or \( r_{WG(J)} \)), and Intraclass Correlation (or ICC). The two tests assess with different approaches the congruence among team members on their response to measured items. The \( r_{WG(J)} \) index compares the observed within-group variances to an expected variance from random responding (James et al., 1984; 1993); the ICC index is based on a nested-ANOVA design and analyzes within-team and between-team variances (James, 1982). The use of different statistic tests provides methodological and statistical triangulation (Faraj and Sproull, 2000) and its conclusion is more rigorous.

The results of the aggregation analysis for each construct are reported in Table 4. The IRA values of all the multi-item instruments – cognitive capability (based on two sub-constructs of awareness of expertise location, and shared task understandings), team performance, and task conflict – were high (\( r_{WG(J)} > 0.7 \) is often used as a heuristic for judging high vs. low within-group homogeneity (Cohen et al., 2001)), suggesting a satisfying level of homogeneity among responses within each team. In contrast, the ICC values are moderately acceptable (James, 1982) and are comparable to other similar studies (e.g., Faraj and Sproull, 2000). The calculation of three indices suggests a reasonable level of agreement within all the teams. As thus, aggregating individual responses to the team level is justified.

Table 4. Descriptive Statistics and Aggregation Analysis for All Variables

<table>
<thead>
<tr>
<th>Labels</th>
<th>Description</th>
<th>Mean</th>
<th>SD</th>
<th>Scale Range</th>
<th>Cronbach ( \alpha )</th>
<th>Aggregation Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Indiv. level</td>
<td>Team level</td>
</tr>
<tr>
<td>CC</td>
<td>Cognitive Capability</td>
<td>4.07</td>
<td>0.42</td>
<td>1-5</td>
<td>0.92</td>
<td>0.94</td>
</tr>
<tr>
<td>EL</td>
<td>Awareness of Expertise Location</td>
<td>4.08</td>
<td>0.48</td>
<td>1-5</td>
<td>0.93</td>
<td>0.94</td>
</tr>
<tr>
<td>TU</td>
<td>Shared Task Understanding</td>
<td>4.06</td>
<td>0.45</td>
<td>1-5</td>
<td>0.89</td>
<td>0.92</td>
</tr>
<tr>
<td>TP</td>
<td>Team Performance</td>
<td>4.00</td>
<td>0.48</td>
<td>1-5</td>
<td>0.89</td>
<td>0.90</td>
</tr>
<tr>
<td>CF</td>
<td>Task Conflict</td>
<td>1.62</td>
<td>0.53</td>
<td>1-5</td>
<td>0.79</td>
<td>0.81</td>
</tr>
</tbody>
</table>

Construct Validity

This study involves three constructs: conflict, cognitive capability, and team performance. Cognitive capability was assessed using two sub-constructs of team cognition as explained before. The validity of the three constructs was assessed in terms of their internal consistency of measurement, convergent validity, and discriminant validity.

Table 4 presents the Cronbach alpha levels of the measured constructs at both individual level and team level. The Cronbach alpha levels are all greater than the commonly-used 0.70 level, demonstrating internal consistency of measurement.
The analysis of the convergent and discriminant validity was conducted using principal factor analysis of the three constructs (Table 5). Using a varimax rotation and a forced extraction\(^2\), the three expected factors explained 75% of the total variance. Most items loaded high on their expected factors with the exception of TP05, whose loadings of 0.572 was much lower than the recommended 0.7 level. Further examination of the item revealed that assessing a team's interactions with people outside the team might not be a relevant measure of team performance for the participated student teams. Therefore, item TP05 was dropped from later data analysis. The cross-loadings were comparatively low (all were less than 0.45), providing evidence that all factors were measures of different concepts. Discriminant validity was therefore readily concluded.

### Table 5. Summary of Principle Component Analysis of Task Conflict, Cognitive Capability, and Team Performance

<table>
<thead>
<tr>
<th>Labels</th>
<th>Items</th>
<th>Cognitive Capability</th>
<th>Expected Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Team Performance</td>
</tr>
<tr>
<td>EL01</td>
<td>The team had a good &quot;map&quot; of each other's talents and skills.</td>
<td>0.723</td>
<td>0.377</td>
</tr>
<tr>
<td>EL02</td>
<td>Team members were assigned to tasks commensurate with their task-relevant knowledge and skill.</td>
<td>0.686</td>
<td>0.433</td>
</tr>
<tr>
<td>EL03</td>
<td>Team members knew what task-related skills and knowledge they each possess.</td>
<td>0.732</td>
<td>0.416</td>
</tr>
<tr>
<td></td>
<td>Team members knew who on the team has specialized skills and knowledge that is relevant to their work.</td>
<td>0.707</td>
<td>0.427</td>
</tr>
<tr>
<td>TU01</td>
<td>Team members had a common understanding of the application domain that the system was to support.</td>
<td>0.853</td>
<td>0.112</td>
</tr>
<tr>
<td>TU02</td>
<td>Team members had a common understanding of the technologies used in the development process.</td>
<td>0.833</td>
<td>0.201</td>
</tr>
<tr>
<td>TU03</td>
<td>Team members had a common understanding of the project development procedures.</td>
<td>0.870</td>
<td>0.12</td>
</tr>
<tr>
<td>TU04</td>
<td>Overall, team members shared their visions of the project. Please evaluate performance of the project team in terms of:</td>
<td>0.680</td>
<td>0.331</td>
</tr>
<tr>
<td>TP01</td>
<td>1) the amount of work the team produced.</td>
<td>0.268</td>
<td>0.834</td>
</tr>
<tr>
<td>TP02</td>
<td>2) the efficiency of team operations.</td>
<td>0.299</td>
<td>0.841</td>
</tr>
<tr>
<td>TP03</td>
<td>3) the team's adherence to the schedule.</td>
<td>0.211</td>
<td>0.852</td>
</tr>
<tr>
<td>TP04</td>
<td>4) the quality of work the team produced.</td>
<td>0.272</td>
<td>0.817</td>
</tr>
<tr>
<td>TP05</td>
<td>5) the effectiveness of the team's interactions with people outside the team.</td>
<td>0.341</td>
<td>0.572</td>
</tr>
</tbody>
</table>

\(^2\) Factor analysis using the extraction rule of eigenvalue-over-1 resulted in four factors. Items loadings suggested satisfactory measurement of the four constructs of Awareness of Expertise Location, Shared Task Understanding, Team Performance, and Task Conflict. Since the average of the two constructs of Awareness of Expertise Location and Shared Task Understanding would be used for Cognitive Capability in hypothesis testing, a forced extraction of three factors was used here to justify the later calculation of cognitive capability.
Regarding the conflicts in your group on some development issues during the past ONE week,

<table>
<thead>
<tr>
<th>Conf01</th>
<th>How much conflict was there between you and the others?</th>
<th>-0.090</th>
<th>-0.132</th>
<th>0.913</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conf02</td>
<td>How much disagreement were you directly involved in?</td>
<td>-0.078</td>
<td>-0.149</td>
<td>0.913</td>
</tr>
<tr>
<td>Conf03</td>
<td>To what extent were any issues debated among other members and yourself?</td>
<td>-0.164</td>
<td>-0.034</td>
<td>0.760</td>
</tr>
</tbody>
</table>

Initial Eigenvalue 7.67 2.06 1.53
Percentage of variance explained 51.11 13.72 10.17
Cumulative percentage of variance explained 51.11 64.83 75.00

Note: Factor loadings are of rotated solution using Varimax with Kaiser Normalization. Boldface indicates factor loadings of items selected to measure the variable.

N=201 (data collected from 70 teams surveyed at 4 or 3 time points; team data with equal-to-or-less-than-50% member participation were excluded.)

Table 6 calculated the correlation coefficients between measurement items and the three constructs. This practice is suggested by Gefen and Straub (2005) as another valid procedure for assessing construct validity. Gefen and Straub argued that to demonstrate both convergent and discriminant validities, loadings of measurement items on their assigned variables (marked in bold in Table 5) should be larger in magnitude than any other loading. Table 5 presented the expected pattern, providing another evidence of construct validity.

Table 6. Correlation Analysis of Measurement Items and Construct Values

<table>
<thead>
<tr>
<th>Variables and Items</th>
<th>Cognitive Capability</th>
<th>Team Performance</th>
<th>Task Conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Capability</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team Performance</td>
<td>0.64</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Task Conflict</td>
<td>-0.28</td>
<td>-0.24</td>
<td>1</td>
</tr>
<tr>
<td>el01</td>
<td>0.87</td>
<td>0.56</td>
<td>-0.24</td>
</tr>
<tr>
<td>el02</td>
<td>0.83</td>
<td>0.57</td>
<td>-0.22</td>
</tr>
<tr>
<td>el03</td>
<td>0.88</td>
<td>0.60</td>
<td>-0.25</td>
</tr>
<tr>
<td>el04</td>
<td>0.87</td>
<td>0.60</td>
<td>-0.22</td>
</tr>
<tr>
<td>tu01</td>
<td>0.82</td>
<td>0.47</td>
<td>-0.23</td>
</tr>
<tr>
<td>tu02</td>
<td>0.82</td>
<td>0.50</td>
<td>-0.25</td>
</tr>
<tr>
<td>tu03</td>
<td>0.82</td>
<td>0.44</td>
<td>-0.23</td>
</tr>
<tr>
<td>tu04</td>
<td>0.79</td>
<td>0.56</td>
<td>-0.27</td>
</tr>
<tr>
<td>tp01</td>
<td>0.58</td>
<td>0.89</td>
<td>-0.18</td>
</tr>
<tr>
<td>tp02</td>
<td>0.62</td>
<td>0.92</td>
<td>-0.23</td>
</tr>
<tr>
<td>tp03</td>
<td>0.55</td>
<td>0.90</td>
<td>-0.23</td>
</tr>
<tr>
<td>tp04</td>
<td>0.57</td>
<td>0.88</td>
<td>-0.21</td>
</tr>
<tr>
<td>conf01</td>
<td>-0.25</td>
<td>-0.23</td>
<td>0.89</td>
</tr>
<tr>
<td>conf02</td>
<td>-0.24</td>
<td>-0.25</td>
<td>0.89</td>
</tr>
<tr>
<td>conf03</td>
<td>-0.25</td>
<td>-0.16</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Note: Labels of items are explained in Table 4.
All correlation coefficients are significant at 0.01 level.
N = 201

Hypotheses Testing
Analysis was conducted on the team-level dataset. As explained before that both conflict and cognitive capability are dynamic in nature, the investigation of their hypothesized direct and interaction effects on team performance should test time effect explicitly as another moderating factor. For this reason, I selected multilevel-models-of-change approach as the testing method in order to incorporate time effects explicitly in the model (Singer and Willett 2003). The multilevel models of change is considered appropriate because it formalizes time in a model as a variable so that its effects can be concluded from the resulting statistics. More specifically, I tested the hypothesis using the following 2-level model:

Level-1:  \[ Y_{ij} = \pi_{0i} + \pi_{1i} Time_{ij} + \varepsilon_{ij} \]

Level-2:  \[ \pi_{0i} = \gamma_{00} + \gamma_{01} CF_{ij} + \gamma_{02} CF_{ij} \times CC_{ij} + \xi_{0i} \]
\[ \pi_{1i} = \gamma_{10} + \gamma_{11} CF_{ij} + \gamma_{12} CF_{ij} \times CC_{ij} + \xi_{1i} \]

Where:

- \( Y_{ij} \): the dependent variable (team performance) measured for team \( i \) at time \( j \)
- \( CF_{ij} \): the extent of task conflict measured for team \( i \) at time \( j \)
- \( CC_{ij} \): the level of cognitive capability calculated for team \( i \) at time \( j \)
- \( \varepsilon_{ij} \), \( \xi_{0i} \), and \( \xi_{1i} \): residuals at cross-team and within-team levels

The level-1 sub-model hypothesizes that team cognition results from team communication and evolves over time; the level-2 sub-model assumes that time-caused-changes vary across teams due to their different team characteristics. The two levels are methodologically distinguished by their associated residuals, which indicate the extent to which cross-team and within-team variances are explained by the model. By substituting for \( \pi_{0i} \) and \( \pi_{1i} \) from the level-2 sub-model into the level-1 sub-model, a full or composite multilevel model for change was arrived as described below:

\[ Y_{ij} = \gamma_{00} + \gamma_{10} CF_{ij} + \gamma_{01} CF_{ij} \times CC_{ij} + \gamma_{11} Time_{ij} + \gamma_{12} CF_{ij} \times CC_{ij} \times Time_{ij} + \left( \zeta_{0i} + \zeta_{1i} Time_{ij} + \varepsilon_{ij} \right) \]

Note that the residual of the composite model (in parentheses) has an occasion-dependent component \(- \zeta_{1i}\)\( Time_{ij}\) - the value of which, although unexplained by the model, is dependent on the time of measurement. The mathematical form of the composite residual reveals two common properties of occasion-specific residuals: autocorrelation and heteroscedasticity. Autocorrelation means that the residuals are correlated with each other across repeated occasions. Heteroscedasticity refers to that the residuals having unequal variances across occasions of measurement. These conditions require special treatment in model estimation. In this study, we use Full Maximum Likelihood (FML) to estimate parameters (including both regression coefficients and variance components). FML computes goodness-of-fit statistics that describe the fit of the entire model.
Under FML, the goodness-of-fit statistics describes how a model fits with the sample data (Singer and Willett 2003, p. 87-90).

The sample size of 201 data points is adequate for multilevel models of change (For a general multilevel model, Snijders and Bosker (1999) considered samples of 30 or more to be sufficient). The models were estimated using SPSS Version 14.0. To better assess the prediction power of adding cognitive capability and time effect to the conflict-team performance relationship, I tested three models – unconditional model (using the gross sample mean to estimate a team’s performance), conflict model (including task conflict and task conflict-time interaction), and the hypothesized full model (including task conflict, task conflict-cognitive capability interaction, and their time interactions). The results are reported in Table 7.

**Table 7. Summary of Multi-level Time Analysis for Conflict and Conflict X Cognitive Capability Interaction**

<table>
<thead>
<tr>
<th></th>
<th>Team Performance</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unconditional Model</td>
<td>Conflict Model</td>
<td>Full Model</td>
</tr>
<tr>
<td>Intercept</td>
<td>4.074***</td>
<td>4.356***</td>
<td>4.217***</td>
</tr>
<tr>
<td>Conflict</td>
<td>-0.335*</td>
<td>-1.054*</td>
<td></td>
</tr>
<tr>
<td>Conflict X Cognitive Capability</td>
<td></td>
<td>0.226*</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>0.061</td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td>Time X Conflict</td>
<td>0.032</td>
<td>-0.321*</td>
<td></td>
</tr>
<tr>
<td>TIME X Conflict X Cognitive Capability</td>
<td></td>
<td>0.081*</td>
<td></td>
</tr>
<tr>
<td>Residuals</td>
<td>0.138</td>
<td>0.123</td>
<td>0.089</td>
</tr>
<tr>
<td>Pseudo $R^2$</td>
<td></td>
<td>10.9%</td>
<td>35.5%</td>
</tr>
<tr>
<td>-2 Log Likelihood</td>
<td>234.22</td>
<td>208.31</td>
<td>138.17</td>
</tr>
<tr>
<td>Akaike's Info Criterion (AIC)</td>
<td>240.22</td>
<td>224.31</td>
<td>158.17</td>
</tr>
<tr>
<td>Schwarz's Bayesian Criterion (BIC)</td>
<td>250.13</td>
<td>250.73</td>
<td>191.20</td>
</tr>
</tbody>
</table>

Note: *$p<0.05$  ** $p<0.01$  *** $p<0.001$(two-tailed)  
Coefficients are unstandardized  
N = 201

Model evaluation was based on deviance statistics (including -2 Log Likelihood, AIC, and BIC, the smaller the statistics, the better), and Pseudo $R^2$'s. Pseudo $R^2$'s calculated the percentage of reduced residuals against the residuals of the unconditional model, which used sample mean as the only parameter for estimation. Thus, pseudo $R^2$ statistics should be interpreted as the proportional reduction in residual variance (Singer and Willett 2003, p.102-103).

As indicated in the Table 7, the coefficients of task conflict and task conflict-time interaction were negative and significant. It supported the hypothesis H1 that task conflict had negative effect on team performance, and H2 that such negative effect would get more severe over time, suggesting that task conflict happened in a late stage would be more detrimental than task conflict happened in an early stage. In contrast, coefficients of task conflict-cognitive capability interaction and task conflict-cognitive capability-time interaction were both positive and significant, supporting H3 that with high cognitive capability, teams are better able to handle task conflict for quality performance.
A close examination of the model-fit statistics suggested that the full model fitted well for the sample data. The full model reduced 35.5% of residuals on the estimation of team performance, presenting a satisfactory prediction power of the model. Another interesting observation may come from the comparison between the conflict model and the full model. Not only presented a poor model-fit, the conflict model could not detect the time influence on the task conflict – team performance relationship. Both the coefficients for time and task conflict-time interaction were not significant (their $p$-values were 0.375 and 0.713 separately). This result suggests that task conflict is a complex cognitive process that requires both time and cognitive capability. Any investigation of the dynamic task conflict-team performance relationship could be inclusive and misleading if cognitive capability is not examined.

**Summary and Discussions**

Based on information processing theory and team cognition theory, this study proposed cognitive capability as an important moderator on the task conflict – team performance relationship. A longitudinal study was conducted in 70 student software development teams and multi-level model of change was applied to analyze the data collected at different time points. Results supported the proposition that while task conflict interferes with team performance, its detrimental effects get more severe over time; and cognitive capability, which develops along with the maturing of team cognition as team members work together on the focal project, helps restrain and convert the undesirable effect of task conflict on team performance toward beneficial and constructive.

The results provided strong empirical support to the common wisdom that when managed skillfully, task conflict could bring benefits to the software development process. To investigate the positive potential of task conflict to software development teams, Robey et al. (1993) proposed conflict resolution as an intervening mechanism, arguing that task conflict could benefit software development teams if it was satisfactorily resolved. But there left no answer as to when such conflict management is mostly crucial for teams to be productive. This study filled the gap with the implication that task conflict needs to be handled early to avoid its more detrimental effects in later stages. Given the lack of investigation of time influence in conflict studies (Jehn and Mannix 2001), this finding provided empirical support to the stage models proposed in the qualitative literature.

Another important implication of the study was that the effect of task conflict was contingent on teams’ ability to process information. As revealed in the results of Table 7, not only the dynamic effect of conflict was difficult to detect, the resulting model presented poor predictive power if cognitive capability was not included in the model. This suggests that conflict management is a complicated cognitive process restrained by the team’s ability to process information. In addition,
improving cognitive capability through the development of mature team cognition was found to be particularly effective in helping restrain and convert the undesirable effect of task conflict on team performance toward beneficial and constructive.

As with all empirical work, this study is subject to limitations. While the subjects were engaged in a relatively extended project (5 weeks and 4 weeks) and had a vested interest in the outcome of the team's work, the use of student subjects raises the possibility that findings may not accurately reflect the behavior of software project teams working in a business organization. However, most prior studies share this characteristic and there is evidence that students are good proxies for “real-world” people in many contexts (King and He 2006). Further studies of conflict “in the rough” are needed to better understand how the factors considered in this study ultimately play out in the other settings.

In this study all student teams were instructed to work on similar projects with the same technology (Microsoft Access Databases). The purpose was to reduce the possible confounding factors of different information requirements that may arise from different tasks and technologies (Tushman and Nadler 1978). But it also excluded the possibility of examining the role that task and technology characteristics might play in the process of conflict management. Again, additional studies which consider a range of technologies and tasks would provide useful insight into the role of these factors in this process.

Since the constructs of task conflict, cognitive capability, and team performance were self-assessed using online surveys, common method bias could present potential threat to the validity of the results. One method to assess the extent of common method bias is to examine the relationship of interested variables with a “marker variable”, which is theoretically unrelated to the constructs of interest (Podsakoff et al. 2003). The assumption is that if severe common method bias exists, it should have same effect on all observed variables. During the study I surveyed some participated students on their computer efficacy and computer anxiety using established instruments from the literature. Correlation analysis of Table 8 revealed that there was no significant correlation between the constructs of interest and the two theoretically irrelevant variables. As thus, one can conclude that significant common source bias did not present in the study.

<table>
<thead>
<tr>
<th></th>
<th>Cognitive Capability</th>
<th>Team Performance</th>
<th>Task Conflict</th>
<th>Computer efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer efficacy</td>
<td>0.111</td>
<td>0.002</td>
<td>0.142</td>
<td></td>
</tr>
<tr>
<td>Computer Anxiety</td>
<td>-0.143</td>
<td>0.078</td>
<td>0.031</td>
<td>0.469</td>
</tr>
</tbody>
</table>

Note: All measures were aggregated to team-level. Correlations were insignificant except the one between Computer Efficacy and Computer Anxiety (p-value <0.001) N=98

Another limitation is the measure of cognitive capability. In this study, cognitive capability was measured based on 8 items of team cognition. Although it was argued that team cognition and cognitive capability exhibits similar moderating
effect on the conflict-team performance relationship, the two concepts are not exactly the same. By definition, cognitive
capability is a broader concept than team cognition, including not only the way knowledge and expertise are organized in
teams, but also the detailed contents of these knowledge and skills. New instruments need to be developed to capture the
level of cognitive capability in software development teams. Considering the current chaos in team cognition literature on
measuring team cognition (Cannon-Bower and Salas 2001; Cooke et al. 2000, 2001; Mohammed et al. 2000), capturing
cognitive capability could be a challenging task. But its importance in information processing systems dealing with complex
tasks (such as software development teams) should encourage such research effort.


