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# Testing a Second-Order Factor Structure of Team Cognition in Distributed Teams

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# TESTING A SECOND-ORDER FACTOR STRUCTURE OF TEAM COGNITION IN DISTRIBUTED TEAMS

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## ABSTRACT

The present research develops and tests a hierarchical model of the underlying behavioral processes of team cognition. Team cognition is represented as a second-order construct comprised of three first-order dimensions (team learning, team reflexivity, and team mental model). The proposed second-order construct was embedded in a nomological network as a mediator between collaboration mode (collocated vs. non-collocated technology-mediated) and task outcomes (team productivity and team interaction quality). The partial least squares approach was used to test the measurement and structural model. As hypothesized, team cognition significantly influenced team productivity and team interaction quality outcomes. Further, collaboration mode significantly improved team cognition through its specific effects on the team learning, team reflexivity, and team mental model first-order dimensions of team cognition. The results substantiate 1) the conception of team cognition as a multidimensional construct, 2) the use of second-order factors to address potential multicollinearity problems, and 3) use of higher-order constructs to present a more parsimonious model.

**Keywords:** hierarchical model, mental model, reflexivity, second-order factor, team cognition, team learning

## INTRODUCTION

Team cognition has been defined to as the ways in which teams process and use information (MacMillan, Entin, & Serfaty, 2004). More specifically, team cognition refers to a team-wide information sharing and exchange process, knowledge structures held by members of a team and the ways in which the team uses these knowledge structures. These knowledge structures are often referred to in the literature as schemas (e.g., Rentsch & Woehr, 2004) or mental models (e.g., Hinsz, 2004). Mohammed, Klimoski and Rentsch (2000) argued that there has been a significant amount of confusion and ambiguity about how to measure team cognition. Further, these measurement problems and inadequate conceptual development over how to measure cognitive structure at the group level were cited as significant reasons for lags in empirical research on shared mental model. This study argues that use of a higher-order construct that allows one to reflect team cognition from multiple perspectives could provide improved performance of relevant models. Accordingly, the main objective of this study was to develop and test a model that specifies a multidimensional structure of team cognition. The model's conceptualization draws from the theories of team-based learning (Edmondson, 1999), team reflexivity (De Dreu, 2007), and team mental model (Klimoski & Mohamed, 1994).

## MULTIDIMENSIONAL STRUCTURE OF TEAM COGNITION

As stated earlier team cognition has been referred to as the ways in which teams process and use information (MacMillan, Entin, & Serfaty, 2004). In addition, the team cognition literature has suggested that team mental models evolve and ultimately converge across time as a result of communication among group members (Rentsch & Woehr, 2004). Crossan, Lane and White (1999) presented a conceptualization of cognition at the individual, team and organizational level. Individual cognition was related to individual interpretation of information and environmental stimuli. Group cognition was marked by the sharing and evaluation of individually-held mental models and subsequent team-wide encoding of a mutually accepted mental model. Finally, integration and institutionalization of group level cognition outcomes is considered as organizational learning. Mohammed and Dumville (2001) noted that team cognition also involves the maintenance of a common ground (i.e. consensus on interpretation) and situation awareness (e.g., awareness of task progress/status, location of expertise, solution adequacy). Perception, learning and decision-making processes have also been associated with cognition in general. Edmondson (1999) described team cognition as the process of integrating multiple viewpoints within a psychosocial context that is characterized by psychological safety (i.e. encouraged participation where members are free from criticism of ideas). In summary, the varied conceptualizations of team cognition in the related literature consistently refer to behaviors associated with team learning, team reflection on task strategy, task status and interpersonal interactions, and team mental model derived from an acquired shared understanding. Consequently, these three constructs or factors are assessed for their potential role in collectively defining a second-order construct defined as team cognition.

## RESEARCH MODEL AND HYPOTHESES

Edwards (2001) proposed an integrative analytical framework based on structural equation modeling (SEM), which allows for the simultaneous inclusion of higher-order (multidimensional) constructs and their dimensions as latent variables. Figure 1 below presents the conceptual framework within which the hierarchical model of team cognition is tested. Based on the theory of affordances (Kirschner, Strijbos, Kreijns, & Beers, 2004) and social impact theory (Latane, 1981), the framework argues that collaboration mode will impact team productivity and team interaction quality outcomes through the mediating effects of a formative second-order factor team cognition. Further, team cognition is comprised of three first-order factors (team learning, team reflexivity, and team mental model) modeled as manifest variables or indicators.

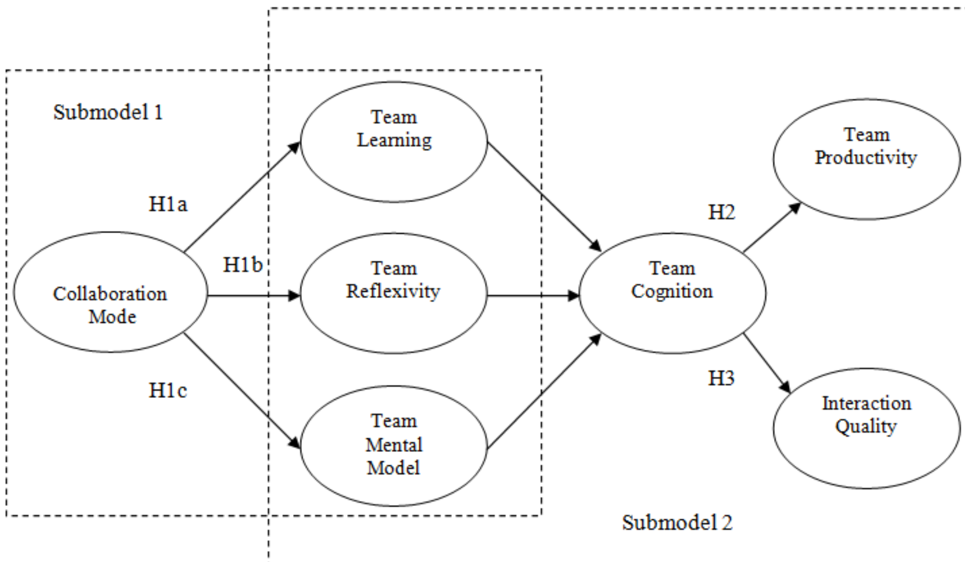


**Figure 1.** *Research Model*

### Collaboration Mode and Team Cognition

Kirschner et al. (2004), suggested that in order to achieve successful collaborative learning outcomes, a learning environment must provide 1) tools and procedures (*technological affordance*), 2) the opportunity to stimulate, facilitate, and maintain information exchange and idea evaluation (*educational affordance*), and 3) a cooperative, supportive, and trusting climate (*social affordance*). Social impact theory (SIT) suggests that behavior is guided by social influence derived from 1) salience or importance attributed to team members (*strength*), 2) time, spatial, or interpersonal distance among team members (*immediacy*), and 3) the quantity of influential sources (*numbers*). Recent research has also shown that relative to collocated teams, non-collocated technology-mediated teams inherently exhibit lower strength and immediacy effects and therefore encounter more negative team process behaviors such as withdrawal from participation (e.g., Blaskovich, 2008) diminished communication/information exchange (e.g., DeLuca & Valacich, 2006), lack of shared understanding (e.g., Miranda & Saunders, 2003), and intra-team conflict (e.g., Hinds & Mortensen, 2005). Further, the process losses inherent to non-collocated technology-mediated teams tend to create difficulty in assessing the current state of a task's solution and execution plan alignment with task requirements and monitor any motivational or interpersonal problems that may arise (De Dreu, 2007; Edmondson, 1999). Consequently, the following hypothesis is proposed:

**HYPOTHESIS 1.** *Teams working in a face-to-face collaboration setting should exhibit more effective team learning, team reflexivity, and team mental models than in a technology-mediated setting.*

### Team Cognition and Collaboration Outcomes

Effective team learning and accurate shared team mental models provide declarative and procedural knowledge that facilitates task execution, minimizes duplication of effort and facilitates synergy and efficiency which in turn promotes greater productivity. In addition, teams that are unable to adequately reflect on task status and alignment with task objective are likely to experience process losses, frustration, conflict, and distrust (Hoegl, Weinkauf, & Gemuenden, 2004). Team reflexivity can stimulate a process of shifting from bad to good ideas and problem solutions, and ultimately improved team performance (De Dreu, 2007) and can promote development of cooperative goals and minimize disconfirmation of expectations (Briggs, Reinig, & de Vreede, 2008) that result in a supportive and cooperative task environment (Tjosvold, Tang & West, 2004). Thus, the following hypotheses are proposed:

**HYPOTHESIS 2.** *Improved team cognition will be positively associated with team productivity.*

**HYPOTHESIS 3.** *Improved team cognition will be positively associated with team interaction quality.*

## RESEARCH METHODOLOGY

To test the research model and hypotheses, a laboratory experiment was conducted to examine the effects of two different modes of team collaboration – face-to-face and technology-mediated collaboration. Forty-eight participants were drawn from a population of Management Information Systems undergraduate students familiar with the Systems Development Life Cycle approach to software design and knowledge of structured programming. The teams were required to enhance the functionality of a hypothetical university information system. The experimental task required each team to construct software design documentation that included (1) a hierarchy chart, (2) a list of function prototypes, and (3) pseudocode for each function identified as part of a solution to the problem.

### Measures

The behavioral observation approach was used in assessing team learning, team reflexivity, and shared mental model by using three trained observer ratings of associated task-related and affect-related behaviors. Observer ratings can be superior to self-report data collection because it allows real-time measurement of dynamic and emergent behaviors and self-report data can be distorted due to affect and inaccurate recall. In providing their ratings, three trained observers used a rating scale that ranged from 1 (very low) to 7 (very high). The interrater agreement index for all scale ratings ranged from $a_{wg(j)} = 0.85$ to $a_{wg(j)} = 0.97$ indicating very good interrater agreement (Brown & Hauenstein, 2005). Scale items appear in Table 1 below. The team productivity measure was determined by awarding one point for each correct specification of any data value of a specific data file, correct output and input data value of a program module (i.e., function or subroutine), and correct specification of program statement needed in a specific program module.

### Measurement Model

To assess internal consistency reliability, convergent validity and discriminant validity of the construct measurements, the constructs' composite reliabilities (CR) and the average variance extracted (AVE) were calculated using PLS. Regarding internal consistency (reliability), composite reliability scores for every construct (ranging from 0.874 to 0.975, as shown in Table 1) are well above 0.70, which is the suggested benchmark for acceptable reliability (Chin, 1998). Table 1 also indicates with the exception of one item-to-construct loading of 0.696 all of the items have loadings at 0.700 or above and the t-statistic for the item to construct loadings were all significant at $p \leq .01$. These results indicate that the measurement model has displayed both item internal consistency reliability and item convergent validity.

**Table 1. Composite Reliability, AVE, and Indicator Loadings**

| **Construct and Item Level Values** | | **loading** |
|---|---|---|
| **Team Learning (Composite Reliability = 0.975; AVE = 0.908)** | | |
| TeamLearn1 | Some team members were just listening without providing any verbal input | 0.937 |
| TeamLearn2 | Team-wide consensus was confirmed before moving forward with an idea | 0.977 |
| TeamLearn3 | All team members provided useful verbal input | 0.926 |
| TeamLearn4 | Ideas were thoroughly discussed and evaluated among all team members | 0.971 |
| **Team Reflexivity (Composite Reliability = 0.894; AVE = 0.740)** | | |
| Reflexivity1 | Frequent double-checking the work done by others is done right | 0.946 |
| Reflexivity2 | Frequent double checking that the solution is meeting requirements | 0.915 |
| Reflexivity3 | Team made obvious effort to create and maintain a positive climate | 0.700 |

| Team Mental Model (Composite Reliability = 0.972; AVE = 0.921) | | |
|---|---|---|
| MentalModel1 | There were some difference of opinion or concern about the correctness of the proposed solution | 0.926 |
| MentalModel2 | There was significant confusion about what is going on | 0.940 |
| MentalModel3 | Some team members required a lot of explanations about what was going on | 0.978 |
| **Team Interaction Quality (Composite Reliability = 0.874; AVE = 0.700)** | | |
| IntQual1 | Felt frustrated or tense about another team member's behavior | 0.886 |
| IntQual2 | Expressed negative opinion about another's team member's behavior | 0.912 |
| IntQual3 | Observed others express a negative opinion about your behavior | 0.696 |

Discriminant validity is evidenced when all the loadings of the scale items on their assigned latent variables or construct are larger than their loading on any other latent variable. Table 2 below provides the correlations of each item to its intended latent variable (i.e., loadings) and to all other constructs (i.e., cross loadings).

**Table 2. Indicator Loadings**

| | Indicator to Latent Variable Loadings | | | |
|---|---|---|---|---|
| Item | Team Learning | Team Reflexivity | Team Mental Model | Team Interaction Quality |
| TeamLearn1 | .937 | .580 | .608 | .628 |
| TeamLearn2 | .926 | .661 | .652 | .685 |
| TeamLearn3 | .977 | .698 | .681 | .713 |
| TeamLearn4 | .971 | .659 | .550 | .641 |
| Reflexivity1 | .619 | .946 | .491 | .672 |
| Reflexivity2 | .609 | .915 | .454 | .570 |
| Reflexivity3 | .532 | .698 | .463 | .613 |
| MentalModel1 | .719 | .684 | .943 | .681 |
| MentalModel2 | .573 | .427 | .960 | .556 |
| MentalModel3 | .590 | .453 | .976 | .619 |
| IntQual1 | .608 | .706 | .467 | .886 |
| IntQual2 | .336 | .334 | .662 | .696 |
| IntQual3 | .765 | .704 | .526 | .912 |

Table 3 below indicates that the AVE square roots that appear in the diagonal are larger than any correlation between the associated construct and any other construct (Chin, 1998; Majchrzak et al., 2005). This AVE analysis result and the item to construct loadings discussed above suggest that the measurement model displays discriminant validity.

**Table 3. Latent Variable correlations and square root of AVE**

| | Team Learning | Team Reflexivity | Team Mental Model | Interaction Quality |
|---|---|---|---|---|
| **Team Learning** | **.953** | | | |
| **Team Reflexivity** | .682 | **.860** | | |
| **Team Mental Model** | .653 | .542 | **.960** | |
| **Interaction Quality** | .700 | .714 | .644 | **.837** |

Note: square root of the constructs' AVE appear in the diagonal

### Structural Model

Using PLS Graph (Version 3.0 Build 1130), the structural model and hypotheses were assessed by examining path coefficients and their significance levels (Chin, 1998). The proposed model conceptualized three first-order constructs (team learning, team reflexivity, and team mental model) modeled as formative indicators (i.e. manifest variables) of the second-order construct – team cognition. Because PLS Graph (Version 3.0 Build 1130) does not directly permit the representation of second-order latent constructs, it was necessary to separately test the first-order constructs that formed the second-order construct in a sub-model, and then use the resulting computed first-order factor scores as manifest indicators of the second-order construct that is later used in a separate model (Yi & Davis, 2003). Therefore, two sub-models were separately tested (see Figure 3 below): Sub-model 1 related the first-order constructs to their reflective indicators and determinants (collaboration mode), and Sub-model 2 related the second-order construct (team cognition) comprised of factor score loadings derived from collaboration mode effects to the remaining model variables (team productivity and team interaction quality).

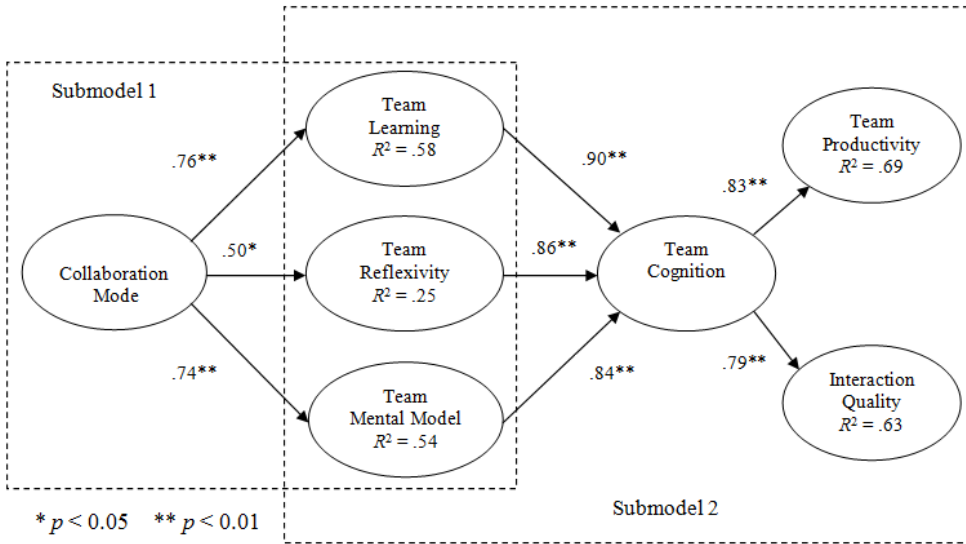


**Figure 2.** *PLS Test Results of Research Model*

Figure 2 above summarizes the model-testing results. Supporting Hypothesis 1, collaboration mode had significant effects on all three first-order dimensions of team cognition: team learning ($\beta = 0.76$, $p < 0.01$), team reflexivity ($\beta = 0.50$, $p < 0.01$), and team mental model ($\beta = 0.74$, $p < 0.01$). The second-order factor, team cognition, had a significant effect on team productivity ($\beta = 0.83$, $p < 0.01$) thereby providing support for Hypothesis 2. Supporting Hypothesis 3, team cognition had a significant effect on team interaction quality ($\beta = 0.79$, $p < 0.01$). The proposed research model provided the best fit to the data (i.e. overall explained variance in the model) as compared to all other possible configurations (e.g., omitted paths, first-order factors only, etc.).

## DISCUSSION

This study attempted to investigate the multidimensionality of team cognition. In testing the hierarchical model of team cognition, the study was successful in explaining the underlying mechanisms through which team cognition mediates the impact of collaboration mode on team productivity and team interaction quality. All three dimensions of team cognition were significantly influenced by collaboration mode. Moreover, the overall team cognition significant effect suggests that learning, reflexivity, and shared interpretation are essential for facilitating team productivity. In other words, in addition to facilitating information and transactions, collaboration mode also operates on team level cognitive functioning. Further, poor team cognition can give rise to frustration that result in poor interactions among team members.

The findings offer an extension to prior research on team cognition by extending the operationalization of team cognition. The results suggest that team cognition can be modeled as a second-order composite latent construct determined by three first-order factors (team learning, team reflexivity, and team mental model). The use of a second-order factor structure can enhance the conceptualization and estimation of team cognition models as a result of the capture of an overall representation of team cognition through the underlying commonality among its first-order dimensions. In addition, the multilevel conceptualization of team cognition allows for analysis at different levels of abstraction – overall team cognition or a specific underlying dimension. This suggests that hierarchical models offer both greater flexibility and parsimony in specifying model constructs. The use of team learning, team reflexivity, team mental model as a parsimonious higher-order construct takes advantage of their conceptual overlap (capturing multiple aspects of team cognition), while maintaining the unidimensionality of their measure.

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