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Virtual Team Common Knowledge: Construct Specification and Effect on Knowledge Integration Effectiveness

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VIRTUAL TEAM COMMON KNOWLEDGE: CONSTRUCT SPECIFICATION AND EFFECT ON KNOWLEDGE INTEGRATION EFFECTIVENESS

LES CONNAISSANCES PARTAGÉES DANS LES ÉQUIPES VIRTUELLES : CONCEPTUALISATION ET ANALYSE DES EFFETS SUR L'INTÉGRATION EFFICACE D'EXPERTISE.

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Abstract

Common wisdom in the literature on virtual team is that rigid, explicit and formal forms of coordination are required for the integration of different expertise to take place, while tacit forms of coordination are difficult to establish and maintain. This study challenges this claim and evaluates the contribution of virtual team common knowledge – a tacit coordination mechanism – on virtual teams' knowledge integration effectiveness. In an attempt to reconcile the different theoretical stances adopted in previous studies, we offer a new conceptualization for "virtual team common knowledge" and assess its structural and psychometric properties. A measure is developed and tested with 700 individuals spread across 102 virtual teams in the field. The evidence suggests that virtual team common knowledge is formed by common task knowledge, common expertise knowledge, common IT interaction knowledge, and common specialized knowledge. Virtual team common knowledge is also found to positively influence knowledge integration effectiveness.

Keywords: Virtual team, Common Knowledge, Knowledge Integration, PLS

Résumé

La recherche sur les équipes virtuelles a, jusqu'à maintenant, principalement étudié les bienfaits des techniques de coordination explicites et formelles. Toutefois, peu d'études ont été effectuées concernant la nature et/ou le rôle des méthodes de coordination tacites dans de telles équipes. La présente recherche vise à combler ce manque dans la littérature en proposant une structure multidimensionnelle du concept des connaissances partagées dans les équipes virtuelles. Ce concept est présenté comme une forme de coordination tacite ayant un effet positif sur l'intégration efficace d'expertise dans les équipes virtuelles. La présente étude, effectuée auprès de 102 équipes virtuelles tirées d'une large firme multinationale, confirme la conceptualisation proposée ainsi que les bénéfices des connaissances partagées sur l'intégration efficace d'expertise dans les équipes virtuelles.

Mots-Clés: Équipes Virtuelles, Connaissances Partagées, Intégration d'Expertise. PLS.

VIRTUAL TEAM COMMON KNOWLEDGE: CONSTRUCT SPECIFICATION AND EFFECT ON KNOWLEDGE INTEGRATION EFFECTIVENESS

Introduction

Virtual teams – defined as groups of geographically-dispersed individuals who use information technologies to communicate and coordinate their work (Hinds and Bailey 2003; Maznevski and Chudoba 2000; Townsend et al. 1998) – have been a subject of considerable attention over the last ten years in both research and practice communities. Virtual teams are often seen as providing significant advantages, including working across geographical, temporal, functional, and organizational boundaries, facilitating access of knowledge, generating new and high quality products, reducing operating costs, and increasing work efficiency (Haas 2006; Malhotra et al. 2001; Sole and Edmonson 2002). However, achieving these outcomes seems to depend on the ability of virtual team members to coordinate their actions successfully (Alavi and Tiwana 2002; Malhotra and Majchrzak 2004). This study focuses on the coordination that facilitates the integration of expertise in virtual team. If the integration of expertise is a benefit often taken for granted in virtual team research, very little is known about the nature and type of coordination mechanisms for knowledge integration.

There exist two main ways of coordinating and synchronizing work in virtual teams: *explicit coordination* (which refers to the interpersonal behaviors of virtual team members to manage work interdependencies) and *tacit coordination* (i.e., synchronization of members actions based on unspoken assumptions about what others in the team are likely to do). Thus far, virtual team research has mainly studied explicit forms of coordination, including behavioral control strategies (Piccoli and Ives 2003), knowledge and information sharing (Cummings 2004; Majchrzak et al. 2000), patterns of ICT usage (Malhotra and Majchrzak 2004; Majchrzak et al. 2005; Maznevski and Chudoba 2000), and temporal coordination mechanisms (Massey et al. 2003; Montoya-Weiss et al. 2001). Overall, studies found that explicit coordination mechanisms have positive impacts on several group processes and outcomes, such as stronger team cohesion (Beranek and Martz 2005; Walther and Bunz 2005), reduced conflicts (Montoya-Weiss et al. 2001), and better quality outputs (Massey et al. 2003).

In contrast to explicit forms of coordination, less research exists on tacit forms of coordination in virtual teams. The evidence suggests that tacit coordination can be problematic in virtual team because it is affected by several informational barriers such as failure to communicate and retain unique information, parallel and ineffective information processing, challenges for spontaneous communication, and lack of a shared context (Cramton 2001, Hightower and Sayeed 1996, Hinds and Bailey 2003, Alavi and Tiwana 2002). This study brings a new perspective on the study of tacit coordination mechanisms by looking at how common knowledge among team members can act as a valuable tacit form of coordination for virtual teams. Rooted in shared cognition literature (e.g., Brandon and Hollingshead 2004; Cannon-Bowers and Salas 2001; Wegner 1987) and organizational learning theories (Grant 1996a; Grant 1996b), the paper argues that common knowledge represents a tacit coordination mechanism that enables people to synchronize their inputs without the need for rich interpersonal communication and formal coordination approaches (see Rico et al. 2008), thus avoiding the aforementioned informational barriers. Anticipation process required by tacit knowledge can effectively rests on the elements of members' knowledge set that are commonly held between them, or lie at the intersection of their knowledge sets (Grant 1996a, Grant 1996b).

While the notion of common knowledge has a fairly rich tradition in collocated team research (see for instance Cannon-Bowers and Salas 2001 and Rico et al. 2008), our understanding of the nature of common knowledge and its role in virtual teams remains much more limited. More precisely, we believe that two primary research gaps characterize the current literature on common knowledge in virtual teams. First, elements of shared cognition acting as tacit coordination mechanisms have been assessed in many ways using different theoretical stances, thus leading to some theoretical fragmentation. For instance, Cramton (2001) covered the theme of common knowledge in virtual teams as a "mutual knowledge problem" defined through five informational inefficiencies, suggesting that lack of mutual knowledge is observable through dysfunctional communication and coordination behaviors. In their conceptual paper on knowledge integration in virtual teams, Alavi and Tiwana (2002) argue that constraints on transactive memory and insufficient mutual understanding represent important challenges for knowledge integration in virtual teams. Others have studied the phenomena of transactive memory (Malhotra and Majchrzak 2004; Sole and Edmonson 2002; Yoo and Kanawattanachai 2001;

Kanawattanachai and Yoo 2007), collective mind (Yoo and Kanawattanachai 2001), and team awareness (Espinosa et al. 2007) as the main components of virtual team members' common knowledge basis, generally suggesting that these concepts have important implications for the performance of virtual teams. In sum, while the notion of common knowledge has received some attention in the virtual team literature and there is indication that it can have important impacts on virtual team performance, no shared meaning has emerged in respect to its conceptualization or the way it acts as a tacit form of coordination.

Second, resulting from this absence of shared meaning, a variety of measures are used in studying common knowledge, making it more difficult to cumulate research findings in useful ways. Beyond the differences due to the lack of shared meaning, there is also no consensus on the scope and depth of components of common knowledge The concept of common knowledge has often been operationalized broadly and/or in opposite, has frequently been reduced to a very specific element of virtual team shared cognitive basis. In fact, some research has looked at the concept in its aggregated form, with relatively little account for the specific elements of the team's structure, processes, and characteristics that are the objects of members' shared cognitive representation. While such an holistic conceptualization has been useful to assess the general nature and impacts of the phenomenon of common knowledge, it limits our understanding of the specific key components of virtual team members' cognitive elements that need to be commonly held in order to be successful. Other studies have adopted the opposite approach, and have looked at a very narrow set of elements of the team process that are held in common into virtual team members' cognitive structure.

To address the aforementioned gaps in research, the present paper provides a new conceptualization of virtual team common knowledge. To deal with the issue of theoretical fragmentation outlined above, this conceptualization reconciles several theoretical stances into a manageable set of elements that, together, define the overall common knowledge basis acting as a tacit coordination mechanism of virtual teams. The proposed conceptualization also highlights the multidimensional nature of virtual team common knowledge, thereby addressing the gap in research concerning the ambiguity in scope and depth that characterizes the current literature on the construct. Such a multidimensional view of common knowledge also help explain how multiple elements of virtual team members' cognitive structure combine together to form a powerful tacit coordination mechanism.

The rest of the paper is structured as follows. First, a conceptualization for the construct of virtual team common knowledge is proposed, and its impact on team outcomes is explained. Second, the method used to develop and test the structure and impact of the construct is presented, followed by the results of the PLS analyses. Finally, contributions and limitations of the study are discussed, along with avenues for future research.

Conceptualizing Virtual Team Common Knowledge

In research on traditional teams, the phenomena of tacit coordination and common knowledge are rooted in different streams of research such as transactive memory systems (Brandon and Hollingshead 2004, Lewis 2003, Wegner 1987), shared mental models (Cannon-Bowers et al. 1993), and expertise coordination (Faraj and Sproull 2000), structuration theory (Orlikowski and Yates 1994, Sole and Applegate 2000). Organizational learning and knowledge management research also provide conceptual advances concerning the concept of common knowledge (Grant 1996a; Grant 1996b). As shown in Table 1, the aforementioned streams of research have been the anchoring point of most research on tacit coordination in virtual teams.

Table 1. Virtual Team Common knowledge and knowledge integration effectiveness

Authors	Concept referring to tacit coordination	Underlying literature	Main contribution on team processes and outcomes
Alavi and Tiwana (2002)	Common knowledge, transactive memory system, shared context	Knowledge-based theory, transactive memory systems	Potential challenges for knowledge integration in virtual teams.
Baba et al. (2004)	Shared knowledge, cognitive convergence	Shared cognition, cognitive consensus	Shared cognition alone is not sufficient to account form performance gains.

Cramton (2001)	Mutual knowledge	Mutual knowledge, information sampling, attribution theory	Lack of mutual knowledge are associated with informational problems within virtual teams.
Espinosa et al. (2007)	Team knowledge, team awareness	Shared cognition, transactive memory systems, team mental models	Team knowledge and awareness facilitates coordination in virtual teams.
Kanawattanachai and Yoo (2007)	Transactive memory systems, expertise location, task-knowledge coordination	Transactive memory systems	Positive impact of transactive memory systems on tem performance.
Malhotra et al. (2001)	Cross-functional knowledge and skills	Knowledge management	Help team leverage the use of complementary knowledge and skills
Malhotra and Majchrzak (2004)	Shared/common understanding within the team	Mutual knowledge, Transactive memory system	Positive impact on team effectiveness, and knowledge creation
Orlikowski and Yates (1994)	Genres of organizational communication, genre repertoires	Structuration theory	Genre repertoires include a rich array of socially-recognized communication patterns that evolve over time.
Sole and Edmonson (2002)	Situated knowledge, awareness	Transactive memory systems, expertise coordination	Awareness of expertise location and availability facilitates usage of situated knowledge in virtual teams.
Sole and Applegate (2000)	Shared norms of ICT usage for knowledge sharing	Adaptive structuration theory, structuration theory	Effective technology use norms are hypothesized to positively affect team outcomes
Yoo and Kanawattanachai (2001)	Transactive memory system; collective mind	Socially-shared distributed cognition, collective mind, transactive memory systems	Transactive memory and collective mind are important drivers of team performance at different points in time.

Drawing upon prior research on organizational teams (Marks et al. 2001), shared cognition literature (Brandon and Hollingshead 2004; Cannon-Bowers et al. 1993; Cannon-Bowers and Salas 2001), and on past IS research, as presented in Table 1, the concept of virtual team common knowledge is defined here as the organized set of knowledge items that are commonly held by individuals in respect to their team's structure and processes (adaptation of Klimoski and Mohammed 1994; Mohammed and Dumville 2001). It represents the aspects of virtual team members' cognitive structure that are common held or "shared" by them at a certain point of the team's lifecycle, or lie at the intersection of their knowledge sets (Grant 1996a, Grant 1996b). In fact, each member of a given virtual team is likely to possess cognitive representation of key aspects of the team's properties, processes, challenges, goals, etc. What shapes the construct of virtual team common knowledge is the presence of accurate and overlapping mental representations of such properties, processes, challenges, goals, etc.

Our conceptualization of virtual team common knowledge rests on two main principles. First, *virtual team common knowledge is a dynamic property of a team at a given point in its lifecycle* (Marks et al. 2001). Virtual team common knowledge is conceptualized at the team-level of analysis because the existence of the construct emerges from the combination of overlapping individual-level cognitive representations taking place within the team setting. In fact, even if the cognitive representations about team processes and properties are held by individual members of virtual teams, the "commonness" and accurateness of such cognitive representations happen at a higher level of abstraction, which is the team level of analysis.

Second, *virtual team common knowledge is a multidimensional construct*, meaning that members of virtual teams are very much likely to have shared cognitive representations of multiple complementary yet theoretically-distinct elements of their team's structure and processes (Espinosa et al. 2007). Support for this multidimensional view of virtual team common knowledge can be found in various streams of research, such as the knowledge-based view (Grant 1996a) and shared mental model research (Cannon-Bowers et al. 1993). For instance, Grant (1996b) states that different types of common knowledge can be found within organizational teams and work units, such as common knowledge about the distribution of expertise, shared behavioral norms, common domain-specific knowledge, and others. Similarly, Cannon-Bowers et al. (1993) suggest that multiple mental models co-exist within a team (i.e. equipment model, task model, team interaction model, and team model), thereby complementing each other and shaping the overall content and structure of that team's common knowledge basis. The next section provides more information about the way such a multidimensional view of common knowledge is applied to the context of virtual teamwork.

Four dimensions of virtual team common knowledge

We draw on the literature on knowledge management (Anand et al. 1998; Grant 1996a), shared mental models (Cannon-Bowers et al. 1993; Mohammed and Dumville 2001), team cognition (Lewis 2003; Lewis 2004; Wegner 1987; Brandon and Hollingshead 2004) and on virtual teams research (Cramton 2001; Malhotra et al. 2000; Malhotra and Majchrzak 2004; Orlikowski and Yates 1994) to propose four dimensions of virtual team common knowledge: (1) common task knowledge, (2) common expertise knowledge, (3) common specialized knowledge, and (4) common IT interaction knowledge.

> *Hypothesis 1: Virtual team common knowledge is a second-order factor model formed by four dimensions: common task knowledge, common expertise knowledge, common specialized knowledge, and common IT interaction knowledge.*

Common task knowledge

The first dimension of virtual team common knowledge is called *common task knowledge*, and refers to the degree of shared understanding existing amongst virtual team members about the characteristics of the task and the way it should be conducted (adapted from Cannon-Bowers et al. 1993). In other words, it captures the extent to which virtual team members have a homogeneous cognitive representation of the attributes of the task and the actions needed to foster its accomplishment (Brandon and Hollingshead 2004). According to the literature on team mental models (Cannon-Bowers et al. 1993; Klimoski and Mohammed 1994), effective team performance of knowledge-based groups requires that their members hold common and overlapping cognitive representations of the task requirements, procedures, strategies, and environmental constraints. When they do so, they are better able to predict each other's action and coordinate their work successfully, which lead to increasing levels in knowledge utilization and performance at the team level (Klimoski and Mohammed 1994).

Thus far, few empirical studies have attempted to conceptualize the notion of common task knowledge in virtual teams or isolate its impacts on team outcomes. However, there is evidence showing that failure to establish common knowledge about the task's attributes and procedures can have detrimental effects on the way virtual team members access and utilize knowledge at the team level. For example, Sole and Edmonson (2002) found that heterogeneous cognitive representations of the way to perform the collective task in virtual teams hamper the exchange of information between geographically-dispersed individuals, and lead to sub-optimal usage of individuals' knowledge. Similarly, Cramton (2001) found that the lack of mutual knowledge in regards to the salience of information exchanged within virtual team can lead the team to overlook valuable knowledge sources, which have negative impacts on the overall group dynamics. Finally, in an experiment involving 30 groups comprised of 5 geographically-dispersed coworkers, Huang et al. (2002) observed that virtual team members who adopted a "goal setting structure" (i.e. a process structuring mechanism designed to orient team members' efforts toward the common goal at any time during the project) exchanged information more efficiently than members of virtual teams who did not rely on such process structure mechanism. Based on the previous findings, common knowledge about the task in virtual teams appears to be an important element of their shared cognitive structure.

Common expertise knowledge

The second dimension of virtual team common knowledge, *common expertise knowledge*, represents the degree to which members of virtual teams have developed shared and accurate cognitive representations of each others' expertise domains within the team (Grant 1996a; Lewis 2003; Lewis 2004). The concept of common expertise knowledge is very similar to the notion of transactive memory systems, which represents shared repertoire of "who knows what" within teams (Brandon and Hollingshead 2004; Lewis 2003; Lewis 2004; Wegner 1987). According to Grant (1996), common expertise knowledge is an important type of common knowledge facilitating the integration of specialized knowledge in organizations. Without such type of common knowledge, members of workgroups become more susceptible to engage in unproductive information seeking efforts (Brandon and Hollingshead 2004; Wegner 1987), and might overlook valuable knowledge sources residing within their own team (Lewis 2004).

Thus far, studies that investigated the impact of common expertise knowledge in virtual teams have found that the concept has positive effects on team processes and outcomes. In a longitudinal study of 38 student teams spread across six different universities in four countries, Yoo and Kanawattanachai (2001) observed that with sufficient time and communication volume, a transactive memory system (i.e. a shared repertoire of who knows what within a given team) can be developed and maintained within virtual teams, and leads to increasing levels of team performance, a finding that has been also observed by Mortensen and Hinds (2002) in their study of 12 virtual teams in the field. In the same vein, Malhotra and Majchrzak (2004) found that developing and maintaining accurate information about "who know what" within virtual teams has positive impacts on team effectiveness and knowledge creation. Finally, conceptual contributions by Alavi and Tiwana (2002) and Griffith et al. (2003) also suggest that transactive memory systems in virtual teams may play an important role in transforming potential team knowledge into usable knowledge at the team level. Hence, the presence of common expertise knowledge should be an important aspect of virtual teams' shared cognitive basis.

Common specialized knowledge

The third dimension of common knowledge, *common specialized knowledge,* refers to the overlap in specialized knowledge domains existing within virtual teams. Without some similarities in people's specialized knowledge and skills, the benefits of having unique and heterogeneous expertise may be attenuated due to failure to share and interpret information appropriately, impossibility to challenge and validate other people's perspectives, and opportunity cost associated with efforts deployed for cross-functional learning (Grant 1996b). According to Carlile and Rebentisch (2003), the unique terminology, tools, and practices that define each domain of expertise within groups establish knowledge boundaries across domains, which, at the team level, is likely to make knowledge integration more difficult. People with heterogeneous expertise and skills should be able to represent their own knowledge to others for successful knowledge integration to happen, which is greatly facilitated when commonalities in specialized knowledge grounds exist amongst members of a work unit.

Here again, few studies have explicitly assessed the effects of common specialized knowledge on virtual team processes and outcomes. However, the absence of common specialized knowledge and its negative impact on knowledge integration is surfaced in Malhotra et al.'s (2001) study of a virtual team composed of eight geographically-dispersed experts. More precisely, the authors report that efforts to use discipline-specific vocabulary failed in many instances because members of the virtual teams were not all equally versed in each other's domain of expertise. This lack of common specialized language constrained the fluid exchange of information and the successful integration of people's expertise. However, the authors also observed that the use of metaphors helped to resolve the problems associated with lack of task-related common knowledge, and allowed people to achieve mutual understanding. In keeping with the above arguments, we argue that the presence of common specialized knowledge within virtual teams is likely to be an important element of its shared cognitive repertoire.

Common IT interaction knowledge

The fourth dimension of virtual team common knowledge is *common IT interaction knowledge*, and captures the extent to which members of virtual teams possess similar cognitive representations about the way to use information technologies to pursue their collaborative work in their team setting. The concept of common IT interaction knowledge represents an adaptation of Cannon-Bowers et al.'s (1993) notion of "interaction team mental model", which reflects the collective cognitive representation of the interaction structure of a group. When groups can rely on shared IT-enabled communication patterns and socially-recognized interaction structures, information seeking and providing behaviors are more effectively conducted.

Contrary the previous dimensions of common knowledge, common IT interaction knowledge has received much attention in research on virtual teams. For example, Malhotra et al. (2001) noted that when team members had developed a shared awareness of their IT-enabled communication structure, they have been able to use information technologies more efficiently for coordinating work and sharing knowledge, and eventually adapt the IT features to fit their informational needs. In a study of 2 dispersed teams spread across three or more physical locations, Sole and Applegate (2000) found that the effectiveness of knowledge sharing within virtual teams seems to depend less on the characteristics of the technology chosen, and more on the extent to which knowledge sharing practices are well established and represent habitual actions within the team. On a similar note, Massey et al. (2003) found that the reliance on temporal coordination mechanisms –an interaction process structure that help direct the pattern, timing, and content of interaction incidents in a team (see Massey et al. 2003: 131)- helped virtual team members organize their interaction behaviors, which, in turn, lead to increasing levels of performance. Finally, Orlikowski and Yates' (1994) concepts of "genres of organizational communication" and "genres repertoire" are other examples of common IT interaction knowledge basis studied in virtual teams. Broadly stated, a genre of organizational communication is a distinctive type of communication, characterized by a socially-recognized communicative purpose and common aspects of form, while a community's genre repertoire indicates the overall set of established communicative practices (Orlikowski and Yates 1994). As the authors claim, genre presence assumes that communicative practices are socially recognized, implicitly or explicitly, within a community, even though they can be modified during the team's project. When genres are shared and well established within virtual teams, their enactment leads to effective information sharing and improved coordination efficiency. In keeping with the above arguments, we argue that the presence of common IT interaction knowledge will play an important role to facilitate task accomplishment in virtual teams.

The Effect of Virtual Team Common Knowledge on Knowledge Integration Effectiveness

In order to provide a sound conceptualization for virtual team common knowledge, we establish its nomological validity by looking at its effect on knowledge integration effectiveness. Basically, knowledge integration effectiveness refers to a team's ability to coordinate successfully the usage of its members' knowledge at the team level (adapted from Grant 1996a; Tiwana and MacLean 2005). The usage of knowledge integration effectiveness as a criterion variable for testing the impact of virtual team common knowledge is explained next, and synthesized in Table 2.

Table 2. Virtual Team Common knowledge and knowledge integration effectiveness

Examples of knowledge items that are commonly held by VT members	Contribution to knowledge integration effectiveness in VTs
Characteristics of the team task and actions that need to be done to achieve it	Ensures that VT members' knowledge items will be used in accordance to the task requirements
Key milestones, challenges, and objectives that characterize the team task	Allow people to adjust their personal usage of knowledge to fit with the anticipated actions of their teammates
Each VT members' area of expertise, talents and skills	Reduces the likelihood of redundant efforts and duplication of taskwork activities
Repertoire of "who knows what" within the team	Allow people to concentrate their efforts on what they do best, which results in the optimization of knowledge usage at the team level
Patterns of IT-enabled communication and coordination within the team	Helps people adapt their interactions based on who they are communicating
Members' preference and habits in terms of IT usage for communication and coordination	Reduces time and efforts spent at communication and coordinating teamwork activities
Domain-specific knowledge of other teammates	Allow people to resolve complex situations and problems that inhibit the usage of their knowledge within the team when cross-functional interaction are needed
Technical concepts used by different specialists within the team	Reduces the challenges created by cross-functional knowledge domains

Virtual team common knowledge is expected to positively influence knowledge integration effectiveness for four main reasons. First, virtual team common knowledge enhances comprehension and interpretation of the information that is communicated among individuals (Alavi and Tiwana 2002; Krauss and Fussell 1990). In fact, when individuals must relate to each other before applying their personal knowledge to the task, virtual team common knowledge enables team members to formulate their contributions, feedback, and requests for information with awareness of what other teammates know and do not know (Krauss and Fussell 1990). Conversely, the absence of common knowledge will make knowledge integration less effective because members have greater difficulty to understand each other's expertise.

Second, common knowledge about the team's interaction structure and its members' expertise makes the overall process of coordinating virtual team members' inputs more efficient by allowing them to perform tasks that are commensurate with their respective specialized knowledge area and by optimizing the team's overall communication and coordination processes (Faraj and Sproull 2000; Lewis 2003). Research on transactive memory (Brandon and Hollingshead 2004; Lewis 2003; Wegner 1987), information sharing (Stasser and Titus 1985; Stasser and Titus 1987), and shared mental models (Mohammed and Dumville 2001) have shown that a shared understanding of each members' respective domain of expertise is associated with less redundancy of efforts, more effective usage of knowledge within teams, increased work specialization, and greater likelihood that valuable knowledge will not be overlooked within the team.

Third, virtual team common knowledge allows team members to integrate their knowledge when interpersonal exchanges and explicit forms of coordination are impossible between individuals, or too costly to be performed. Wittenbaum et al. (1996) refer to this process as a "tacit form of coordination", which they define as *the synchronization of members' actions based on unspoken assumptions about what others in the group are likely to do*. More specifically, when common knowledge about the team task and virtual team members' expertise exists within the team, members assume what others are likely to do based on their presumed expertise, and consequently adjust their personal usage of knowledge to fit with the anticipated actions of their teammates (Wittenbaum et al. 1996). This results in both effective and efficient integration of knowledge at the team level.

Fourth, virtual team common knowledge contributes to knowledge integration effectiveness by facilitating the alignment of individuals' knowledge inputs with the demand of the collective task. In fact, when individuals have developed a shared view of the properties of the task and the procedures and strategies that govern its successful completion, the usage of knowledge at the individual level will more likely be done in such a way to foster the effective progression of the task at the team level (Cannon-Bowers et al. 1993).

> *Hypothesis 2: There is a positive relationship between virtual team common knowledge and knowledge integration effectiveness in virtual teams.*

Method

Scale development and initial validation

To develop and test the content and structure of the construct virtual team common knowledge, a five-step process was used based on Churchill (1979) and Moore and Benbasat's (1991) guidelines for scale development and validation. The first step consisted in developing new survey items based on the existing definitions and conceptualizations of the four dimensions of virtual team common knowledge and knowledge integration effectiveness available in the literature. Ten items were developed for each dimension of virtual team common knowledge, and eight for knowledge integration effectiveness[1]. In the second step, the items generated were presented to a pool of four experts knowledgeable in the topic of common knowledge and virtual teamwork. After refining the wording of the items based on the experts' feedback, we then performed two rounds of card sorting (Moore and Benbasat 1991). For each round, fifteen different individuals were provided color-coded cards, with blue cards used for the definitions of the constructs and white cards used for the items. Then, participants were asked to match each item (white cards) with its corresponding definition (blue card). Only the items that had been matched more than 80% of the time with the appropriate definition were kept after each round of card sorting. The fourth step consisted of having three managers of existing knowledge-based virtual teams filling the questionnaire to make sure that the items were relevant and meaningful for practitioners. This

[1] Note that all questionnaire items were validated by following the same procedure. All items, except those for common expertise knowledge (Faraj and Sproull 2000), represent new items developed by the authors.

led to minor adjustments to the wording of a few questions. Finally, the questionnaire was sent via web-based surveys to a set of sixty members from four ongoing virtual teams in a large consulting firm. Forty-five usable questionnaires were used to perform reliability analyses. Redundant items and items showing erratic psychometric properties (i.e. Cronbach alpha lower than .70 and high cross-loadings in exploratory factor analyses) were discarded. The final set of items used in this paper is shown in Figure 1.

Figure 1. Measurement of Constructs

Knowledge integration effectiveness
(Scale: 1 = strongly disagree; 3 = neutral; 5 = strongly agree)
1. Our team fully benefits from its members' expertise.
2. Members of our team effectively integrate their specialized knowledge at the team level.
3. Our team is successful at leveraging its members' expertise.
4. Our team is effective at coordinating the usage of its members' specialized knowledge at the team level.
5. The expertise held by members of our team is combined successfully at the team level.

Virtual Team Common knowledge
(Scale: 1 = strongly disagree; 3 = neutral; 5 = strongly agree)

Common task knowledge
1. People in our team have a shared understanding of the collective task and the way it should be accomplished.
2. People in our team have a shared understanding of the key milestones, challenges, and objectives that characterize the collective task.
3. People in our team have a shared understanding of the main constraints inherent to the realization of the collective task.
4. People in our team hold a common understanding of the actions that need to be done in order to achieve the team's goal.
5. People in our team have a shared understanding about the way work is distributed amongst its members.

Common expertise knowledge
1. People in our team have a good "map" of each others' talents and skills.
2. People in our team are assigned to tasks that fit with their task-relevant knowledge and skills.
3. People in our team know what task-related skills and knowledge they each possess.
4. People in our team know who on the team has specialized skills and knowledge that is relevant to their work.
5. I know which team members have expertise in specific areas.

Common IT interaction knowledge
1. Our team relies on shared norms of IT usage for communication and coordination.
2. People in our team have developed a shared understanding about the way to use IT to communicate and coordinate their work.
3. People in our team know how to adapt their usage of IT based on who they are interacting with.
4. This team has established shared routines of IT usage for communication and coordination.
5. Within our team, IT usage practices for communication and coordination are fairly predictable.

Common specialized knowledge
1. I have some knowledge that is similar to the domain-specific knowledge of other teammates.
2. I have the necessary knowledge and skills to understand the technical concepts used by my teammates who are specialists in areas different than mine.
3. Despite differences in team members' areas of specialization, there is overlap in our domain-specific knowledge grounds.
4. There are some similarities across team members in terms of our respective specialized knowledge areas.
5. Despite differences in expertise domains within our team, team members understand each other when they use technical terms and concepts related to their area of specialization.

As shown in Figure 1, the measure of virtual team common knowledge includes 20 questions (five for each dimension) measuring the extent to which common knowledge has been developed within a given virtual team. Items were built in such a way that the absence of common knowledge within the team on a specific dimension will make it less likely for respondents to select high values on the scale, whereas the presence of strong common knowledge will encourage the opposite. It is important to mention that all questions used to measure the dimensions of virtual team common knowledge are answered by members of virtual teams (designated leader and team members), and represent individual level cognitive assessment of team level phenomena (dimensions of virtual team common knowledge).

Consistent with the knowledge-based view and its recent adaptation to organizational teams (e.g., Alavi and Tiwana 2002; Tiwana and MacLean 2005), knowledge integration effectiveness in virtual teams is defined here as the extent to which a virtual team is successful at coordinating the usage of its members' specialized knowledge at the team level. It is conceptualized as a collective phenomenon because even though the specialized knowledge is held at the individual level (i.e. within each virtual team member cognitive structure), its integration takes place at the team level. To measure the construct, five questions were developed in order to obtain virtual team members' perceptions of the effectiveness with which their team has been successful at coordinating the use of its members' specialized knowledge (see Figure 1).

Field study

The next phase of the conceptualization of virtual team common knowledge consisted in testing the scales shown in Table 3 with a large sample of existing virtual teams in the field. Data on virtual teams were collected in a large North American IT consulting firm, which has activities distributed in 16 different countries on 4 continents. Reliance on virtual teams to conduct knowledge-based projects is of strategic importance for the firm given the company's massive efforts for improving global service delivery across the world. Consulting work at this firm was mainly centered around three types of projects, namely software development and maintenance, business process re-engineering, and systems integration. The following three criteria were used to identify virtual teams for the study: (1) members of the team must be working on a specific project with a defined output, (2) members of the team must be spread across two or more geographical locations, and (3) the team had to be ongoing at the time of the study.

A total of 1197 personalized e-mails were sent to members and leaders of 114 virtual teams over 6 months. Overall, 700 respondents (626 members and 74 team leaders) spread across 102 virtual teams provided usable survey data, for a rate of response of 58.8%. The final sample consisted of 68.3% male and 49.5% of the respondents were between 31 and 45 years old. On average, respondents had 11 years and 10 months of experience in the function they were performing within their virtual team, and where members of the company for 7 years and one month. Individuals performed a wide range of functions within their respective virtual team, with the three most represented functions being system analyst/developer (43.3%), business analysts (12.2%), and database administrators (8.7%). As for the team tasks performed, they represented a variety of knowledge-based tasks such as business process reengineering, product/software development, system implementation and integration, and system maintenance. The size of the teams varied between 2 to 40 members, with an average of 11 members. As for task completion, teams had completed, on average, 65% of their overall project, and were in existence for an average of 35 months.

Data aggregation

To determine whether aggregation of individual responses to the team level was justifiable or not, two statistical tests were conducted. First, an Intra-Class Correlation (ICC) coefficient was calculated for all constructs of the model. The ICC compares within and between team variances using a one-way ANOVA procedure that assesses whether membership in a given team leads to more homogeneous answers (Klein and Kozlowski 2000). The ICC can also be interpreted as the percentage of the variance in a construct that is attributable to team membership. In general, researchers using ICC usually conclude that aggregation is warranted when the F-test for the ANOVA is significant. Second, an Inter-Rater Agreement (IRA) coefficient was calculated based on James et al.'s (1984) formula for multi-item construct[2]. The IRA assesses within-team agreement for each construct within each virtual team, and is useful to answer to following question: "How high is within-team agreement on a given construct within a given team?" Common practice is to conclude that aggregation of individual-level responses to the team level is appropriate if the IRA coefficient equals or exceeds 0.70.

Table 4 reports the ICC and IRA coefficients for the research constructs. The analyses indicate that all ICC values are significant at $p<.01$ except for common specialized knowledge ($p = .10$), whereas the IRA coefficients exceed the threshold value of .70 prescribed by James et al. (1984) for all research constructs. Overall, the results of those tests suggest that aggregating virtual team members' responses to the team level is appropriate. Virtual team members' responses were thus averaged for each item of the constructs to create team-level measures.

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[2] $r_{WG(J)} = J\,[1 - (s_{xj}^2/\sigma_{EU}^2)] \,/\, J\,[1 - (s_{xj}^2/\sigma_{EU}^2) + (s_{xj}^2/\sigma_{EU}^2)]$
J = number of items used to measure the theoretical construct
s_{xj}^2 = mean of the observed variances on the J items
σ_{EU}^2 = mean of on the J items that that would be expected if all judgments were due exclusively to random measurement error. For constructs measured using 5-point Likert scale, as it is the case here, this value is equal to 2.

Table 4. Aggregation statistics				
Constructs	**ICC**	**IRA**	**Smallest IRA value**	**% of teams above .70**
Common knowledge				
Task	.10**	.97	.91	100%
Expertise	.08**	.95	.78	100%
IT	.10**	.96	.60	99%
Specialized	.03†	.95	.68	99%
Knowledge integration effectiveness	0.07**	.98	.89	100%

Notes: † = significant at $p = .10$
** = significant at $p < .01$

Results

The model of virtual team common knowledge and its influence on knowledge integration effectiveness is analyzed using partial least squares (PLS), a component-based approach that is suitable with relatively small datasets. PLS allows the testing of the measurement model—psychometric properties of the scales used to measure a variable, and the estimation of the structural model—the strength and direction of the relationships between the variables. The model to be tested is a second-order factor model with reflective measures for the first-order factors and formative measures for the second order factor (Jarvis et al. 2003). A reflective conceptualization of second order factors would have been misleading because the four types of common knowledge are not expected to covary together, and are contributing in a unique way to shape the development of virtual team common knowledge. Also, PLS supports the testing of higher-order models, using the hierarchical component model as suggested by Wold (Chin et al. 1996). Smart PLS 2.0 beta (Ringle, et al. 2005) was used to perform the analysis.

Assessing the measurement model

The assessment of item loadings, reliability, and discriminant validity is performed for the first-order constructs. All first-order constructs are reflective. Items for reflective constructs should be unidimensional in their representation of the latent variable, and therefore correlated with each other. We first looked at the items loadings and all met the minimum requirement of .70, showing that more than half of the variance is captured by the constructs. We also looked at cross-loading to determine if items loads on other constructs as well as on their own theorized constructs. All items' loadings are higher on their intended construct than on any other construct and so all items were kept. Loadings and cross-loadings are displayed in Table 5.

Table 5. Loadings and Cross-loadings					
	Common Expertise Knowledge (CEK)	Common IT Interaction Knowledge (CITK)	Common Specialized Knowledge (CSK)	Common Task Knowledge (CTK)	Knowledge Integration (KI)
cek_1	**0.8682**	0.4229	0.4784	0.5691	0.6733
cek_2	**0.8306**	0.3608	0.3655	0.5598	0.629
cek_3	**0.9188**	0.4536	0.4763	0.5551	0.6859
cek_4	**0.8694**	0.3579	0.294	0.4284	0.5238
cek_5	**0.7789**	0.3826	0.4024	0.3095	0.5286
citk_1	0.2425	**0.8334**	0.3218	0.3285	0.3845
citk_2	0.412	**0.8954**	0.4498	0.4498	0.4391
citk_3	0.4907	**0.886**	0.5397	0.5426	0.5295
citk_4	0.3805	**0.8781**	0.4253	0.4423	0.4714
citk_5	0.4753	**0.8944**	0.4745	0.4895	0.5099
csk_1	0.334	0.3607	**0.7498**	0.2838	0.4162
csk_2	0.3432	0.2725	**0.7777**	0.315	0.5019
csk_3	0.3926	0.4027	**0.8494**	0.3646	0.5048
csk_4	0.3671	0.3734	**0.7667**	0.3277	0.4378
csk_5	0.427	0.5569	**0.7881**	0.6239	0.6247
ctk_1	0.5672	0.4909	0.4759	**0.9004**	0.6403
ctk_2	0.4912	0.4561	0.4155	**0.8927**	0.6046
ctk_3	0.5174	0.416	0.3996	**0.8952**	0.6038
ctk_4	0.4686	0.4573	0.4878	**0.9283**	0.6187
ctk_5	0.5391	0.5083	0.488	**0.865**	0.6569
ki_1	0.6568	0.4562	0.575	0.6728	**0.8998**
ki_2	0.6649	0.5451	0.6097	0.6255	**0.9091**
ki_3	0.6926	0.5444	0.5836	0.6735	**0.9283**
ki_4	0.6648	0.5056	0.5942	0.6141	**0.9448**
ki_5	0.6348	0.4227	0.6072	0.6309	**0.9278**

Third, composite reliabilities were calculated and all met the recommended value of 0.80 showing good reliability (see Table 6). Lastly, average variance extracted (AVE) and correlations amongst constructs were calculated. AVE are all well above the recommended level of 0.50 (Chin 1998), with the lowest value at .615 for common specializes knowledge (CSK). The square root of the AVE is compared with the correlation amongst the construct and indicates that constructs are more highly related to their own measure than to other constructs, as shown in Table 6. Results for the measurement model support the validity and reliability of the 20-item instrument for common knowledge and the 5-item scale for knowledge integration effectiveness. Therefore this conceptualization of virtual team common knowledge can be used to test the contribution of virtual team common knowledge to the development of knowledge integration effectiveness.

Table 6. Intercorrelations among Reflective Constructs							
Construct	# items	Composite reliability	1	2	3	4	5
1. Common Expertise Knowledge	5	0.931	0.854				
2. Common IT interaction knowledge	5	0.944	0.465	0.878			
3. Common specialized knowledge	5	0.890	0.478	0.511	0.787		
4. Common task knowledge	5	0.953	0.578	0.521	0.507	0.896	
5. Knowledge integration	5	0.966	0.719	0.538	0.644	0.698	0.922

Diagonal elements are the square roots of average variance extracted

Assessing the structural model

The two research hypotheses were tested by examining the magnitude and significance of structural paths in the PLS analyses and the percentage of variance explained in endogenous variables, which are reported in Figure 2. A bootstrapping procedure with 500 samples was used to generate t-statistics and standard errors (Chin 1998). Test of the structural model is used to assess (1) the structure of common knowledge, and (2) the influence of virtual team common knowledge on the effectiveness of knowledge integration. The structure of virtual team common knowledge hypothesized is a second-order factor formed by four factors.

The higher-order factors are created using the indicators of its lower order factors. This repeated indicator approach, allows the model to be estimated using the standard PLS algorithm (Chin et al. 1996). This also allows the examination of the relative path weights of the factors forming higher order constructs. Results (Figure 2) for the structure of virtual team common knowledge show that its four dimensions have positive and significant paths, supporting hypothesis 1. Although all paths have values close to each other, their relative importance from the most to the least important is: (1) task, (2) expertise, (3) IT interaction and (4) specialized knowledge.

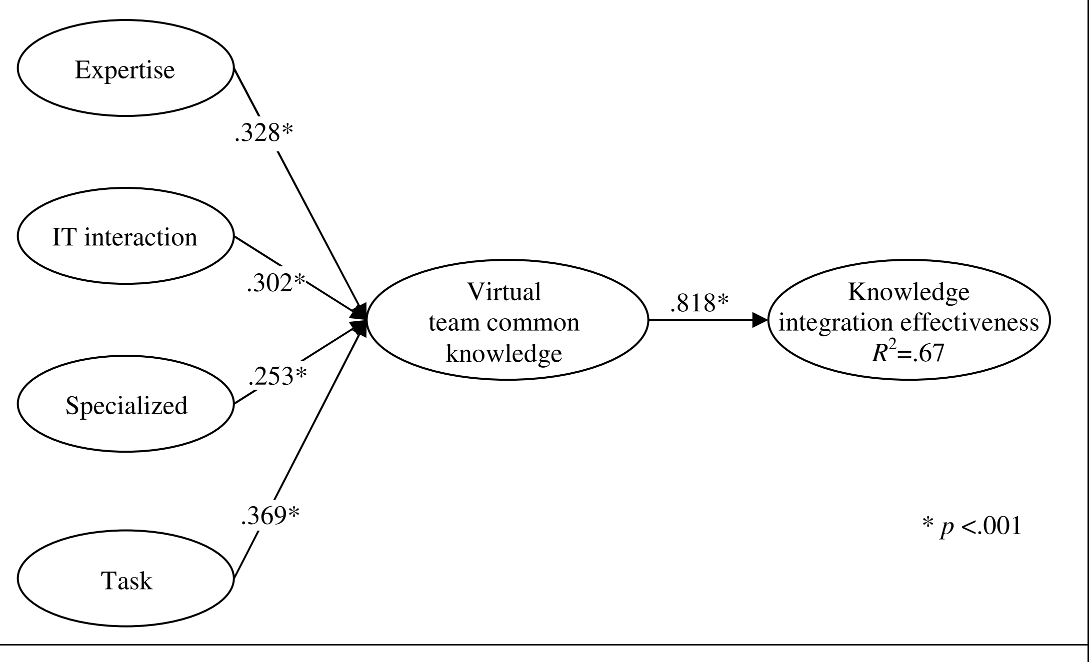

Figure 2. PLS Results for Structural Model

Hypothesis 2 was also supported, as virtual team common knowledge had a positive impact on knowledge integration effectiveness (beta = .818; *t*-value = 22.845; p<.001). Overall, 67% of the variance of knowledge integration effectiveness was explained by virtual team common knowledge. This result provides evidence for the nomological validity of the common knowledge construct.

Common Method Bias

Finally, we tested for common method bias using a statistical approach suggested by Podsakoff et al. (2003) as implemented in PLS by Liang et al. (2007). A latent method factor was added to the model to determine if the common method variance has a substantial impact on the observed relationship between predictor and criterion variables in our model. Results show that most paths linking the latent method factor to the model indicators are not significant and that in all cases the indicators' substantive variances are greater than their method variance. These results suggest that common method bias is not likely to be a serious threat to the internal validity of this study, despite the fact that responses were collected in a single setting through a survey.

In summary, we hypothesized that virtual team common knowledge influences the effectiveness of their knowledge integration. By considering the tangible expected outcomes of virtual team common knowledge, we expected to be able to assess the nomological and predictive validities of the construct (Carmines and Zeller, 1979). Results show that virtual team common knowledge explains 67% of the variance in the knowledge integration effectiveness. We also proposed that virtual team common knowledge is a second-order multidimensional latent construct formed by the definitional properties of common expertise knowledge, common IT interaction knowledge, common specialized knowledge, and common task knowledge. Results support this structure, with significant paths linking all first-order factors to the second-order factor—virtual team common knowledge.

Discussion and Conclusion

This paper contributes to the literature on virtual team effectiveness by addressing two main issues. First, a common wisdom in the literature on virtual team is that rigid, explicit and formal forms of coordination are required for the integration of different expertise to take place, while tacit forms of coordination are difficult to establish and maintain. We challenged this assumption by conceptualizing common knowledge as a tacit coordination mechanism well suited for virtual teams, instead being something difficult to develop and maintain. The multidimensional conceptualization we proposed offers detailed information about the structure of this important tacit form of coordination. Drawing on the literature on shared cognition (e.g., Brandon and Hollingshead 2004, Cannon-Bowers and Salas 2001, Wegner 1987) and organizational learning theories (Grant 1996a, Grant 1996b), this paper conceptualized virtual team common knowledge as a multi-dimensional construct formed by expertise, IT interaction, specialized, and task-related knowledge. The empirical evidence supports this conceptualization.

Second, a recurrent claim is that much of the anticipated benefits of virtual teams depend on their ability to effectively coordinate activities and knowledge. We seek and found empirical support linking common knowledge as a tacit form of coordination and the effectiveness of knowledge integration within virtual teams. Given that spontaneous and interactive mechanisms of coordination are constrained by temporal and geographical dispersion, virtual team members are likely to benefit from the coordinative capabilities of tacit mechanisms of coordination, such as a strong common knowledge basis.

The paper contributes to research by developing and testing a construct that can help us better understand how virtual teams work and what factors can influence the important process of integrating knowledge in virtual teams. For practice, the paper shows the importance of virtual team common knowledge as an antecedent of knowledge integration effectiveness and can therefore serve to managers when leading virtual teams. In fact, results indicate that the shared cognitive basis of virtual teams is an important asset to develop and maintain within virtual teams. To do so, leaders of virtual teams should try to assess the state of their team in regards to the four components of common knowledge discussed in the paper. By doing so, they could better adapt their leadership styles in order to either maintain a high level of common knowledge if it is already well establish, or reinforce it if they sense that common knowledge problems exist.

While the paper answers some research issues regarding knowledge management in virtual teams and the existence and importance of virtual team common knowledge in particular, it raises as many questions as it provides answers. First, future research is needed to further refine the measurement of the construct of common knowledge in virtual teams and test the measure in other settings. This could be done in teams working in contexts other than IT consulting industry, and with team having different degrees of virtuality. Second, more research is also needed to expand the nomological net associated with virtual team common knowledge in order to assure its proper measurement. After sufficient testing of the construct measurement, research will need to focus on identifying its effects on other virtual team outcomes, especially performance-related outcomes (e.g., efficiency, effectiveness, output quality, creativity and innovation). Finally, given the strong influence of virtual team common knowledge on knowledge integration effectiveness, a promising avenue for future research should consist in identifying other antecedents of this important construct. For instance, high levels of functional and cultural diversity within the team, language differences, limited experience of working together, and fluid team membership represent team design factors likely to create challenges for the development of common knowledge in virtual teams. Still, more research is needed in order to evaluate the main impact of those design properties on virtual team common knowledge. Also, other factors associated with the interaction structure of the team might have an influence on virtual team common knowledge, such as the number of face-to-face meetings between individuals (e.g., with all team members, with a subset of team members), the amount of time spent with individuals working at remote location (e.g., number of days, number of visits), and the patterns of IT usage within the team (e.g., media choice, media characteristics, features used). In sum, we suggest that more research should be conducted in order to identify other antecedents of common knowledge development within virtual teams.

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