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Information technologies, knowledge integration, and performance in virtual teams

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Thesis Abstract

Virtual teams – defined as groups of geographically-dispersed individuals working together to accomplish a common goal and who rely heavily on information technologies (ITs) to communicate and coordinate their work – have recently captured the attention of numerous scholars and practitioners. The ability of virtual teams to cross various boundaries (e.g., geographical, temporal, cultural, etc.,) has made them an attractive means for leveraging the resources of distributed organizations. However, the factors and mechanisms that influence their performance remain mostly unclear. To address this issue, this thesis proposes three essays where each contributes to better understand the phenomenon of virtual team performance in a specific way. In the first essay, an integrative model of virtual team performance is developed and used to review the extant empirical literature. This exercise has lead to the identification of a set of key direct and indirect drivers of virtual team performance. The second essay offers a knowledge-based view of virtual team performance and proposes a conceptual framework of knowledge integration effectiveness in virtual teams. The framework identifies three integration mechanisms enabled by information technologies and describes how the usage of those mechanisms can facilitate knowledge integration effectiveness in virtual teams. The framework also outlines the role of common knowledge as a key factor leading to effective knowledge integration in virtual teams, and discusses the linkage between knowledge integration effectiveness and virtual team performance. Finally, the third essay provides an empirical demonstration of the conceptual framework of knowledge integration effectiveness developed in the second essay. The framework is tested with 700 individuals working in 102 existing knowledge-based VTs and who use IT to coordinate the use of their knowledge inputs across boundaries. Results indicate that the impact of IT on knowledge integration effectiveness is fully mediated by the common developed within VTs about their collective task, the distribution of expertise, the IT-enabled communication structure of the team, and members' specialized knowledge domains. Consistent with the premises of the first two essays, knowledge integration effectiveness was positively associated with VT performance. Overall, this thesis brings a new perspective for understanding the phenomenon of virtual team performance, describes gaps in current research, and recommends avenues for future research.

Résumé de la Thèse

Les équipes virtuelles – définies comme des groupes de travail dont les membres sont géographiquement dispersés et utilisent intensivement les technologies de l'information (TI) afin de communiquer et coordonner leurs efforts – ont retenu l'attention de nombreux chercheurs et gestionnaires au fil des dernières années. Le potentiel des équipes virtuelles d'opérer à travers différentes frontières (géographiques, temporelles, culturelles, etc.,) rend ces équipes très attrayantes pour permettre d'optimiser l'utilisation des ressources dans les organisations distribuées. Toutefois, les facteurs et mécanismes qui facilitent la performance des équipes virtuelles demeurent vagues et équivoques. Afin de pallier à ce manque dans la littérature, la présente thèse suggère trois essais où chacun vise à mieux comprendre le phénomène de la performance des équipes virtuelles sous un angle spécifique. Dans le premier essai, un modèle intégratif de la performance des équipes virtuelles est développé et utilisé afin de synthétiser la littérature empirique sur ce sujet. Cet exercice a permis l'identification d'un ensemble de facteurs qui influencent directement et/ou indirectement la performance des équipes virtuelles. Le deuxième essai propose une perspective plus spécifique de la performance des équipes virtuelles ancrée dans la théorie des connaissances. Plus précisément, cet essai offre un cadre conceptuel visant à identifier les antécédents et les impacts de l'intégration efficace des connaissances dans les équipes virtuelles. Le cadre théorique illustre de quelle façon les TI permettent l'activation de différents mécanismes d'intégration qui, en retour, influencent l'efficacité avec laquelle les connaissances des membres sont intégrées au niveau de l'équipe. Le cadre conceptuel souligne également l'importance de posséder des connaissances communes au sein des équipes virtuelles et discute de la relation entre l'intégration efficace des connaissances et la performance des équipes virtuelles. Enfin, le troisième essai offre une démonstration empirique du modèle conceptuel développé dans le second essai. Ce modèle est testé auprès de 700 individus œuvrant au sein de 102 équipes virtuelles et qui utilisent les TI pour coordonner l'utilisation de leur connaissances. Les résultats démontrent que l'impact des TI sur l'efficacité de l'intégration des connaissances est totalement médié par le niveau de connaissances communes développé par les membres des équipes virtuelles par rapport à la tâche collective, la distribution d'expertise au sein de l'équipe, la structure de communication supportée par les TI et aux domaines de connaissances de chacun. De manière cohérente avec les prémisses des deux essais premiers essais, l'intégration efficace des connaissances possède un effet positif sur la performance des équipes virtuelles. Dans son ensemble, cette thèse offre un regard nouveau sur le phénomène de la performance des équipes virtuelles, identifie des enjeux importants pour ce thème de recherche ainsi que des avenues de recherche qui méritent d'être approfondis dans le futur.

Dissertation Overview

The Context

For some years now, *virtual teams* – traditionally defined as groups of geographically-dispersed individuals working together to accomplish a common goal and who rely heavily on information technologies to communicate and coordinate their work (Townsend et al. 1998, p. 18) – have captured the attention of numerous scholars and practitioners. The ability of virtual teams to cross geographical, temporal, cultural, functional, and organizational boundaries has made them a particularly attractive means for leveraging the resources of distributed organizations (Alavi and Tiwana 2002, Haas 2006, Jarvenpaa and Leidner 1999, Jarvenpaa et al. 2004, Majchrzak et al. 2000, Sole and Edmonson 2002). However, an in-depth look at the extant research reveals that the benefits of virtual teams might not be as important as was anticipated, or at least should be discussed with some reserve. For instance, there is evidence showing that virtual teams are often outperformed by collocated teams in terms of communication and coordination effectiveness (Galegher and Kraut 1994, Hightower and Sayeed 1996, Warkentin et al. 1997), productivity (Andres 2002, Straus and McGrath 1994), and member satisfaction (Chidambaram and Jones 1993, Hollingshead et al. 1993). The evidence also suggests that virtual teams are likely to experience dysfunctional team dynamics such as frequent conflicts (Hinds and Bailey 2003, Hinds and Mortensen 2005), and difficulties in establishing shared understanding between team members (Cramton 2001, Malhotra et al. 2001, Sole and Edmonson 2002). Nevertheless, there are also studies showing that the successful combination of expertise within cross-functional virtual teams can enable distributed organizations to generate high quality and innovative outputs while simultaneously achieving impressive efficiency gains (Balthazard et al. 2004, Majchrzak et al. 2000, Malhotra et al. 2001, Malhotra and Majchrzak 2004). In sum, even though the management of virtual teams has become a fairly "popular" research topic in the last few years, the equivocal nature of the empirical findings concerning the performance of those teams suggests that the topic deserves greater theoretical development and empirical investigation.

Towards a Knowledge-Based View of Virtual Teamwork

Among the approaches that have been used to assess the performance of virtual teams and their value for organizations, the study of knowledge management processes has emerged as an important one. Essentially, this perspective outlines the potential of virtual teams for leveraging the knowledge asset of distributed organizations by performing different knowledge management processes. Thus far, most research has been devoted to understanding two such knowledge management processes: knowledge sharing and knowledge transfer. In fact, several scholars have suggested that knowledge needs to be shared and transferred among members of virtual teams to allow them to function efficiently and effectively (Cummings 2004, Griffith et al. 2003, Majchrzak et al. 2000, Malhotra et al. 2001, Malhotra and Majchrzak 2004, Robey et al. 2000). Interestingly, researchers who have looked at knowledge sharing and knowledge transfer within virtual teams usually find that knowledge is simultaneously a valuable resource and a source of communication difficulty. In fact, studies find that geographical dispersion generates logistical and technological constraints the inhibit the exchange and transfer of knowledge in many ways, such as limiting possibilities for spontaneous communication

(Hinds and Bailey 2003), constraining the exchange of unique information (Cramton 2001, Hightower and Sayeed 1996), and by making site-specific and situated knowledge difficult to re-contextualize in other settings for subsequent application (Sole and Edmonson 2002).

In this dissertation, a complementary perspective is used to assess the performance of virtual teams, one that focuses on the integration of specialized knowledge at the team level. More precisely, a knowledge integration perspective of virtual teamwork suggests that rather than being shared and transferred, knowledge needs to be integrated in virtual teams, which means that each individual keeps his/her specialized knowledge but mechanisms are put in place to assure that the team optimizes the use of such knowledge and performs as a unified whole. In more specific terms, knowledge integration is the process of coordinating the usage of specialized knowledge in organizations, work units, and teams (Grant 1996a). Fostering knowledge integration in virtual teams appears to be an appropriate way to benefit from the opportunities of the virtual team context while avoiding important group process losses. The main reason behind this argument is that the coordination costs inherent to the activity of knowledge integration are likely to be much lower than the costs (cognitive strains, efforts, time) experienced by individuals for sharing or transferring knowledge between them (Grant 1996a), and thus less affected by the idiosyncratic components of the virtual team context.

In order to contextualize the phenomenon of knowledge integration to the realm of virtual teams, this dissertation relies on Robert Grant's knowledge based-theory and its core concept of knowledge integration (Grant 1996a, Grant 1996b). Essentially, the knowledge-based theory posits that the specialized knowledge held by individuals represents a firm's most strategically-significant resource, and that the integration of specialized knowledge is the key organizational process leading to increased work unit performance and sustained competitive advantage (Grant 1996a). Within virtual teams, knowledge integration represents the activity through which the usage of the specialized knowledge held by their members is being coordinated at the team level across geographical boundaries (Alavi and Tiwana 2002). According to the knowledge-based view (Grant 1996a, Spender 1996) and recent empirical studies on expertise and knowledge integration in organizational teams (Alavi and Tiwana 2002, Faraj and Sproull 2000, Haas 2006, Okhuysen and Eisenhardt 2002, Tiwana and MacLean 2005), the successful integration of knowledge results in a situation where organizational teams are better able to extract the full value of their members' expertise and skills, which represents a strong enabler of team performance (Grant 1996a, Hackman 1987). Nevertheless, the phenomenon of knowledge integration in virtual teams has received limited attention in the Information Systems (IS) research community, which constitutes the primary gap that the present research attempts to address.

The knowledge-based view of virtual teamwork proposed in this dissertation is likely to benefit research on virtual teams in different ways. First, the knowledge-based theory describes the process through which the specialized knowledge of individuals is combined and synthesized at different levels of an organization (e.g., teams, work unit, organizations, organizational networks), and illustrates how this process influences the performance of work units. Its application to the realm of virtual teams is likely to shed some light on the way to leverage a very important resource in distributed organizations:

the specialized knowledge of its members. In fact, the argument that a virtual team represents a promising work configuration to permit the integration of knowledge across boundaries has been made many times in the IS and OB literatures (e.g., Jarvenpaa and Leidner 1999, Malhotra et al. 2001, Sole and Edmonson 2002, Townsend et al. 1998), but research has yet to provide theoretical frameworks and generate empirical evidence that would equate the prevalence of such an argument.

Second, the nature of the phenomenon of knowledge integration itself is well suited to the idiosyncratic context of virtual teamwork and the opportunities and challenges it raises. In fact, the whole process of knowledge integration in virtual teams is about optimizing the usage of the specialized knowledge of their members without the need for cross-functional knowledge sharing and knowledge transfer between them. Instead, what is needed is that virtual team members use the integration mechanisms that will ensure an effective coordination of their knowledge inputs at the team level, not necessarily the sharing or transfer of knowledge between individuals (Alavi and Leidner 2001). As mentioned earlier, there is empirical evidence showing that because knowledge sharing and knowledge transfer impose important costs to individuals, they are particularly difficult to conduct within virtual teams (Cramton 2001, Malhotra et al. 2001, Robey et al. 2000, Sole and Edmonson 2002). Thus, we argue that the pragmatic nature of the knowledge integration process, in contrast to knowledge sharing and knowledge transfer, is well suited for the context of virtual teams.

Finally, the premise of the knowledge-based theory puts emphasis on several factors that have been found to be important drivers of performance in small group research, such as matching team coordination mechanisms to the characteristics of the task at hand (Andres and Zmud 2001, Gittel 2002, Kraut and Streeter 1995), the beneficial impacts of developing and maintaining common knowledge within the team about different aspects of its structure and processes (Cannon-Bowers et al. 1993, Faraj and Sproull 2000, Wegner 1987), and the importance of leveraging the knowledge and skills of interdependent individuals (Hackman 1987, Lewis 2003). For all those reasons, we argue that a knowledge-based view of virtual teamwork represents a viable approach for assessing the performance of virtual teams.

A Three-Essay Dissertation

The dissertation is made of three different and complementary essays that explore the themes of virtual team performance and knowledge integration in depth.

In the first essay, an integrative model of virtual teams is developed and used to review the extant empirical literature on virtual team performance. This model presents three conceptually-distinct sets of antecedents of virtual team performance, namely (1) the design properties of virtual teams, (2) the emergent processes their members perform to manage their collaborative work, and (3) the emergent states they experience during the course of their team project. The central premise of the framework is that in order to gain a better understanding of virtual team performance, one must recognize their multi-faceted nature by looking at the way those three sets of factors mutually influence each other and affect the different types of performance of virtual teams. Guided by Webster and Watson's (2002) methodology for reviewing the literature, the model was used to map out the current empirical evidence about virtual team performance found in published journal papers across different fields. By cumulating findings from 86 empirical studies, it was possible to derive a set of direct and indirect drivers of virtual team performance that can be used as a foundation for establishing best practices for the management of virtual teams. Beyond identifying key enablers and inhibitors of virtual team performance, the review also demonstrates that greater understanding of the phenomenon can be obtained by applying two fundamental principles to virtual teams research, namely (1) distinguishing the types of performance assessed in virtual teams, and (2) integrating the antecedents of such performance measures. Finally, this review of the empirical literature has been useful to identify avenues for future research on virtual teams.

The second essay offers a novel look at the issue of virtual team performance, and does so by proposing a conceptual framework of IT-enabled knowledge integration in virtual teams. Over the last 10 years, many researchers have claimed that virtual teams represent viable work configurations to leverage firms' knowledge asset across geographical boundaries, yet very little is known about the factors that facilitate the process of knowledge integration in virtual teams or about the role(s) played by information technologies to support that activity. To address this gap, the second essay proposes a comprehensive framework of knowledge integration in virtual teams. Grounded in the knowledge-base theory (Grant 1996a, Grant 1996b), shared mental models literature (Cannon-Bowers et al. 1993), and research on coordination in work units and teams (Faraj and Sproull 2000, Gittel 2002, Kraut and Streeter 1995, Van de Ven et al. 1976), this essay identifies key mechanisms that facilitate the effective integration of knowledge in virtual teams, specifies how information technologies support the usage of those mechanisms, and provides information about the context under which they are most effective. The main contribution of the second paper lies in the development of a new model of virtual teamwork that presents knowledge integration effectiveness as a central driver of virtual team performance. It also provides managers with a set of propositions to help them integrate the knowledge of their distributed workforce under different task demand conditions.

The third and final essay aims at testing empirically the premise of the comprehensive model of knowledge integration in virtual teams, which was developed in the second essay. To achieve that purpose, a cross-sectional field study of existing virtual teams has been conducted in a large multi-national company operating in the consulting industry. The data was collected using web-based surveys sent to team leaders and members of 102 knowledge-based virtual teams operating across two or more geographical workspaces. Consistent with the premises of the knowledge-based view, knowledge integration effectiveness was found to be a powerful antecedent of virtual team performance. The survey results also show that the impact of information technology on knowledge integration effectiveness is fully mediated by the degree of common knowledge developed between virtual team members during the course of the team project. Common knowledge, in return, was found to be a strong predictor of knowledge integration effectiveness in virtual teams. Overall, findings support the premises of the preceding two papers by showing a strong relationship between knowledge integration effectiveness and virtual team performance, and by demonstrating the critical importance of integrating the antecedents of virtual team performance. This paper complements previous research on knowledge management in virtual teams by providing an empirical demonstration of the key antecedents of knowledge integration effectiveness within a large sample of existing knowledge-based virtual teams.

Contribution of Authors

For the first essay, Olivier Caya acted as the first author, Mark Mortensen acted as the second author, and Alain Pinsonneault acted as the third author. For the paper that is included in the present thesis, the first author performed the vast majority of the writing while the second and third authors provided important advices and feedback to the first author, who then had to make changes to the paper.

For the second essay of the thesis, Olivier Caya acted as the first author and Alain Pinsonneault acted as the second author. The main contribution of the first author was to write the manuscript in its totality (100%) and adapt its format in accordance with the established guidelines for paper submission at the Academy of Management conference. Several draft versions of the paper have been generated during the years of 2006-2007. Alain Pinsonneault reviewed the different drafts of the paper and provided feedback to the first authors about how to improve the content of the paper.

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CHAPTER I: Understanding Virtual Team Performance

An Overview of the Current Research on Virtual Team Performance

It is in the early 90's that the IS discipline became interested in the phenomenon of virtual teams, which coincided with the vast interest devoted to group support systems (GSS), group decision support systems (GDSS), and group communication support systems (GCSS) (see Pinsonneault and Kreamer 1990 for a review). Over the years, the topic of virtual teams has grown in importance and is now tightly intertwined with established research streams in the fields of Information Systems, Organizational Behaviour, and Management such as electronic communication, knowledge management, computer-mediated collaborative work, and technology adaptation. As shown in Table 1, the body of research on virtual team performance can be segregated into three main categories, namely (1) studies comparing traditional and virtual teams on performance outcomes and their antecedents, (2) studies assessing the structural and dynamic factors affecting the performance of virtual teams (with no comparison with collocated teams), and (3) review articles and frameworks on virtual team performance and related phenomena. Each group of studies has contributed to enhancing our understanding of the issue of virtual team performance in different and complementary ways.

Table 1. Relevant Literature on Virtual Team Performance

Category of studies	**Main contributions for the phenomenon of virtual team performance**	**Main limitations**	**Examples of studies**
Studies comparing traditional and virtual teams on performance outcomes and antecedents	Outlined key distinctions between collocated and virtual teams Identified important team processes and performance measures influenced by the defining properties of virtual teams	Limited generalizability and practical implications	Hightower and Sayeed 1996, Straus and McGrath 1994, Hollingshead et al. 1993, Warkentin et al. 1997
Studies assessing the structural and dynamic factors affecting the performance of virtual teams	Identified structural properties and team dynamics factors that affect the performance of virtual teams Stimulated the growth and diversity of virtual teams research	Fragmentation of research on the antecedents of virtual team performance	Cramton 2001, Jarvenpaa and Leidner 1999, Malhotra et al. 2001, Hinds and Mortensen 2005
Studies providing a synthesis of virtual team performance literature	Provided structure to the increasingly vast body of research on virtual teams Identified critical avenues for the future of virtual teams research	Limited integration across antecedents of performance and differentiation of performance dimensions No paradigmatic orientation or integrative model of virtual teams performance	Pinsonneault and Caya 2005, Hertel et al. 2005, Powell et al. 2004, Martins et al. 2004, Webster and Staples 2006

Studies comparing face-to-face with virtual teams

The first group of studies relevant for the issue of virtual team performance includes those that compared collocated teams and virtual teams in terms of process effectiveness and performance outcomes. In the vast majority of the cases, these studies were conducted in experimental settings where members of virtual teams were spread across different workspaces, like rooms within the same building or different buildings on the same campus. Conversely, members of collocated teams were all located in the same work environment. As mentioned above, the focus of those studies was to compare these two types of teams in regards to different group processes and outcomes, such as communication effectiveness (e.g., Smith and Vanacek 1990), coordination effectiveness (e.g., Galegher and Kraut 1994), quality of outcomes (e.g., Cass et al. 1991), team member satisfaction (e.g., Hollingshead et al. 1993), and others. Among the most consistent findings that emanate from those studies, we note a tendency for collocated teams to outperform virtual teams in terms of the level of team productivity (e.g., Andres 2002, Galheger and Kraut 1994, Hollingshead et al. 1993), member satisfaction with the communication condition (Hollingshead et al. 1993, Straus and McGrath 1994), and communication and information sharing effectiveness (e.g., Hightower and Sayeed 1996, Smith and Vanacek 1990, Warkentin et al. 1997, Thompson and Coovert 2003). Interestingly, most studies found no difference between virtual teams and collocated teams in terms of the quality of output being realized, which suggests that the virtual team context might have detrimental impacts on some dimensions of performance but not others. Overall, this category of studies contributed to the IS literature by outlining key structural properties of virtual teams that make them different than collocated teams (i.e. geographical dispersion of members, reliance on information technology), and by identifying some team processes and performance dimensions that are particularly affected by those defining characteristics of virtual teams. However, the practical implications and the generalizability of those studies should be interpreted with some reserve since most of them were conducted in controlled environments, within a very short time period (between 30 minutes and 1 hour), with a fairly low level of team dispersion, and rarely in organizational settings.

Studies assessing the structural and dynamic factors that affect the performance of virtual teams

The second category of studies relevant for the issue of virtual team performance includes those that looked directly at the drivers of virtual team performance without comparison with collocated teams. Usually, those drivers of virtual team performance fall into one of two categories, namely (1) the structural properties of virtual teams (e.g., team size, cultural diversity, temporal dispersion, available information technologies), or (2) the group dynamics factors that take place within these teams (e.g., interpersonal trust, team cohesion, IT-enabled coordination and communication patterns). For instance, Gibson and Gibbs (2006) assessed the effect of "virtuality" (i.e. geographical dispersion, electronic dependence, structural dynamism, and national diversity) on team performance in 56 virtual teams in the aerospace industry. They found a negative relationship between all four components of virtuality and the level of team innovation, but also observed that a psychologically-safe communication climate helps attenuate each of those negative effects. Other examples of structural and dynamic factors that were found to affect the performance of virtual teams include the level of expertise found within virtual teams (Balthazard et al. 2004, Malhotra et al. 2001), the establishment of shared understanding between team members (Sole and Edmonson 2002, Yoo and Kanawattanachai 2002), conflicts and conflict management (Hinds and Bailey 2003, Mortensen and Hinds 2001, Hinds and Mortensen 2005, Montoya-Weiss et al. 2001), knowledge sharing effectiveness (Cummings 2004, Majchrzak et al. 2000, Malhotra et al. 2001, Malhotra and Majchrzak 2004), and leadership style (Kayworth and Leidner 2001, Yoo and Alavi 2001, Paul et al. 2003). Overall, those studies have instilled a much needed diversity within the research of virtual teams in terms of the topics investigated, the reference disciplines and theories used to develop research models, and the methods adopted to test them. They also greatly contributed in identifying key structural and dynamic factors affecting the performance of virtual teams. This category of research also includes a growing number of studies conducted in the field setting, with examples of teams such as research and development teams (Hinds and Mortensen 2005), software development teams (Espinosa et al. 2007), consulting teams (Majchrzak et al. 2005, Malhotra and Majchrzak 2004), product development/design teams (Gibson and Gibbs 2006, Malhotra et al. 2001, Sole and Edmonson 2002), and others. However, a natural downside of the growing diversity of research has been to create a fragmentation in the body of knowledge about the antecedents of virtual team performance. In fact, the wide array of phenomena and theories used to understand the issue of virtual team performance has made it rather difficult for researchers and practitioners to isolate a set of best practices for the effective management of virtual teams.

Review articles on virtual team performance and related phenomena

The third group of studies relevant to the understanding of virtual team performance includes those that provided a synthesis of the empirical literature on the performance of virtual teams and related phenomena. Those studies are often referred to as "review articles" and "integrative frameworks" of virtual teams. In general, the method used by the authors of such papers was to cumulate the available body of research about certain topics or phenomena relevant to the management of virtual teams (e.g., virtual team processes and outcomes, culture), structure the empirical findings of those researches using a certain classification scheme (e.g., input-process-output model, stage model of team development), and formulate a manageable set of propositions and/or meta-findings that synthesize key observations within and across those previously identified studies. Over the last five years, different review papers have been published in IS, OB, and Management disciplines, each addressing the issue of virtual teamwork in its own manner. For instance, some researchers have used the traditional input-process-output model of small group effectiveness (Cohen and Bailey 1997, Hackman 1987) to review the empirical literature on virtual teams and identified key design properties and team processes affecting their performance. Examples include Martins et al. (2004) and Powell et al.'s (2004) reviews of the empirical literature on virtual teams, Pinsonneault and Caya's (2005) conceptual framework of virtual teams, and Webster and Staples' (2006) review of virtual teams vs. traditional teams. Using a different approach, Hertel et al. (2005) reviewed the literature on virtual teams by using the stages of team development as the main axioms for structuring their analysis of virtual teamwork, suggesting that some factors might be more important than others for the success of virtual teams at a specific point of their lifecycle. For their part, Schiller and Mandviwalla (2007) analyzed the current state of the art of theory application and development in virtual team research, and provided a framework for appropriating reference-discipline theories. Overall, the main contribution of these studies has been to simplify the complexity of virtual team research by structuring the current body of knowledge available about virtual teamwork. Also, most of these review articles contain insightful avenues for future research which, if addressed, could enhance our understanding of the phenomenon of virtual team performance. Nonetheless, we note that some confusion persists among researchers about the main characteristics of virtual teams and the way to conceptualize them. For instance, some researchers define trust as an attitudinal team outcome within virtual teams (Webster and Staples 2006) while others categorize that same variable as an interpersonal team process (Martins et al. 2004, Pinsonneault and Caya 2005). Moreover, although the aforementioned review papers have identified several success factors that affect the performance of virtual teams, they have remained relatively vague in respect to the way those factors are connected with each other. In sum, a clear paradigm for virtual team research has not yet emerged, and more research is needed to better understand the multi-faceted nature of virtual teams and the way the performance enablers of such teams interact with each other.

Towards a Knowledge-Based View of Virtual Teamwork

In light of the above section, we note that researchers have adopted different approaches to unpack the phenomenon of virtual team performance. Some have compared virtual teams to traditional teams in terms of process and outcome effectiveness. Others have looked directly at the key structural and group dynamic factors affecting the performance of virtual teams, with no contrast with traditional teams. Finally, review articles and integrative frameworks have been produced in order to structure the available body of knowledge about virtual team performance. In the present dissertation, we use two of those three approaches in a way that will complement the current body of research on virtual team performance.

First, we develop an integrative model of virtual teams that captures their main characteristics and dimensions and we use the model to review the current empirical literature on virtual team performance. Our main objective is to complement and extend previous reviews on virtual team performance by emphasizing the need to integrate the main antecedents of virtual team performance and differentiate between the types of performance used in virtual team research. A secondary objective of this review is to provide a sound and integrative conceptualization of virtual teams that can be used to circumscribe their main components.

Second, we try to understand the phenomenon of virtual team performance through the lens of the knowledge-based view (Grant 1996a) and its core concept of knowledge integration. More precisely, the integration of knowledge is the activity of coordinating the usage of knowledge in work units and teams. By proposing a knowledge-based view of virtual teamwork, our main argument is that the performance of virtual teams is directly related to their ability to coordinate the usage of their members' knowledge input across geographical boundaries. Therefore, this second approach of studying the performance of virtual teams will complement the current body of research that looked at the structural properties and group dynamics factors that influence the performance of virtual teams.

Summary

During the last decade, virtual teams have received substantial attention in both academic and practice communities. Today, research on virtual teams exhibits a great deal of diversity in terms of topics investigated, theories, methods, and numerous academic journals from many disciplines are publishing research papers about virtual teams. Nevertheless, research on virtual teams has not reached maturity, and several themes relevant for the management of virtual teams demand further investigation. In the present dissertation, we focus on two of those important themes: (1) the performance of virtual teams, and (2) the integration of specialized knowledge in virtual teams. In the next paragraphs, we briefly discuss how the three essays of this dissertation address those fundamental topics.

Essay 1: Integrative Model of Virtual Team and Review of the Empirical Literature on Virtual Team Performance

In the first essay, we address a research gap that appears to be caused by the rapid growth and great diversity of virtual team research. For some, growth and diversity within a stream of research can be seen as a sign of maturation and emancipation (Fabian 2001, Robey 1996) as multiple perspectives, paradigms, and methods are applied to study a given phenomenon. But for others, it can also lead to fragmentation, lack of cumulative history, and unfocused coverage of critical aspects of a research stream (Benbasat and Weber 1996). This might have been the case for virtual teams research. In fact, the vast interest recently devoted to virtual teams and the fact that studies have evolved in a fairly non-integrated way have generated some confusion about their main characteristics and about the factors that contribute to increase their performance. For instance, numerous studies have focused on the antecedents of trust in virtual teams (Aubert and Kelsey 2003, Jarvenpaa et al. 1998, Jarvenpaa and Leidner 1999, Jarvenpaa et al. 2004, Zolin et al. 2004), yet according to Jarvenpaa et al. (2004) the relationship between trust and performance remains equivocal. Similarly, the impact of information technology and geographical dispersion on virtual team performance remain difficult to isolate. Some studies have found that computer-mediation and distance detrimentally affect virtual team productivity and member satisfaction with communication conditions, but have found no impact on other measures of performance such as decision quality and product quality (Andres 2002, Chidambaram 1996, Gallupe and McKeen 1990, Hollingshead et al. 1993, Straus and McGrath 1994). Other researchers observed that virtual teams are able to generate outputs for which the level of quality, efficiency, and technical innovation are impossible to reach in conventional collocated teams (Majchrzak et al. 2000, Malhotra et al. 2001). Finally, other studies found that the impacts of computer mediation and geographical distance on performance are mediated by important group processes and states (Marks et al. 2001) such as communication effectiveness (Warkentin et al. 1997), coordination effectiveness (Galheger and Kraut 1994, Piccoli et al. 2004), the amount of conflicts (Hinds and Mortensen 2005, Mortensen and Hinds 2001), and the degree of shared understanding existing within the team (Cramton 2001, Yoo and Kannawattanachai 2002). Overall, there is still some confusion in current IS literature in respect to the main drivers of virtual team performance and the nature of their impact. The extant research has reached a point where an integrative conceptualization is needed to identify the key components and processes of virtual teams, analyze the way the components and processes affect each other, and understand how they affect virtual team performance. This is what the first essay aims to do. It addresses the following research questions:

- *What are the key dimensions of virtual teams, and how are they related to each other?*
- *What are the main drivers of virtual team performance?*

- *What important research avenues should be explored in order to foster our understanding of virtual team performance?*

To provide answers to the above research question, the first essay combines the extant literature on small group effectiveness (Campion et al. 1993, Cohen and Bailey 1997, Hackman 1987, Janz et al. 1997) with studies on virtual teams and proposes an integrative model of virtual teams. Within this model, four key dimensions are identified and the relationships between them are discussed. Those four dimensions are (1) the design characteristics of virtual teams (IT, task, and membership design), (2) the emergent processes enacted by their members (IT, interpersonal, task), (3) the emergent states they experience (IT, interpersonal, task), and (4) the performance of the virtual teams (productivity, viability, personal satisfaction and learning). Then, using that model, a review was done of the current empirical literature on virtual team performance following Webster and Watson's (2002) concept-centric methodology. By cumulating empirical evidence within and across 86 studies, numerous direct and indirect drivers of virtual team performance have been identified, thereby offering a set of best practices that can help in managing virtual teams effectively. Beyond identifying the main static and dynamic properties of virtual teams that affect their performance, this essay demonstrates the value of two fundamental principles for virtual teams researchers and practitioners: (1) the importance of differentiating between the types of performance measures, and (2) the criticality of integrating the antecedents of performance. Finally, the synthesis of the extant empirical literature conducted in this first essay has also allowed us to identify important avenues for future research on virtual teams.

Essay 2: A Conceptual Framework of Knowledge Integration in Virtual Teams

In the first essay, we found that the coordination of expertise represents an important team process for virtual teams given its positive effect on team performance (i.e., output quality and creativity/innovation). However, we also noted that few studies have looked at the antecedents of expertise coordination in the IS literature. In the second essay, we address this gap by developing a comprehensive framework of IT-enabled knowledge integration in virtual teams. Broadly stated, knowledge integration is the process of coordinating the usage of specialized knowledge in organizations (Grant 1996a, Grant 1996b, Spender 1996). It contrasts with other knowledge management processes such as knowledge sharing and knowledge transfer since it does not focus on the flow of knowledge taking place between a provider and a recipient. Instead, knowledge integration aims at optimizing the coordinated use of knowledge at the team level by reducing cross-functional knowledge sharing and transfer between individuals (Grant 1996, Spender 1996). According to tenants of the knowledge-based theory (Grant 1996, Kogut and Zander 1996, Spender 1996), knowledge integration is the knowledge management process that is the most closely associated with increased work unit performance and sustained competitive advantage. Understanding the phenomena of knowledge integration in virtual teams would therefore represent an important step forward in our attempt to understand how to leverage the performance of such teams.

To date, very few researchers have studied the phenomenon of knowledge integration in virtual teams, although it has been said many times that virtual teams could enable firms to leverage their knowledge asset across distances. The conceptual paper of Alavi and Tiwana (2002) is, from what we know, the most comprehensive study published on the topic thus far. In that paper, the authors present four main challenges for knowledge integration in virtual teams, and discuss how functionalities of knowledge management systems can help virtual team members resolve them. Those challenges were more accurately reflected by (1) constraints on transactive memory, (2) insufficient mutual understanding, (3) failure in sharing and retaining contextual knowledge, and (4) inflexibility of organizational ties. While Alavi and Tiwana's (2002) paper represents the first attempt to adapt theories from knowledge management research to the realm of virtual teams, we think greater theoretical development is needed in order to circumscribe the main drivers of knowledge integration success in those teams. For instance, although Alavi and Tiwana (2002) rely upon Robert Grant's (1996) knowledge-based theory as a conceptual underpinning, they leave many important components of the theory unexplored, such as the usage of integration mechanisms and the role of common knowledge as key enablers of knowledge integration. In fact, Alavi and Tiwana (2002) focus their analysis primarily on the available features and functionalities of knowledge management systems, and provide limited information about the team processes enabled by those technologies or the way they are being used by virtual team members. Finally, important design properties of virtual teams are not taken into account in their conceptual paper, such as characteristics of the task performed by the teams (e.g., interdependence, complexity, non-routineness), measures of team diversity and team dispersion (e.g., geographical, temporal, functional, etc.), and the performance of the team (e.g., effectiveness, efficiency, innovation). Thus, we think that the development of a comprehensive framework of IT-enabled knowledge integration in virtual teams is likely to benefit to researchers interested in the management of knowledge in virtual teams as well as managers who seek to leverage the intellectual capital of their dispersed workforce. With these considerations in mind, the second essay attempts to provide answers to the following research questions:

- *What are the factors that facilitate the integration of knowledge in virtual teams?*
- *Under which conditions are those factors most effective?*
- *What is the role played by information technologies to facilitate knowledge integration in virtual teams?*
- *What is the relationship between knowledge integration and virtual team performance?*

To address those questions, the second essay presents a conceptual framework of IT-enabled knowledge integration in virtual teams. This framework is grounded on Robert Grant's (1996a, 1996b) knowledge-based theory, which combines a set of theoretical premises explaining how knowledge integration is facilitated in organizational context and why it represents a strategic activity. The adaptation of the knowledge-based theory to the realm of virtual teams has been made by supplementing its fundamental assumptions with the literature on shared mental models (Cannon-Bowers et al. 1993, Klimoski and Mohammed 1994, Brandon and Hollingshead 2004, Lewis 2003, Wegner 1997), studies on coordination in small groups and work units (Faraj and Sproull 2000, Van de Ven et al. 1976, Kraut and Streeter 1995, Gittel 2002), and virtual team research (Majchrzak et al. 2000, Malhotra and Majchrzak 2004, Maznevski and Chudoba 2000, Cramton 2001, Jarvenpaa et al. 2004). The framework identifies the main IT-enabled integration mechanisms that facilitate knowledge integration in virtual teams, and specifies the context within which those mechanisms are likely to be most effective. Overall, this essay contributes to research on virtual teams by proposing a new comprehensive model of IT-enabled knowledge integration in virtual teams, and by bridging across concepts from different but complementary theories relevant for virtual team research. It also offers guidance to virtual team managers by helping them take advantage from the specialized knowledge of their distributed workforce under different task demand conditions.

Essay 3: Knowledge Integration Effectiveness and Performance in Virtual Teams

The third essay attempts to complement the second essay by providing an empirical test of the comprehensive framework of knowledge integration in virtual teams. As mentioned earlier, very few studies have assessed the phenomena of knowledge integration in virtual teams, and even fewer have provided empirical evidence concerning the factors that facilitate this important activity and the impacts it has on virtual team performance. For instance, Alavi and Tiwana (2002) identified a set of challenges to resolve in order to facilitate knowledge integration in virtual teams, but the absence of empirical validation of their research propositions makes it hard to tell which of those challenges are the most critical, if they reinforce each other, and whether or not the usage of knowledge management systems actually helps attenuate those challenges. It also leaves the relationship between knowledge integration and virtual team performance unaccounted. Ultimately, the scarcity of cumulative findings about knowledge integration greatly limits the breadth and depth of advices one can formulate to managers of virtual teams who are looking for ways to leverage the expertise of their employees across geographical boundaries. Providing some answers to the following research questions will shed some light on those research gaps:

- *What are the key mechanisms facilitating the effective integration of knowledge in virtual teams? Which of them are the most important? Under which context are they most effective?*
- *What are the impacts of information technologies on knowledge integration effectiveness in virtual teams?*
- *What is the relationship between knowledge integration effectiveness and virtual team performance?*

The above questions were addressed by conducting a cross-sectional study of existing knowledge-based virtual teams at a large multinational firm in the IT consulting sector. Overall, 700 individuals spread across 102 different virtual teams completed a web-based survey asking about their experience within their respective virtual team. Data about the usage of information technologies, IT usage for integration mechanisms, task characteristics, and knowledge integration effectiveness were analyzed at the team level, and performance was obtained using leaders' perception of the team success. Consistent with the premises of the research model, results show that knowledge integration effectiveness has a strong positive impact on virtual team performance. It was also found that the impact of IT on knowledge integration effectiveness is fully mediated by common knowledge in virtual teams. Those findings calls for greater contextualization of the impact of IT in knowledge-based virtual teams, and outline the importance of accounting for team-level emergent states that might mediate the impact of IT on team outcomes.

TABLE 2. Summary of the three essays

Dissertation Title: Information Technologies, Knowledge Integration, and Performance in Virtual Teams				
		Essay #1	**Essay #2**	**Essay #3**
General information	***Title***	Understanding Distributed Teams: An Integrative Model and Synthesis of Research on the Effect of Emergent Processes, and Emergent States on Performance	A Conceptual Framework of Knowledge Integration in Virtual Teams	Knowledge Integration Effectiveness and Performance in Virtual Teams
	Type of article	Review of the empirical literature	Conceptual paper	Empirical paper
	Purpose	Provide an integrative model of virtual team, and use the model to review the empirical literature on virtual team performance.	Propose a comprehensive model of IT-enabled knowledge integration in virtual teams grounded on the knowledge-based theory.	Empirically assess the main antecedents of knowledge integration effectiveness and performance in virtual teams.
Relevant literature	***Theoretical underpinning***	Small group research, electronic collaboration, virtual teams research	Knowledge-based theory, coordination theory, shared mental models	Knowledge management, coordination theory, shared mental models, virtual teams research
	Key authors/sources	Hackman (1987), Marks et al. (2001), Cohen and Bailey (1997), Majchrzak et al. (2000), Maznevski and Chudoba (2000)	Grant (1996), Cannon-Bowers et al. (1993), Daft and Lengel (1984), Van de Ven et al. (1976), Lewis (2003), Malhotra and Majchrzak (2004)	Grant (1996), Cannon-Bower et al. (1993), Gray and Meister (2004), Van de Ven et al. (1976), Faraj and Sproull (2000)
	Keywords	Virtual teams, performance, electronic collaboration, small group research	Virtual teams, knowledge integration, computer-mediation communication, coordination mechanisms.	Virtual teams, information technology, knowledge integration, common knowledge, team performance.
Methodology	***Research design***	Qualitative review of the empirical literature (Webster and Watson 2002)	Review and integration of relevant literature	Cross-sectional survey of existing knowledge-based virtual teams at a large multinational company.
	Unit of analysis	Empirical essays published in academic journals	Not applicable	Virtual teams (team level analyses)
	Data collection strategy	In-depth search of peer-reviewed empirical paper publications	Not applicable	Electronic survey of virtual team members and leaders of a large multinational IT organization
	Data analysis	Concept-centric review of the literature (Webster and Watson 2002)	Not applicable	Partial Least Square analysis (PLS)
Publications	***Targeted journal publications***	International Journal of e-Collaboration*, MISQ Review	To be determined	Information Systems Research
	Conferences and presentations	Academy of Management 2005*, INGRoup Conference 2006*	Academy of Management 2006*, ASAC 2006*	Academy of Management 2008, ICIS 2008

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CHAPTER II (ESSAY 1): Understanding Virtual Team Performance: An Integrative Model and Synthesis of Research on the Effects of Team Design, Processes, and States

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ABSTRACT

Much research has been devoted to understanding virtual teams. However, our knowledge of the direct and indirect impacts of different elements of virtual teams, such as geographical dispersion, conflict, and IT usage on performance is relatively limited and non-integrated. The present paper advances our understanding by developing an integrative model of virtual teams that describes the relationships between team design, emergent processes, emergent states, and five dimensions of performance (output quality, creativity and innovation, production efficiency, learning, and members' satisfaction with team process). We use the model to synthesize the extant research. One hundred and twenty-two empirical articles published between 1990 and 2007 were analyzed. The paper provides insights as to how virtual teams work and what factors directly and indirectly affect performance. It also identifies avenues for future research on virtual teams.

Introduction

Technological advances, a globally distributed workforce, and a rapidly changing business context have created both the ability and need for organizations to operate across distance. Virtual teams,[2] defined as *interdependent individuals physically separated from one another and relying on information technologies to communicate, collaborate, and coordinate work to achieve a common goal* (Cramton 2001; Maznevski and Chudoba 2000), are seen as a means to face these challenges. They allow firms to leverage their intellectual capital, enhance work unit performance, face the changing customer demands, and acquire and sustain a competitive advantage in turbulent and competitive environments (Jarvenpaa and Leidner 1999; Malhotra et al. 2001; Sole and Edmonson 2002; Townsend et al. 1998). As a result of their increasing prevalence, virtual teams have become the subject of considerable research attention, yielding insights into both the functioning of virtual teams and the drivers of their performance.

Despite this attention, the body of research on virtual team remains fragmented, making it difficult to obtain an integrated and holistic view of the factors that contribute to or inhibit virtual team performance (Pinsonneault and Caya 2005). Important advances can be made in understanding virtual teams by working on two related fronts: taking a differentiated view of team performance and analyzing the complex nomological network that links those types of performance to their antecedents (Bell and Kozlowski 2002; Kirkman and Mathieu 2005; Martins et al. 2004).

[2] The terms virtual teams, dispersed teams, distributed teams, far-flung teams, and global teams are also used to represent teams that rely on IT to perform their work and span multiple geographical locations. In this paper, we use the term virtual teams to represent this construct.

Turning first to the construct of performance, scholars of traditional groups and teams have conceptualized performance as being composed of distinct but interrelated factors including: quantity, quality, and innovation of outputs; production efficiency; willingness to continue working together; and member satisfaction, learning, and growth (Hackman 1987, 1990; Guzzo and Dickson 1996). To date, however, research on virtual teams has largely studied performance as an undifferentiated construct. In some cases, particular dimensions of performance are measured (e.g., quality of outcomes) and results are generalized to a broader notion of performance (Yoo and Kanawattanachai 2001; Kirkman et al. 2004). In other cases, measures of specific dimensions of performance are aggregated into a global performance construct (Hinds and Mortensen 2005; McDonough III et al. 2001). While this holistic view of performance facilitates comparison across studies, it conceals the interactions and interdependencies among different performance dimensions (e.g., efficiency-innovation tradeoffs) and among their antecedents.

Second, most prior studies have focused on the direct impacts of elements of virtual team design (e.g., members' geographic dispersion, team diversity) on performance. With a few exceptions (e.g., Gibson and Gibbs 2006; Maznevski and Chudoba 2000; Hollingshead et al. 1993; Yoo and Kanwattanachai 2001; Kanwattanachai and Yoo 2007), there has been limited focus on the factors that mediate and moderate the relationships between virtual team design characteristics and performance. Extant research, however, suggests that disentangling such relationships and identifying indirect effects can be quite important. For example, while we lack empirical evidence linking computer mediated communication (CMC) directly to output quality, it is likely to have a negative indirect effect because it hinders communication and information sharing among team members (e.g., Chidambaram and Jones 1993; Cramton 2001; Hightower and Sayeed 1996). Such information sharing has, in turn, been positively associated with output quality and satisfaction of members with team processes (e.g., Piccoli et al. 2004; Smith and Vanacek 1990; Warkentin et al. 1997). Further, the relationships among relevant antecedents of specific types of performance are often left unexplored. For example, while uniquely-held expertise and shared understanding are positively correlated with outcome quality and innovation (Balthazard et al. 2004; Majchrzak et al. 2000; Malhotra and Majchrzak 2004; Sole and Edmonson 2002; Yoo and Kanawattanachai 2001), the relationship between these predictors remains unclear. Mapping and exploring the nomological paths linking key virtual team characteristics and performance provides us a more complete understanding of virtual team, thus providing managers with better tools to effectively manage virtual teams.

This paper proposes an integrative model that identifies key elements of virtual teams, how they are interrelated, and how they directly and indirectly affect different dimensions of team performance. Drawing on the work of Ilgen et al. (2005) and Marks et al. (2001), our model suggests that virtual teams can be conceptualized as composed of three components: design factors (e.g., geographical dispersion, IT features and infrastructure, or the nature of the task), emergent team processes (e.g., managing conflicts, exerting specific styles of leadership, using computer-mediated communication, or relying on formal behavioral control mechanisms), and emergent team states (e.g., level of trust, cohesion, shared understanding of IT usage, or shared mental models). Team design factors can affect different types of performance directly and/or indirectly, through emergent team processes and states.

The paper contributes to both research and practice. For research, we provide an integrative model that can serve as a theoretical foundation for future research on virtual teams. The integrative model highlights the prevalent and important mediating and moderating roles played by team processes and states and allows us to better understand effects of several elements of virtual teams on different types of team performance. We use this framework to synthesize extant research on virtual teams, identify gaps, and recommend avenues for future research. The paper thus helps scholars to situate and integrate existing virtual team research. For practice, we provide managers with insights as to how they can design virtual teams and manage processes and states so that they can obtain the outcomes they wish to obtain (e.g., output quality, production efficiency, innovation and creativity, member satisfaction, individual learning, and desire to work together in the future).

The paper is structured as follows. In the first section, we present the theoretical model. We then use the model to synthesize prior research and examine the antecedents of the three dimensions of virtual team performance in an integrated fashion. We conclude the paper with a discussion of implications for research and practice.

A Theoretical Model of Virtual Teams

Our model focuses on the interrelationships among several characteristics of virtual teams and different types of performance. As shown in Figure 1, we categorize the characteristics of virtual teams into three factors: team design, emergent team processes, and emergent team states (Ilgen et al. 2005; Marks et al. 2001). Each factor is composed of elements related to the interpersonal relationship of team members (interpersonal), the task itself (task), or the information technologies used by the team (IT).

----Insert Figure 1 about here----

Virtual Team Performance

In this model we unpack virtual team performance by separately considering three primary dimensions: productivity, viability, and personal development (Cohen and Bailey 1997; Guzzo and Dickson 1996; Hackman 1987, 1990; Sundstrom et al. 1990). Productivity is the extent to which a team's output meets or exceeds the standards of those receiving it and includes measures like quantity, efficiency, output quality, timeliness, and creativity. Viability is the extent to which carrying out its work permits or enhances a team's ability to continue working together and includes measures like willingness to work together in the future[3]. Finally, satisfaction and personal development is the extent to which a team's experience satisfies the personal needs and contributes to the growth and personal well-being of its members and includes measures such as satisfaction, learning, and personal growth.

Team Design Factors

Team design consists of the initial project configuration which sets up the stage for the team to begin to work. It provides the structural context within which the team evolves. Team design is the set of situational opportunities and constraints that affect the

[3] While there are certainly other interpersonal factors which are closely related and impact viability (e.g., conflict, cohesion, inter-member coordination, mature communication & problem solving, and clear norms and roles (Sundstrom et al. 1990) in the context of this analysis, we consider them antecedents rather than aspects of viability.

occurrence and meaning of virtual teamwork (Johns 2006). Team design includes three aspects of the team, namely interpersonal, task, and IT-related factors (Campion et al. 1993; Janz et al. 1997).

Interpersonal factors (also referred to as membership factors) represent the characteristics of individual team members as well as the resulting team-level structural properties shaped by those individuals attributes. It includes personality traits (Balthazard et al. 2004), expertise (Malhotra et al. 2001), geographical dispersion (Hinds and Bailey 2003), temporal dispersion (Cramton 2001), cultural diversity (Maznevski and Chudoba 2000), functional diversity (Jarvenpaa et al. 2004), team size (Majchrzak et al. 2005), and other properties of the team directly related to its membership.

Task factors refer to both the nature and characteristics of the task being performed. Examples include the required degree of interdependence (Lipnack and Stamps 1997), complexity (Maznevski and Chudoba 2000), and non-routineity (Malhotra and Majchrzak 2004), the task's managerial structure – such as self or formally managed (Jarvenpaa and Leidner 1999; Jarvenpaa et al. 2004), and the task itself such as software development (Malhotra and Majchrzak 2004), new product development (Malhotra et al. 2001), or research & development (Hinds and Mortensen 2005).

IT factors include the types of information technologies used to support virtual team collaborative processes such as computer-conferencing systems (Cass et al. 1992), electronic mail (Mortensen and Hinds 2001), and audio/videoconference systems (Andres 2002). IT design also includes the respective attributes of IT like degree of feedback immediacy (Dennis and Kinney 1998) and synchronicity (Maruping and Agarwal 2003). Together, interpersonal, task, and IT-related elements of the team design form the overall situational opportunities and constraints facing virtual team members and managers as they pursue their collaborative task, which can have both subtle and powerful effects on work unit/team performance (Johns 2006).

Emergent Team Processes

Emergent processes are the interdependent cognitive, verbal, and behavioral activities that convert inputs into outputs (Marks et al. 2001). Emergent processes capture how people act, do their job, interact with other members, and use IT. This is the realm of actions. Team processes are dynamic and typically transient. As team members interact and engage in ongoing activities, new emergent processes are created and existing ones are reinforced and/or incrementally changed. We distinguish three types of emergent team processes: interpersonal, task, and IT-related processes.

Interpersonal emergent processes are the activities performed by members of virtual teams to manage interpersonal relationships among them (Marks et al. 2001). They include strategies for managing conflict (Montoya-Weiss et al. 2001), building trust (Jarvenpaa et al. 1998; Walther and Bunz 2005), and other cognitive, verbal, and behavioral activities used to manage socio-emotional and affective dynamics within the team (Kayworth and Leidner 2001).

Task emergent processes are the activities performed by members of virtual teams to structure, organize, control, and monitor work within virtual teams. Task processes assist individual members in the accomplishment and pursuance of task-related activities and include exchanging task-related information and knowledge (Majchrzak et al. 2000; Maznevski and Chudoba 2000), relying on structured processes (Huang et al. 2002;

Piccoli and Ives 2003), and using formal team coordination mechanisms (Massey et al. 2003).

IT emergent processes refer to the cognitive, verbal, and behavioral activities related to the use of IT and its capabilities. This includes using computer-mediated communication (Maznevski and Chudoba 2000; Robey and Khoo 2000; Yoo and Kanawattanachai 2001) and adapting IT to the context of the team (Majchrzak et al. 2000). Taken together, the three types of emergent processes capture members' interdependent actions aimed at converting inputs into outputs.

Emergent Team States

Emergent team states are the properties of virtual teams that are typically dynamic and vary as a function of the team context, inputs, processes, and outcomes (Marks et al. 2001). Emergent states do not denote interaction processes but reflect the characteristics of a team at a given point in time (Ilgen et al. 2005; Marks et al. 2001; Mathieu et al. 2006). We differentiate between three types of states: interpersonal, task, and IT. Interpersonal emergent states refer to the affective and socio-emotional properties of virtual teams.

At the broadest level, interpersonal states are collaborative climate within which a virtual team operates at a given time. Specific examples include shared team identity (Hinds and Mortensen 2005), amount of conflict (Hinds and Mortensen 2005), degree of trust (Jarvenpaa and Leidner 1999), team cohesion (Chidambaram and Jones 1996), and team empowerment (Kirkman et al. 2004).

Task-related emergent states represent team members' attitudes, values, cognitions, and motivations related to task activities. They include shared mental models and collective minds (Yoo and Kanawattanachai 2001; Baba et al. 2004), transactive memory systems (Mortensen and Hinds 2001), and team awareness (Espinosa et al. 2007; Marks et al. 2001).

Finally, IT-related emergent states are the team's attitudes, values, cognitions, and motivations about IT and its roles in supporting the team's activities. IT states include notions such as shared IT knowledge (Bassellier et al. 2003), media sensitivity (Trevino et al. 1990), computer self-efficacy (Compeau and Higgins 1995; Staples et al. 1999), and perceived technology spirit (DeSanctis and Poole 1994).

As illustrated in Figure 1, team design provides the initial team configuration that shapes the future direction of teams and can facilitate or constrain emergent processes and emergent states. Team design factors can thus influence team performance directly and indirectly, because they facilitate, stimulate, or hinder the emergence of some processes and states. For example, members' geographical dispersion (a design factor) may hinder the development of shared understanding (an emergent team state) in virtual teams because dispersed members often do not correctly interpret other members' behaviors due to their lack of understanding of remote work context (Cramton 2001). This, in turn is likely to negatively affect the quality of the team's output (Yoo and Kanawattanachai 2001). Similarly, temporal dispersion (a design factor) can have a negative effect on output quality by hindering communication and information sharing (Majchrzak et al. 2000; Malhotra et al. 2001; Thompson and Coovert 2003).

The model also shows how emergent processes and states influence one another, sometimes reinforcing or modifying existing states or processes and other times creating new ones (Ilgen et al. 2005; Marks et al. 2001). Emergent processes, through members' repeated actions, contribute to emergent states by facilitating state formation, maintenance, and transformation. For example, teams that pre-emptively manage conflicts (emergent process) are likely to experience low levels of conflicts (emergent state) (Marks et al. 2001; Simons and Peterson 2000). Emergent processes can also serve to reproduce or transform existing states, as in the case where knowledge management within teams serves to update and refine extant transactive memory systems (Brandon and Hollingshead 1999). Emergent states can affect emergent processes by influencing the team selection, routinization, optimization, and structuration of processes. For example, Jarvenpaa et al. (2004) found that trust moderates the impact of communication frequency of team members (emergent team process) on team performance. The framework also captures the recursive relationship between outputs and team characteristics (Ilgen et al. 2005; Marks et al. 2001). The feedback loops, represented in the model by dashed arrows, indicate that variables treated as output factors at time t can become antecedents of contextual and/or emergent process and state variables at time $t+1$.

The overall implication of our model is that while the initial team configuration (team design factors) may directly affect performance, viewing it in isolation is not sufficient to completely understand the drivers of team performance. A more complete understanding can be achieved by analyzing the full causal paths, including the direct and indirect effects that occur through emergent processes and states. This explicitly recognizes the complex, dynamic, and multi-faceted nature of virtual teamwork and enables the integration of findings from different perspectives into a cohesive framework mapping direct and indirect drivers of virtual team performance. We use the framework to synthesize and organize the extant empirical literature on virtual teams, to identify what we know and what we do not know about virtual teams and their performance, and to outline an agenda for future research.

Method

We identified empirical articles on virtual teams[4] by searching peer-reviewed journals published between 1990 and 2007 for papers with the following terms in their titles or abstracts: *virtual team(s)/group(s), distributed team(s)/group(s), dispersed team(s)/group(s), group(s) and communication technology*[5]. Once papers were identified, we then extensively searched each journal in which papers on virtual teams had been identified in the first step. We also searched the major IS-related conference proceedings. Appendix 1 lists the 122 articles included in this analysis and the journals and conferences covered (left column of Appendix 1).

To create a nomological net linking the components of the model, we created one table for each link between constructs in the model (i.e., team design--states, team design--processes, team design--performance, states--processes, processes--performance, states--performance). The results of each study were classified in the tables independently by each author and classification inconsistencies (less than 5%) were resolved through

[4] For the first criteria, *members geographically dispersed* all studies that reported any geographical dispersion (i.e. group members at the same site but in different rooms/workspaces) were included. For the second criteria, *reliance on technology to communicate and coordinate*, we identified the IT used by virtual team members to perform their task/project
[5] We used ABI/INFORMS to perform a preliminary search.

discussion. We then conducted a three-step analysis. First, we analyzed the elements of virtual team design, processes, and states for which we only have direct performance effects (i.e., for which we do not have empirical evidence on second order antecedents). Second, we developed nomological nets of causal paths with first and second order effects on performance (e.g., a team process component which affects a state component, which in turn affects performance). To achieve this, we studied the relationships among the elements of each component (e.g., the relationship among IT processes, task processes, and interpersonal processes; the relationship among IT states, task states, and interpersonal states). Then, we analyzed the relationships among the elements of two components (e.g., the relationships among the three elements of emergent processes and the three elements of emergent states; the relationships among the elements of team design and elements of emergent processes). Third, we analyzed the evidence concerning the feedback loops (depicted in dotted-arrows in Figure 1) and papers that explicitly looked at moderation and mediation effects between team design factors, emergent team processes, and emergent team states elements.

Results

Using the model presented in Figure 1 as a framework, we analyzed the empirical evidence of the direct and indirect effects of team design, emergent processes, and emergent states on virtual team performance. The results are grouped by performance dimensions. Within each dimension, we first present evidence that directly links factors to team performance and for which there is no evidence of second order antecedents. We then present the causal paths we identified i.e., direct antecedents of virtual team performance for which we have found evidence of one or more second order antecedent(s). To represent each of these relationships, we use a functional notation of the form $y=f(x_n[z])$ in which "y" represents the outcome, "x_n" represents the antecedent and z is a valence (+/-) specifying the direction of the relationship.

It must be noted that while our model identifies three distinct dimensions of team performance (productivity, viability, and personal development), to date these have been unevenly studied. We found empirical evidence of both direct and indirect effects for three measures of productivity (production efficiency, output quality, creativity and innovation). Less prevalent, we found evidence for two measures of personal development (members' satisfaction with team process and individual learning) and we found no evidence linking team design, emergent processes and emergent states to team viability (e.g., members' willingness to work together in the future).

Productivity: Output Quality

Figure 2 presents the evidence linking virtual team characteristics to output quality.

----Insert Figure 2 about here----

Output quality is the performance dimension that has been most studied to date. As illustrated in Figure 2, while we have not found any research linking initial design characteristics directly to output quality, we have identified four emergent processes, all of which are themselves positively related to output quality: *active leading* (emergent interpersonal process); *managing work interdependencies and expertise, using structured processes*, and *communicating and sharing information* (all emergent task processes). We also found seven emergent states: *efficacy beliefs*, *trust*, *cohesion and interpersonal relationships*, and *conflict* (all emergent interpersonal states), *shared understanding* (an emergent task state), and *shared norms of IT use* and *task-IT fit* (both emergent IT states) related to output quality. We first turn to the four emergent processes.

Emergent Interpersonal Processes: Active leading

Active leading was found to be positively related to output quality. Virtual teams exhibiting strong leadership reported better quality of outcomes than teams experiencing lower quality leadership (Kayworth and Leidner 2001). Similarly, high performing teams (in terms of output quality) are characterized by more frequent leadership behaviors, including monitoring of interpersonal and task-oriented processes (Carte et al. 2006). Interestingly, Hambley et al. (2007) compared the effects of transformational and transactional leadership styles on virtual team output quality and found no difference, suggesting that both approaches of leadership equally affected output quality.

The evidence suggests that effective leaders perform a wide array of behaviors and roles rather than relying on a few limited approaches to leading. Active leaders perform distinct roles proactively and simultaneously. For example, they mentor (i.e., show empathy and dealing with others with a sensitive and caring way) while also asserting authority without being perceived as inflexible (Kayworth and Leidner 2001). Active leaders also build and sustain strong personal relationships among dispersed members throughout the duration of the project (Pauleen 2003), and they integrate, assemble and combine members' contributions in a coherent collective team outcome (Armstrong and Cole 2002; Yoo and Alavi 2004). Finally, active leaders coordinate and schedule work, initiate communications within the team, and generate an open, constructive, and psychologically safe work climate (Weisband 2002; Yoo and Alavi 2004).

Emergent Task Process: Managing work interdependencies and expertise

Second, empirical evidence indicates that managing work interdependencies and expertise has a positive effect on team performance in general, and output quality in particular. Virtual teams that intentionally develop stronger communication ties and more integrated communication structures produce higher quality outcomes than those exhibiting weaker team coordination and communication (Zack and McKenney 1995). Similarly, Massey et al. (2003) found that the successful synchronization of efforts within virtual teams is positively associated with outcome quality. The importance of managing expertise and work interdependencies is also outlined in Kanawattanachai and Yoo (2007), Malhotra et al. (2001), Malhotra and Majchrzak (2004) who found that the quality of outcomes generated by virtual teams is dependent upon their ability to use appropriate mechanisms and strategies to coordinate the usage of their members' knowledge and expertise. Overall, the evidence suggests that an effective coordination of knowledge usage within virtual teams positively influence output quality of virtual teams.

Emergent Task Process: Using structured processes

Third, using structured processes (formal practices and routines designed to formally structure the task) was found to lead to output of better quality (Massey et al. 2003; Tan et al. 2000; Walther and Bunz 2005). In a study of 10 DTs, Walther and Bunz (2005) found that the reliance of formal rules and work procedures (e.g., sticking to deadlines, making deadline explicit) was positively associated with both perceptual and objective measures of quality of team's outcomes. Similarly, teams relying on a goal setting structure developed greater perceived decision quality than teams that did not use such mechanisms (Tan et al. 2000). The reliance on process structure mechanisms (i.e., scheduling team deadlines, coordinating the pace of work, and specifying the time spent on tasks) was also found to help virtual team members to structure and organize their efforts and interaction patterns, which positively influenced the quality of output they can generate (Massey et al. 2003; Montoya-Weiss et al. 2001).

Emergent Task Process: Communicating and sharing information

Fourth, we find evidence for a positive effect of communicating and sharing information on output quality (Aubert and Kelsey 2003; Smith and Vanacek 1990; Hightower and Sayeed 1996). Knowledge and information sharing was found to positively influence teams' quality of outcomes in cross-functional virtual teams because interdependent coworkers need the informational inputs of other people within the team in order to be able to accomplish their own work (Majchrzak et al., 2000; Malhotra et al., 2001). Similarly, Hightower and Sayeed (1996) and Smith and Vanacek (1990) found that the amount of unique information shared within a team was positively associated with output quality. Finally, Andres (2006) found a positive relationship between information exchange (number of task-relevant information exchange episodes) and quality of outcomes.

In addition to serving as a first-order antecedent, communication and information sharing effectiveness also plays a key role as a step in the indirect causal paths linking output quality to two second-order antecedents: *using computer mediated communication (CMC)* (emergent IT process) and *geographical dispersion* (interpersonal design). In the first, numerous scholars have found effective teams relying on computer mediated communication have greater difficulty in establishing communications as well as effectively sharing information through these media (Cramton 2001; Hightower and Sayeed 1996; Smith and Vanecek 1990; Straus and McGrath 1994; Thompson and Coovert 2002, 2003; Warkentin et al. 1997; Wilson et al. 2006). Although often correlated with CMC use, geographic dispersion of team members yields distinct effects based on actual and perceived proximity of team members. Building on these, scholars have repeatedly found that geographic dispersion negatively impacts communication (Chidambaram and Jones 1993; Cramton 2001; Cramton and Webber 2005; Kayworth and Leidner 2000; Postmes et al. 2002; Smith and Vanacek 1990; Thompson and Coovert 2003; Warkentin et al. 1997).

Emergent Interpersonal State: Efficacy beliefs

As noted, we also found evidence of seven emergent states which positively impact output quality. First, the development of efficacy beliefs within virtual teams is a direct antecedent of output quality (Fuller et al. 2006; Hardin et al. 2007; Staples and Webster 2007). Conceptualized in diverse ways including self-efficacy for teamwork (Staples and Webster 2007), virtual team efficacy (Fuller et al. 2006) and group self-efficacy (Hardin et al. 2007) all these efficacy beliefs have been found to positively affect the quality of outcomes of virtual teams. Using the social cognitive theory (Bandura 1991) as the main theoretical foundation for their analyses, the studies suggest that efficacy beliefs affect performance via different mechanisms, such as influencing members' aspirations, choices, level of efforts and motivation, ability to cope with obstacles and the stress and arousal they cause, and ultimately perseverance in the presence of challenges (Bandura 1991; Staples and Webster 2007).

Emergent Interpersonal State: Trust

Second, we find some evidence that trust positively affects output quality in virtual teams (Kanawattanachai and Yoo 2002; Paul and McDaniel 2004). In a study of 38 virtual teams of students conducting a business simulation game, Kanawattanachai and Yoo (2002) found that high performing teams report higher levels of cognitive and affective-based trust than low performing teams, although the cognitive trust seems more important. In a different setting, Paul and McDaniels (2004) found that trust, especially integrated form of trust, has a positive impact on the quality of remote health care services. This was explained by the fact that a trustworthy environment facilitated the flow of knowledge and cooperation. It is important to note, however, that two studies found no significant relationship between trust and output quality (Aubert and Kelsey 2002; Jarvenpaa et al. 2004).

Beyond trust's direct effect on output quality, we also find evidence that trust is part of a causal chain linking output quality to four indirect antecedents, namely the presence of collocated *subgroups* within virtual teams (interpersonal design), *communicating socio-emotional information* (interpersonal process), *using a structured process* (task process), and *communicating and sharing information* (task process).

First, trust is negatively affected by the presence of collocated *subgroups* within virtual teams (Polzer et al. 2006). In a study of 45 student teams, Polzer et al. (2006) found that when virtual teams are formed of collocated subgroups, their members tend to develop less trust with their geographically-dispersed teammates than with members of their collocated subgroups, thus resulting in low trust at the team level. This detrimental effect of collocated subgroups on trust is more pronounced when members of collocated subgroups are similar nationalities. Subgroups create faultlines, which are hypothetical divisions that split a group into subgroups based on one or more attributes (Lau and Murnighan 1998). Faultlines cause people to categorize members of their own subgroup as "in-group members" while viewing other members as "out-group individuals". In virtual teams, the faultline is often created by geographical dispersion and relationships across distant subgroups tend to be less positive than relationships within collocated subgroups, thereby negatively affecting team-level trust.

Second, the empirical evidence suggests that *communicating socio-emotional information* in virtual teams also facilitate the development and maintenance of trust (Jarvenpaa and Leidner 1999; Wilson et al. 2006). For instance, the development of trust was found to be facilitated by members making affectionate remarks to teammates (Walther and Bunz 2005; Wilson et al. 2006), communicating enthusiasm and optimism, congratulating and encouraging each other, and frequently exchanging socially-oriented messages (Jarvenpaa and Leidner 1999). On the contrary, inflammatory remarks were associated with slow trust development in virtual teams (Wilson et al. 2006). Socially-oriented communications are beneficial for trust development and maintenance as long as they are not made at the expense of a focus on task (Wilson et al. 2006).

Third, *using structured processes* has been found to enhance trust (Walther and Bunz 2005; Jarvenpaa et al. 1998; Jarvenpaa and Leidner 1999; Zolin et al. 2004). Techniques identified to streamline and structure the process of virtual teams include getting the team working as soon as possible after its inception (Walther and Bunz 2005), adhering to team schedule and deadlines (Jarvenpaa and Leidner 1999; Walther and Bunz 2005), having clear roles and responsibilities (Jarvenpaa and Leidner 1999), using team building activity (Jarvenpaa et al. 1998), and constantly monitoring and following-up individuals' contributions to the joint task (Zolin et al. 2004). However, it should be noted that using behavioural control to structure team processes can have detrimental impacts on trust because it increases the likelihood of detecting dysfunctional team behaviors (e.g., reneging and incongruent behaviors), thus leading to trust decline (Piccoli and Ives 2003). The evidence suggests that when they are not a source of pressure in virtual teams, structured processes facilitate the development and maintenance of trust (Jarvenpaa and Leidner 1999).

Fourth, *communicating and sharing information* was also found to be a key antecedent of trust in virtual teams (Jarvenpaa and Leidner 1999; Jarvenpaa et al. 2004; Walther and Bunz 2005). Effective communication and information sharing in virtual teams include communication behaviors such as phlegmatic responses to crisis, providing substantial and timely responses to distant team members, having predictable communication behaviors, and sustaining frequent interactions among members (Jarvenpaa and Leidner 1999; Jarvenpaa et al. 2004). Other examples of effective communication practices having positive effects on trust include explicitly acknowledging reading messages and frequently exchanging task-oriented messages (Jarvenpaa and Leidner 1999; Jarvenpaa et al. 2004; Walther and Bunz 2005).

Emergent Interpersonal State: Cohesion and interpersonal relationships

Third, output quality is positively related to group cohesion and interpersonal relationships. In a study of 13 virtual teams of students, Cramton (2001) found support for a positive association between relationship development and quality of output. This effect appears to be more important at early and late stages of group lifecycle (Chidambaram, 1996). In a field study of 35 virtual teams in sales and service, Kirkman et al. (2004) found that team empowerment, (the extent to which members of virtual teams are committed to their task and perceive their work climate as motivating), was positively associated with two measures of the quality of the work, namely customer satisfaction and process improvement.

Beyond its role as a direct antecedent of output quality, cohesion and interpersonal relationships is also part of a causal chain linking output quality to a number of second order antecedents. Cohesion and interpersonal relationships are positively related to the *presence of subgroups* (interpersonal design) and to *using structured processes* (emergent task process), but negatively affected by *computer-mediated communication* (emergent IT process).

A growing body of research has found that cohesion and interpersonal relationships are negatively affected by the presence of *subgroups* within virtual teams (Polzer et al. 2006; Panteli and Davison 2005). Subgroup formation stimulates the polarization of attitudes and social affiliation between subsets of individuals only. The division created by the formation of subgroups reduces team-level cohesion and interpersonal relationships across subgroups.

Evidence also suggests that *using structured processes* increases cohesion and interpersonal relationships in virtual teams (Huang et al. 2002; Tan et al. 2000; Warkentin and Beranek 1999; Walther and Bunz 2005). Virtual teams that received communication training are able to develop greater cohesion, openness, and commitment than teams that do not receive such training (Warkentin and Beranek, 1999) and teams that are trained on how to establish interpersonal relationships in a virtual context experience a higher level of cohesiveness (Beranek and Martz 2005). In a study of 24 virtual teams and 24 face-to-face teams, Huang et al. (2002) observed that virtual teams relying on a structured dialogue technique had greater collaboration and cohesiveness than teams that did not use those techniques. Similarly, virtual teams who adopt a goal setting structure achieve higher levels of cohesiveness, collaborative climate, and team commitment than teams who do not (Tan et al. 2000). Finally, Walther and Bunz (2005) found that the enactment of formal rules and procedures (e.g., sticking to deadlines, being explicit, getting started) was positively associated with the development of both social and task attraction.

The evidence also suggests that group cohesion and interpersonal relationships are negatively influenced by *CMC* (Andres 2002; Galegher and Kraut 1994; Weisband and Atwater 1999; Chidambaram 1996; Hambley et al. 2007; Warkentin et al. 1997). Surprisingly, the synchronicity of computer mediation does not appear to be a significant factor. For instance, Galegher and Kraut (2004) found that virtual team members relying on asynchronous conference systems to communicate and coordinate work reported significantly lower perceptions of liking toward each others and had fewer socially-oriented interactions than face-to-face teams. Synchronous IT usage was found to hinder the emergence of interpersonal relationships in virtual teams (Weisband and Atwater 1999; Warkentin et al. 1997). It is important to note that the negative effect of computer mediation on group cohesion seems to decrease over time. As members of virtual teams engage in sustained and continuous informational exchanges, they achieve higher levels of immediacy, affection, and cohesiveness (Chidambaram 1996; Walther 1995; Walther 1997). This is consistent with the work of Sarker and Sahay (2003) and Hinds and Mortensen (2005) who found that the development of a shared identity and feelings of belongingness among distributed team members required substantial communication which tends to occur later in a group's lifecycle.

Emergent Interpersonal State: Conflict

Fourth, we find evidence that output quality is negatively influenced by conflict (Mortensen and Hinds 2001; O'Connor et al. 1993). Teams with moderate or high levels of conflict consistently generate outcomes of lower quality compared to teams with low levels of conflict (O'Conner et al. 1993). Similarly, in a field study of 12 distributed teams and 12 collocated teams, Mortensen and Hinds (2001) found that output quality was negatively related to both task and affective conflict in virtual teams. Task conflict is negatively related to output quality in virtual teams while interpersonal conflict does not seem to have significant impact on performance (Hinds and Mortensen 2005). Taken together, these findings suggest that while conflicts in virtual teams are generally detrimental for output quality, task conflict seems to have a stronger negative effect than affective conflict. This is consistent with the work of McDonough III et al. (2001), who observed that behavioral challenges experienced by geographically dispersed coworkers had no impact on output quality, while task-related conflicts were detrimental.

In addition to this direct effect, conflict also serves as a step in a causal chain linking output quality to second order antecedents. Conflict is positively related to *geographical dispersion* (interpersonal design) and the presence of *subgroups* (interpersonal design). Conversely, conflict is negatively related to proactively *managing conflicts* (emergent interpersonal process) and *communicating and sharing of information* (emergent task process).

The evidence indicates that *geographical dispersion* of virtual teams increases conflict (Armstrong and Cole 2002; Hinds and Mortensen 2005; McDonough III et al. 2003, Polzer et al. 2006). In a comparative study of 22 collocated and 21 distributed teams, Hinds and Mortensen (2005) found that members' geographical dispersion was positively related to both task and interpersonal conflict. Members' geographical dispersion increases the behavioral and interpersonal challenges faced by virtual teams and creates an overall climate that make the team more vulnerable to the development of interpersonal conflict (Armstrong and Cole 2002; McDonough III et al. 2003) and of task-related conflicts as well (Hinds and Bailey 2003; Mannix et al. 2002). The negative impact of geographic distribution on conflict is thus frequently caused by the misunderstanding among individuals, unshared contextual information, incorrect explanation of miscommunications, weak interpersonal bonds across sites, and poor information exchange (Amstrong and Cole 2002; Hinds and Bailey 2003; Hinds and Mortensen 2005).

In addition, conflict is positively affected by the presence of collocated *subgroups* within a virtual team, or faultlines (Polzer et al. 2006; Panteli and Davison 2005). In a study of 45 virtual teams, Polzer et al. (2006) found that conflicts were more stringent in virtual teams composed of collocated sub-groups than within fully distributed teams (with no subgroup). A virtual team formed of collocated subgroups represents a conflict-prone environment because it provides an explicit boundary among individuals. Given that collocated members benefit from face-to-face communication and more proximal relationships, they tend to develop more positive attitudes toward their collocated teammates than with their dispersed colleagues who are part of another sub-group (Polzer et al. 2006). Such polarization in turn causes team members to identify more strongly with their subgroup, which then leads to potential conflicts within the team. Taken together, the evidence suggests that:

Conflict is reduced by the extent to which a team *proactively manage conflicts* (Hinds and Bailey 2003; Hinds and Mortensen 2005; Paul et al. 2004). The empirical evidence indicates that interpersonal behaviors and conflict management strategies that stimulate information exchanges and close connections among virtual team members are more effective for managing conflicts than passive strategies of conflict management aimed at suppressing interpersonal exchanges. For instance, in a study of 35 five virtual teams, Montoya-Weiss et al. (2001) found cooperative and competitive strategies of conflict management – approaches emphasizing interpersonal exchanges and proactive position taking of group members – reduced the level of conflicts, which was positively associated with decision quality. Conversely, avoidance and compromise were ineffective conflict management strategies and negatively affected decision quality. In the same vein, Paul et al. (2004) also found that managing conflicts using collaborative conflict strategies was positively associated with team members perceived decision quality. These findings are consistent with Marks et al.'s (2001) review of team processes, which shows the importance of establishing conditions to prevent, control, or guide team conflicts before they occur.

Finally, *communicating and sharing information* was found to reduce conflicts in virtual teams (Hinds and Mortensen 2005; Malhotra and Majchrzak 2004). Hinds and Mortensen (2005) found that the frequency with which members of virtual teams engage in spontaneous communication inhibits conflict in two ways. First, spontaneous communication acts as a moderator between distance and conflict by attenuating the negative impact of geographical distance on members' task and interpersonal conflicts. Second, it indirectly reduces conflicts by fostering shared team identity and context, which reduce the impact of interpersonal and task conflict respectively.

Emergent Task State: Shared understanding

Fifth, research shows that teams that are able to establish and maintain a state of shared understanding about their work context outperform teams that do not have such a shared understanding (Malhotra et al. 2001; Malhotra and Majchrzak 2004; Maznevski and Chudoba 2000; Mortensen and Hinds 2002; Yoo and Kanawattanachai 2001). Establishing a shared understanding allows team members to share communication patterns and knowledge about each others' domain of expertise and to achieve mutual awareness of coworkers' roles and responsibilities and of the procedures needed to pursue the collective task. In a study of 38 virtual teams of graduate student, Yoo and

Kanawattanachai (2001) found that elements of shared cognition such as a transactive memory system and collective mind are key antecedents of output quality in virtual teams, but their respective effects varied over time. A transactive memory system, i.e., mutual awareness of each others' domains of knowledge in the team, positively influenced output quality throughout the team lifecycle. Collective mind, however, was only found to have a significant effect on output quality in later stages of the team lifecycle. Malhotra and Majchrzak's (2004) study of 54 effective virtual teams found that creating a state of shared understanding about goals and objectives, task requirements and interdependencies, roles and responsibilities, and member expertise had a positive effect on output quality. When team members share a similar representation of who is a member of the team and who is not, they tend to generate outputs of better quality than when such perceptions differ among individuals (Mortensen and Hinds 2002).

Shared understanding is also part of a causal chain predicting output quality: it is negatively related to *geographical dispersion* (interpersonal design). Dispersed team members tend to draw on different frames of references and task-domain knowledge, come from professional backgrounds, and use different work routines (Malhotra et al. 2001). In their study of 7 cross-functional virtual teams, Sole and Edmonson (2002) found that members' geographical dispersion limited the development of shared assumptions about local work practices. Also, Cramton (2001) found that geographically and temporally-dispersed members failed to develop a mutual representation of their work environment because members made inaccurate attributions about other colleagues' behaviors.

Emergent IT State: Shared norms of IT use

Sixth, moving from interpersonal to IT-related factors, shared norms of IT use were positively linked to output quality in a number of studies (Malhotra et al. 2001; Majchrzak et al. 2000; Majchrzak and Malhotra 2004; Maznevski and Chudoba 2000; Sarker and Sahay 2003). In a study of 12 virtual teams of US and Canadian students involved in information systems development projects, Sarker and Sahay (2003) found that virtual teams that generated high quality outputs were able to clearly define the channels of communication used by their members in order to support interactions among them. Relying on shared and predictable communication patterns of IT usage and having shared norms or IT usage were also identified by Maznevski and Chudoba (2000), Malhotra and Majchrzak (2004), and Malhotra et al. (2001) as an important team state affecting output quality. Overall, the reliance on shared norms of IT usage limits dysfunctional communication practices such as sharing redundant information (Malhotra et al. 2001; Malhotra and Majchrzak 2004) and processing information in parallel (Cramton 2001).

Emergent IT State: Task-IT fit

Finally, we find evidence that output quality is positively affected by the fit between the task to be performed and the IT used. The evidence suggests that virtual teams that adapt the IT they use and tailor their patterns of use to the task requirements generated outcomes of better quality than those who do not make such adjustments (e.g., Majchrzak et al. 2000; Hollingshead et al. 1993; Walther 2002). Hollingshead et al. (1993) found that the fit between the technology and the task in a virtual team positively affected output quality, and that the task-technology fit depended on the members' cumulative experience using IT and the changes they made to adapt the technology to the group processes. Majchrzak et al. (2000) show that the ability of team members to constantly adapt IT and its usage protocols in order to align them with team and organizational constraints, opportunities, and processes led to a better fit and higher output quality. In a study of three internationally-distributed product development teams, Maznevski and Chudoba (2000) found that when working on a highly interdependent and/or complex task, effective virtual teams (with high output quality) used technology-mediated communications more frequently while less effective teams were unable to match the information processing requirements of highly interdependent and complex tasks to an appropriate pattern of IT usage. Malhotra and Majchrzak (2004) found that virtual teams performing routine tasks generated higher output quality when they used IT mainly for supporting task coordination activities, while teams performing non-routine tasks generated high output quality when they used IT to exchange a greater amount of information and to support interactive exchanges. Hollingshead et al. (1993) found that changing the media used to communicate and coordinate work disrupted the overall collaborative process, which significantly decreased the team's quality of outputs. Finally, the evidence suggests that high performing virtual teams (i.e., producing higher quality of output) resolve complex and ill-defined design problems by expanding the information processing capabilities of their communication media and combining audio-conference systems and desktop applications (Malhotra et al. 2001).

Therefore, task-IT fit has a direct positive effect on output quality and it is part of a causal chain, being positively related to team members' *appropriation of IT* (emergent

IT process) (Hollingshead et al. 1993; Majchrzak et al. 2000; Malhotra and Majchrzak 2004; Walther 2002).

Summary

Taken together, the evidence suggests that while design characteristics have not been found to directly affect output quality, they also appear to have important indirect effects that operate through emergent processes and states. In addition, both emergent processes and states have been shown to affect output quality, although the evidence for the direct effects arising from emergent states is greater. The effects of interpersonal factors (both processes and states) are more important than those of factors related to tasks and IT. The empirical evidence is summarized in the equations below.

Output quality = f(Active leading [+],
Managing work interdependencies and expertise [+],
Using structured processes [+],
Communicating and sharing information [+],*
Efficacy beliefs [+],
Trust [+],*
Cohesion and interpersonal relationships [+],*
Conflict [-],*
Shared understanding [+],*
Shared norms of IT use [+],
Task-IT fit [+])*

Communicating and sharing information = f(Using CMC [-],
Geographic dispersion [-])

Trust = f(Subgroups [-]
Communicating socio-emotional information [+]
Using structured processes [+],
Communicating and sharing information [+]),

Cohesion and interpersonal relationships = f(Structured processes [+],
Using CMC [-],
Subgroups [-])

Conflict = f(Proactive conflict management [-],
Communicating and sharing information [-],
Geographical dispersion [+],
Subgroups [+])

Shared understanding = f(Geographic dispersion [-])

Alignment of task and IT = f(Appropriating IT [+])

** indicate second-order antecedents*

<u>Productivity: Creativity and Innovation</u>

Figure 3 presents the nomological nets of creativity and innovation as well as production efficiency.

----Insert Figure 3 about here----

As illustrated in Figure 3, three interpersonal team design factors: *geographic dispersion*, *structural dynamism*, and *demographic diversity* have been found to affect creativity and innovation. One emergent team process (*using CMC*) and two emergent states (*shared understanding* and *task IT fit*) also affect virtual team creativity and innovation. We turn first to the three design factors.

Interpersonal Design: Geographic dispersion

First, the evidence suggests that geographic dispersion hampers creativity and innovation by reducing contextual knowledge of remote sites and increasing coordination complexity in acquiring knowledge and resources (Gibson and Gibbs 2006). Psychological safety attenuates the negative effect of geographic dispersion on innovation because it increases exchange of contextual knowledge, which aids in efficiently garnering resources (Gibson and Gibbs 2006).

Interpersonal Design: Structural dynamism

Second, creativity and innovation is also negatively affected by structural dynamism (i.e., frequency with which team participants change) because it affects the stability of team members' roles and their interpersonal relationships (Gibson and Gibbs 2006). Again, psychological safety attenuates the negative effect of structural dynamism on innovation because it strengthens interpersonal relationships by increasing trust and reducing perceptions of risk.

Interpersonal Design: Demographic diversity

Third, demographic diversity has been shown to constrain innovation by creating heterogeneous communication preferences and by reducing identification with the team as a whole (Gibson and Gibbs 2006). A psychologically safe communication climate reduces the negative effect of national diversity on innovation by facilitating in-groups/out-groups collaboration and conflict resolution, and by allowing for cultural differences to co-exist (Gibson and Gibbs 2006).

Emergent IT Process: Using CMC

Turning next to emergent processes, using computer mediated communication, (measured as the degree of reliance on e-mail, teleconferencing, collaborative software, and overall electronic communication) was also found to be negatively associated with virtual team creativity and innovation (Gibson and Gibbs 2006). Again, a psychologically safe communication climate helps reduce this negative effect by facilitating informal communication and mutual feedback between virtual team members.

Emergent Task State: Shared understanding

Lastly, with respect to emergent team states, virtual team creativity and innovation was positively associated to shared understanding developed among members. In fact, the evidence from Majchrzak et al. (2000), Malhotra et al. (2001) and Malhotra et al. (2004) suggests that virtual team's creative ability rests on the degree to which they share an understanding of the problem at hand, analysis methods, and technical language and tools used in the team. The diversity of knowledge within cross-functional virtual teams makes them fertile grounds for innovation and creativity, but often generates challenges for their members to simply understand each other as they share information and coordinate their task, thereby constraining the creative process at the team level. Shared understanding about assumptions, task characteristics, work processes and environmental challenges is thus necessary to unlock the creative potential of the team (Majchrzak et al. 2000; Malhotra et al. 2001; Malhotra et al. 2004).

Beyond acting as a first order antecedent, shared understanding also serves as a step in the causal path between creativity and innovation and geographic dispersion. As mentioned earlier, studies also show that *geographical dispersion* inhibits the development and maintenance of shared understanding in virtual teams (Malhotra and Majchrzak 2004; Sole and Edmonson 2002; Cramton 2001).

Emergent IT State: Task-IT fit

Finally, creativity and innovation are positively associated with the degree to which the team's task and IT are aligned (Malhotra and Majchrzak 2004; Malhotra et al. 2001; Malhotra and Majchrzak 2004; Orlikowski and Yates 1994). In their study of 54 virtual teams, Malhotra and Majchrzak (2004) found that successful knowledge creation depends on the teams' ability to use the appropriate technology for the task at hand. When performing routine tasks, the creative needs of teams are adequately addressed by using technology that supports formal coordination activities and work efficiency. In contrast, virtual teams performing non-routine tasks used IT to support interactivity, consensus building, and creativity. Moreover, studies also show that technology appropriation is intertwined with the concept of task-technology fit through a dynamic process of technology adjustments and adaptation moves (Majchrzak et al. 2000; Malhotra et al. 2001; Orlikowski and Yates 1994). For instance, members of virtual teams define IT usage and communication protocols and engage in evaluative choices about the functionalities of IT and the way to use them in order to support the creative needs of their team. Throughout the lifecycle of virtual teams, those IT usage protocols evolve and can be changed or redefined (Majchrzak et al. 2000; Malhotra and Majchrzak 2004; Orlikowski and Yates 1994).

The evidence suggests that adjustments in technology can facilitate knowledge creation and innovation. Again, as noted in the previous section, task-IT fit is, itself predicted by IT appropriation, thus creating a causal chain linking IT appropriation to creativity and innovation.

Summary

Taken together, the evidence suggests that creativity and innovation are affected by design characteristics as well as emergent processes and states, as summarized in the equations below.

Creativity & Innovation = f(Geographical dispersion[-] †,
Structural dynamism[-] †,
Demographic diversity[-] †,
Using CMC [-],
Shared understanding [+],*
Task-IT fit [+])*

† Moderated by: psychological safety [-]

Shared understanding = f(Geographical dispersion [-])
Task-IT fit = f(Appropriating IT [+])

Production efficiency

Continuing with the relationships illustrated in Figure 3, we found no evidence linking design characteristics or emergent states to production efficiency. We did, however, find evidence of the effect of one emergent process: *using CMC* (emergent IT process).

Emergent IT Process: Using CMC

Usage of computer mediated communications is negatively related to the efficiency of virtual teams to produce their outcomes (Andres 2002; Galegher and Kraut 1994; Straus and McGrath 1994). In general, research shows that virtual teams take more time to accomplish their tasks than do traditional teams because they rely more on computer-mediated interactions. Reliance on IT necessitates that members of virtual teams spend time and cognitive energy to both learn how to effectively use the technology and to familiarize themselves with the technology's features and functionalities (Andres 2002; Galegher and Kraut 1994; Straus and McGrath 1994). Attending to these additional demands detracts individuals' attention from their personal tasks and reduces the teams' ability to efficiently generate outcomes. Thus, empirical research suggests that:

Production efficiency = f(Using CMC [-])

Personal Development: Member Satisfaction

Figure 4 presents the nomological nets linking virtual team characteristics to members' satisfaction and learning. While there is no direct relationship between team design factors and either satisfaction or learning, we identified four emergent processes that affect member satisfaction: *active leading* and *communicating and sharing information* (both emergent interpersonal processes), *using structured processes* (emergent task process), and *using CMC* (emergent IT process).

----Insert Figure 4 about here----

Emergent Interpersonal Process: Active leading

First, the evidence indicates that active leading is positively related to virtual team members' satisfaction with the team processes (Armstrong and Cole 2002; Kayworth and Leidner 2000-01; Weisband 2002). Research suggests that this is due to active leaders being perceived as "being on top of things", thereby increasing team members' perceptions of role clarity and well-articulated responsibilities (Kayworth and Leidner 2001). Also, by proactively managing and communicating through a variety of media – with a heavy reliance on IT (Kayworth and Leidner 2001; Yoo and Alavi 2004; Sivunen and Valo 2006), team leaders engage in frequent, timely, and sustained interactions with their colleagues and ensure a continuing "virtual presence" within the group (Kayworth and Leidner 2001; Yoo and Alavi 2004).

Emergent Interpersonal Process: Communicating and sharing information

Second, the evidence indicates that communicating and sharing information effectively and in a timely manner within virtual teams lead to higher process satisfaction (Andres 2006; Jarvenpaa et al. 2004; Piccoli et al. 2004; Smith and Vanacek 1990; Warkentin et al. 1997). Communicating and sharing information ensures that the informational dependencies existing between members are adequately addressed and that the task-related information that is required to accomplish the team task is accessed and utilized (Warkentin et al. 1997). Accurate, timely, and high quality informational exchanges help team members resolve the information processing needs that are driven by their tasks, which results into an increased satisfaction of members towards the overall collaborative process.

However, the link between communication and information sharing and process satisfaction can be better understood by taking into account the level of *trust* in a given team. Jarvenpaa et al. (2004) found that communication frequency is positively related to member satisfaction but only when the level of trust in virtual teams is low. In contrast, communication level is negatively associated with member satisfaction when trust is high within the virtual team. The authors suggest that within high trusting virtual teams, high communication level might cause a member to become suspicious that others are monitoring him/her, therefore detrimentally affecting his/her satisfaction. Conversely, in a low trust situation, frequent communication is useful to provide constant confirmation that teammates are contributing to the task, thus acting as a formal control mechanism. As indicated in the section on output quality, communicating and sharing information is part of causal path and is affected negatively by *geographical dispersion* (Chidambaram and Jones 1993; Cramton 2001; Cramton and Webber 2005; Kayworth and Leidner 2000; Postmes et al. 2002; Smith and Vanacek 1990; Thompson and Coovert 2003; Warkentin et al. 1997), and *using CMC* (Cramton 2001; Hightower and Sayeed 1996; Smith and

Vanecek 1990; Straus and McGrath 1994; Thompson and Coovert 2002, 2003; Warkentin et al. 1997; Wilson et al. 2006).

Emergent Task Process: Using structured processes

Third, there is a positive relationship between using structured processes and member satisfaction (Kaiser et al. 2000; Tan et al. 2000; Walther and Bunz 2005). For instance, dialogue techniques for structuring communication incidents between virtual team members (Huang et al. 2002) and the reliance on relational development training (Beranek and Martz 2005) are positively related to members' satisfaction. However, one study found that behavioral control was negatively related to member satisfaction (Piccoli et al. 2004). In a comparison of self-managed teams with teams relying on formal behavioral control procedures (completing weekly reports about the project planning, work assignments, and progress reporting), Piccoli et al. (2004) found that individuals were more satisfied in the self-managed teams than in those under the behavioral control procedure. They suggest that behavior control mechanisms created pressure on the team to meet and complete the required reports. This pressure, in turn, created a situation where rigid expectations for work commitment and contributions were broken, leading to decreased satisfaction with the team experience. In contrast, team self-direction provided enough flexibility for team members to adapt to task requirements, resulting in a satisfying experience. Therefore, when looking at the effect of structured processes and behavioral control strategies, it appears important to consider the level of rigidity of such strategies (Im et al. 2006). Pre-planned and externally-imposed work structures inhibit flexibility and adaptation, resulting in friction and tension among interdependent individuals. Therefore, the empirical evidence suggests that:

Emergent IT Process: Using CMC

Fourth, and finally, studies found that using computer mediated communication negatively influences members' satisfaction with team process (Cass et al. 1992; Hollingshead et al. 1993; Thompson and Coovert 2002; Thompson and Coovert 2003). Lower satisfaction in virtual teams was primarily due to two factors: the cognitive costs incurred by members of virtual teams to learn how to use the technology and the reduced social cues available in the computer-mediated environment (Hollingshead et al. 1993; Thompson and Coovert 2002; Thompson and Coovert 2003).

<u>Summary</u>

Thus, emergent team processes seem to directly influence member satisfaction, but there is no evidence linking it to either design characteristics or emergent states.

Member satisfaction = f(Active leading [+],
Communicating and sharing information [+]†,*
Using structured processes [+],
Using CMC [-])

Communicating and sharing information = f(Using CMC [-],
Geographic dispersion [-])

†Moderation effect of: Trust [-]

Personal Development: Individual learning

Continuing with the relationships illustrated in Figure 4, while there is no evidence linking design characteristics or emergent processes to individual learning, the evidence suggests that *task--IT fit* (emergent IT state) positively affects individual learning in virtual teams.

Emergent IT State: Task-IT fit

Task-IT fit has a positive impact of virtual team members' level of learning and know-how acquisition. In a study of 263 individuals working in virtual teams, Majchrzak et al. (2005) found that the fit between IT support for work contextualization and perceived task nonroutineness was positively related to members' individual collaboration know-how development. More precisely, they found that under high task nonroutineness context, there is a positive relationship between IT support for contextualization and individual collaboration know-how. However, under low task non-routineness context, partial IT support for contextualization was detrimental for collaboration know-how development. Under high task nonroutineness context, opportunities for misunderstanding are high and individuals benefit more from IT-enabled contextualization. However, a greater level of IT-enabled contextualization generates misunderstanding under routine task conditions, thereby detrimentally affecting individual know-how development (Majchrzak et al. 2005).

As noted in the previous sections, task-IT fit is part of a causal path in which it is positively influenced by the degree of *appropriation of IT* by team members, an emergent IT process (Majchrzak et al. 2000; Malhotra et al. 2001; Orlikowski and Yates 1994).

Individual learning = f(Task-IT fit [+])*

Task-IT fit = f(Appropriating IT [+])

Discussion

During the past fifteen years, scholars have generated a substantial body of knowledge regarding the impacts of various design factors of virtual teams (e.g., members' geographical and temporal dispersion, computer-mediation, task characteristics) on team performance. This paper provides insights into the impact of these factors by integrating emergent team processes and states into the analysis of determinants of virtual team performance. This approach provides a better understanding of the synergistic, complementary, and sometimes opposing effects of different emergent and non-emergent factors. The model also allows the identification of nomological nets linking different virtual team design, process, and state factors to performance.

Our analysis identified significant empirical evidence for five main performance outcomes, namely, output quality (productivity), creativity and innovation (productivity), production efficiency (productivity), member satisfaction (personal development), and individual learning (personal development). *Output quality* is positively affected by exertion of active leadership, effectively managing work interdependencies and expertise, using structured processes, effectively communicating and sharing information (which is negatively affected by usage of computer mediation and group geographical dispersion). Output quality is also positively influenced by shared understanding of the task (which is negatively affected by geographical dispersion), shared norms of IT use, and by task-IT fit (which is positively influenced by the appropriation and adaptation of IT by team members). In addition, output quality is positively affected by the efficacy beliefs of the team members, by the level of trust in the team (which is positively affected by communicating socio-emotional information, using structured processes, and communicating and sharing information, and negatively affected by the presence of subgroups), and by the cohesion of the group and the existence of interpersonal relationships among team members (which is positively affected by usage of structured process and negatively affected by computer mediation and subgroups). Finally, output quality is negatively affected by conflicts (which are reduced by proactive conflict management, effective communication and information sharing, but increased by the geographical dispersion and the presence of subgroups).

While less research has been conducted on the antecedents of *creativity and innovation*, we identified six key drivers. Creativity and innovation is positively influenced by shared understanding among team members (which is negatively impacted by geographical dispersion) and by task—IT fit (which is influenced by IT appropriation and adaption). Creativity and innovation is negatively affected by geographical dispersion, the structural dynamism of the team, demographic diversity, and usage of computer-mediated communications.

Surprisingly, *production efficiency* has received little research attention. The evidence indicates that it is negatively affected by usage of computer-mediated communications. However, we find no other empirical evidence of it antecedents.

Satisfaction of team members with the process is driven by four factors. It is positively influenced by exertion of active leadership, effective communication and information sharing (which is negatively influenced by usage of computer mediation and by geographical and temporal dispersion), and by usage of structured processes. The evidence also suggests that satisfaction is negatively affected by usage of computer mediation.

Finally, while research on *individual learning* is limited, the evidence suggests that it is directly positively influenced by task-IT fit, which, as indicated above, is turn positively influenced by the appropriation of IT by team members.

Benefits of Differentiating Emergent Team Processes and States and Disaggregating Performance

Recognizing the importance of emergent factors in virtual teams and distinguishing among emergent processes, emergent states, and design factors offer theoretical and analytical precision that allows a more complete understanding of the nomological nets related to performance. Design factors provide the initial team set up, which act as inhibitors and/or facilitators for processes and states to emerge. They provide the configurational constraints and opportunities within which virtual team begin to work. Emergent processes are behaviors and actions that team members perform during the execution of their tasks. Emergent states are affects and cognitive factors of team members about the task, team members, and IT usage.

The empirical evidence reviewed provides support for distinguishing these factors because they are influenced differently by design factors and they have different performance impacts. For instance, the evidence suggests that design factors that negatively impacts virtual team performance operate through emergent states to a greater extent than they do through emergent processes. Team design factors (computer mediation, geographical dispersion, and presence of subgroups) affect only one emergent process (communicating and sharing information), but three emergent states (conflict, cohesion and interpersonal relationship, and shared understanding). Although this observation is bounded by the available empirical findings at the time to write the paper, it suggests that virtual team factors may have a greater effect on the development and maintenance of desirable interpersonal, IT, and task-related emergent states than on team processes.

In addition, disaggregating and unpacking virtual team performance by separately considering three primary dimensions (productivity, viability, and personal development) and integrating the dimensions into a single model facilitate comparison across studies and allows a fine grained analysis of the evidence and of the nomological nets linking virtual team outcomes to antecedents.

Contributions and Future Research

The paper makes four contributions to research and practice. For research, the paper provides an integrative model that helps to identify the key elements of virtual team performance and understand how they relate to each other. The model can thus serve as the theoretical foundations of future research. Second, the paper helps scholars to situate and integrate the extant virtual team research as well as identify future research gaps and opportunities. Third, the paper helps recognize the prevalence and importance of mediation and moderation roles of team processes and states and explain the differences between, and the interrelationships among different types of virtual team performance.

For practice, the paper provides managers with an integrated and differentiated view of virtual team performance that can help them identify the key direct and indirect drivers of different types of performance. This can provide managers with insights as to what actions they can take to stimulate the outcomes they wish their virtual team to achieve. In particular, our review suggests that the initial design and set up of virtual teams can trigger the emergence of different processes and states, which can affect performance. Managers need to be cognizant of the implications of the decisions they make when forming teams and how they can adequately manage them throughout teams' lifecycles. For instance, our review shows that members' geographical dispersion has a direct negative effect on the creativity and innovation of virtual teams and a negative indirect effect through a reduction of shared understanding. The negative direct effect can be reduced by fostering a communication climate in which members feel safe to share information and expertise. Geographical dispersion also negatively affects output quality and members' satisfaction by reducing shared understanding, the effectiveness of communication, and the sharing of information and by increasing conflicts. Managers can work directly on the emergent states and processes to reduce the negative effects of geographical dispersion (e.g., proactively managing conflicts, implementing strategies to facilitate information sharing, facilitating shared understanding of the task to be accomplish). Managers should try to balance the advantages gained by accessing people and unique expertise that are geographically dispersed with the process losses that dispersion creates in virtual teams. Our review also indicates that as best they can, managers should work to alleviate the effects of geographically-defined subgroups as they reduce trust and group cohesion, while increasing conflict – all of which reduce output quality.

Our review also has important implications regarding the role and impact of using IT in virtual teams. Computer mediation negatively affects production efficiency, creativity and innovation, and member satisfaction, and indirectly affects output quality through a reduction of shared understanding and group cohesion. The negative effect of computer mediation can be partially offset (for creativity and innovation and member satisfaction) by increasing trust and providing a communication climate in which members feel safe to share information and knowledge. Managers can also insure that norms of IT use are shared by team members and that IT is mindfully appropriated by the team, which increase output quality, individual learning, and creativity and innovation.

Future Research

Our review identified six avenues for future research. First, surprisingly, the role and impact of IT in virtual teams remains relatively understudied. The net effect of IT in virtual teams seems to result in two opposing impacts. On one hand, the evidence indicates that computer mediation negatively affects creativity and innovation, output quality, and satisfaction because it hinders communication and information sharing and it also negatively affects satisfaction and output quality by reducing group cohesion. On the other hand, IT appropriation and adaption leads to a better IT--task fit, which increases output quality and creativity and innovation. Shared understanding of IT use positively influences output quality. More research is needed to better conceptualize the IT artifact and understand how different types of technology (e.g., synchronous vs. asynchronous, individual vs. group, supporting the task vs. supporting team processes) affect key processes, states, and performance types. More research is also needed to develop a better understanding of the process through which groups appropriate technology. We also need to better understand how other IT-related emergent and non-emergent factors affect performance and to better understand the complete nomological net linking IT factors to performance. For example, task--IT fit is likely to affect task-related processes (i.e., work and expertise coordination, communication and information sharing, and structured processes) as well as some state factors such as conflict and shared understanding. Finally, more research is needed to identify the antecedents of key IT-related factors that have been found to affect performance, such as shared understanding of IT use.

Second, the results regarding the effects and antecedents of trust is both interesting and intriguing. We seemed to have spent significant efforts to understand the antecedents and drivers of trust in virtual teams. However, the evidence on the impacts of trust on different types of performance of virtual team is relatively limited both in quantity and in scope. The focus has mainly been on studying the effects of trust on output quality in virtual teams, but there is relatively limited research on how trust might affect creativity and innovation, production efficiency, member satisfaction, and individual learning. Given its potential importance for virtual team performance, our review thus suggests that greater research efforts be directed toward understanding the impact that trust has on virtual team performance.

Third, based on the literature on traditional teams (Hackman 1987, 1990; Guzzo and Dickson 1996; Cohen and Bailey 1997), we identified several types of performance measures and argued that virtual team performance needs to be differentiated. Our findings provide support for the differentiated view of performance and also indicate that research is unbalanced across types of performance. Research is heavily weighted toward team productivity, within which efforts have been focused on output quality, with comparatively few studies of creativity or innovation and production efficiency. The limited research other performance dimensions such as organizational alignment (i.e., the extent to which outputs produced fit organizational needs and goals) limits our ability to address additional questions such as whether the design of virtual teams makes them more likely to veer from project goals or not. More research is needed to study the effect of process factors on output quantity, efficiency, and organizational alignment.

Fourth, there is also limited research on team viability (i.e., the degree to which carrying out work enhances a team's ability to continue working together in the future), which is an important construct to better understand the long viability of virtual teams and potentially how working in virtual teams might affect members' willingness to work in traditional teams in the future. More research is needed on this topic. For instance, interpersonal states like conflict or cohesion are likely to affect team viability through the creation of mutual antagonism or bonding respectively. Also, more research is needed to study whether increased reliance on mediating technologies creates persistent tensions, thereby inhibiting members' ability to work together in the future.

Fifth, our understanding of the effects of working in virtual teams on learning and personal development remains limited. One key understudied area involves the links between interpersonal, task, or IT-related factors and individual learning within virtual teams. More research is needed to determine whether members of virtual team learn as do those in collocated teams; what forms of learning occurs (incidental versus intentional learning); and how learning is distributed among members. Beyond individual learning, future work might also examine the ability of the virtual teams to fulfill other personal needs like those for safety, control, relatedness, autonomy, and affiliation. There is also a need for research on the impacts of IT (either processes or states) on personal development outcomes (e.g., how IT affects social processes and individual achievement of personal needs).

Finally, we focus on the effects of design, states, and processes factors on different types of performance. Another way to analyze the empirical evidence could be to focus on the other dimension we highlight in this paper, that is, analyzing how IT, task, and interpersonal factors interact together and affect performance. Foregrounding these factors might provide additional and complementary insights as to how virtual teams work and what factors drive performance.

Conclusion

The integrative framework presented in this paper and the synthesis of the extant literature help us better understand how and why design characteristics, emergent processes, and emergent states influence the performance of virtual teams. This knowledge can help managers to identify which factors influence particular aspects of virtual team performance and as such provides them better levers to manage those teams. By clarifying the role of emergent processes and states, the paper may also help managers understand the importance of initial team configuration decisions as well as on-going proactive management of different issues such as conflict and communication and coordination of work. At the same time, through this analysis, we have expanded our theoretical understanding of distributed teamwork, complementing prior frameworks of virtual team effectiveness (Martins et al. 2004; Maznevski and Chudoba 2000; Powell et al. 2004; Pinsonneault and Caya 2005). We highlight a number of domains that are understudied and where more research is warranted. Broadly, this review suggests that a differentiated and integrative approach to the study virtual team dynamics and performance provides insights into this complex and multi-facetted phenomenon. As such, our paper clarifies several issues associated with virtual team performance. It also identifies unexplored research avenues and raises new questions. We believe this framework will stimulate and help orient future research on the virtual teams.

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Tables and Figures

Figure 1. Model of Virtual Teams

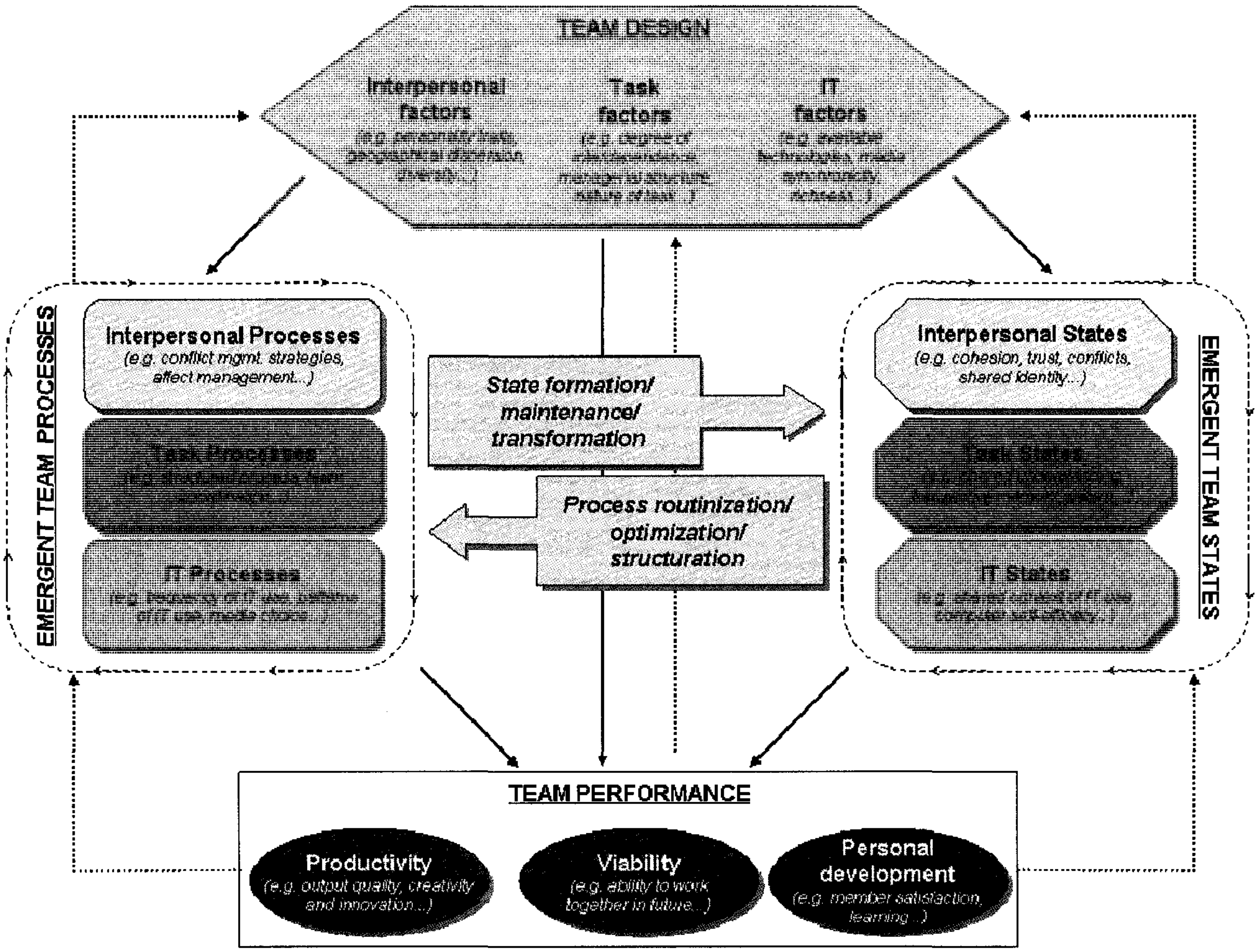


Figure 2. Productivity (1/2): Antecedents of Output Quality

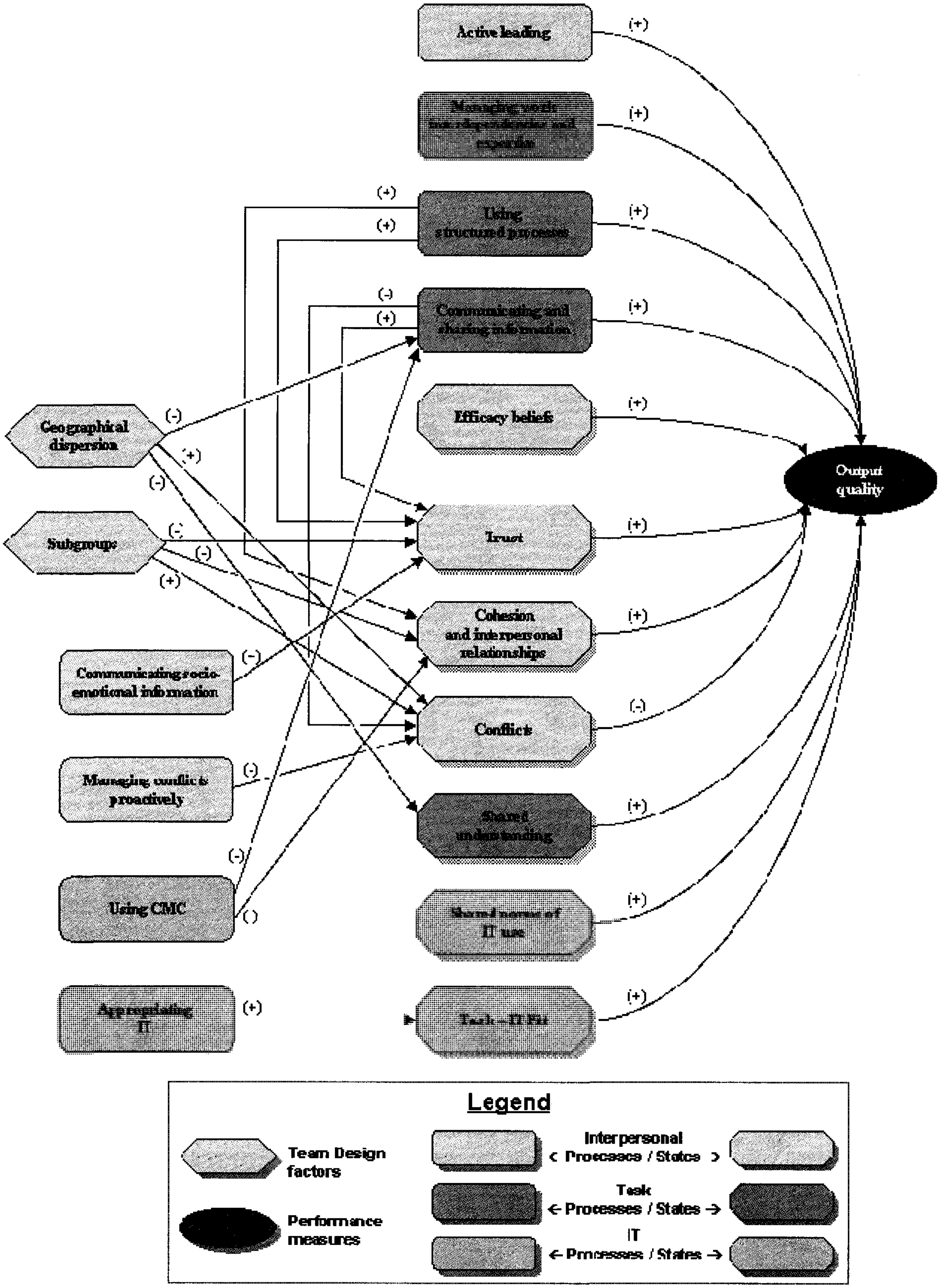
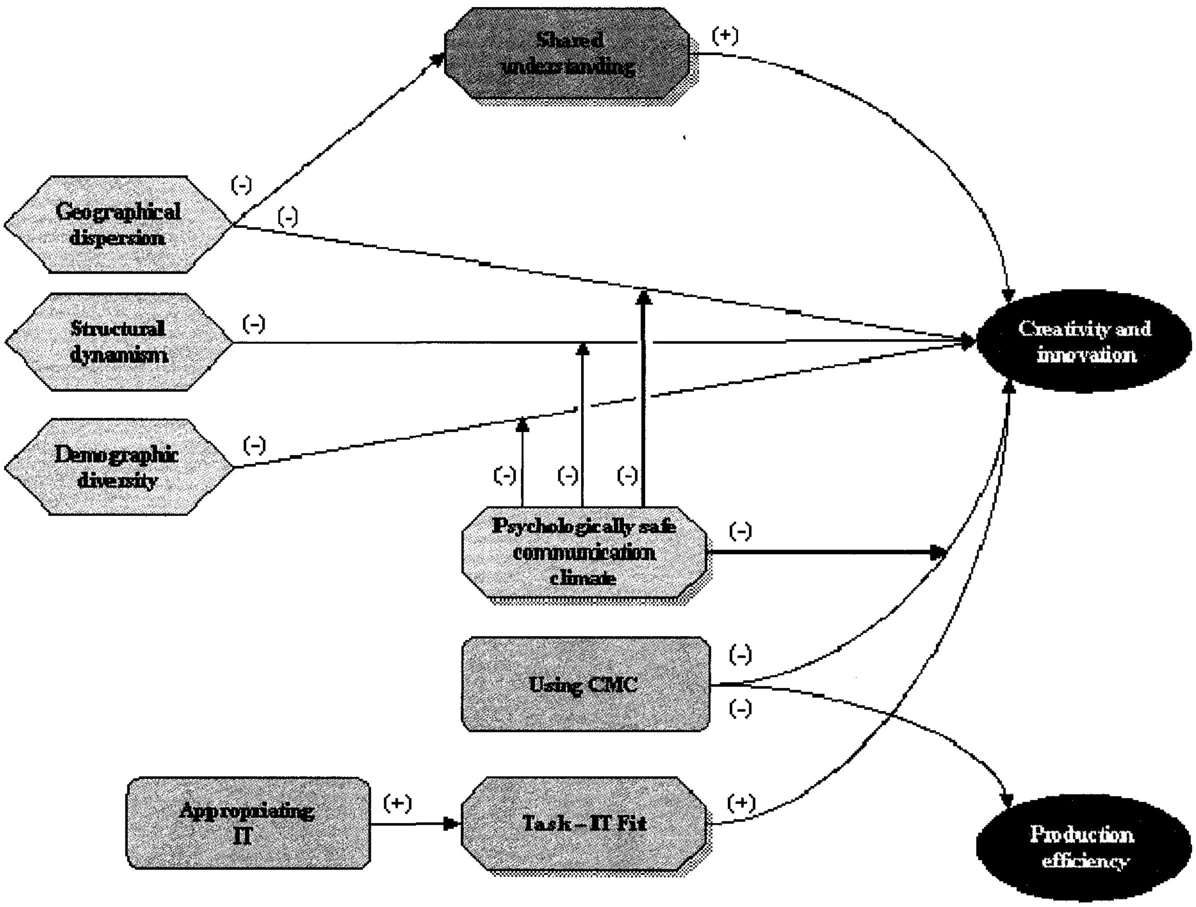


Figure 3. Productivity (2/2): Antecedents of Creativity and Innovation, and Production Efficiency



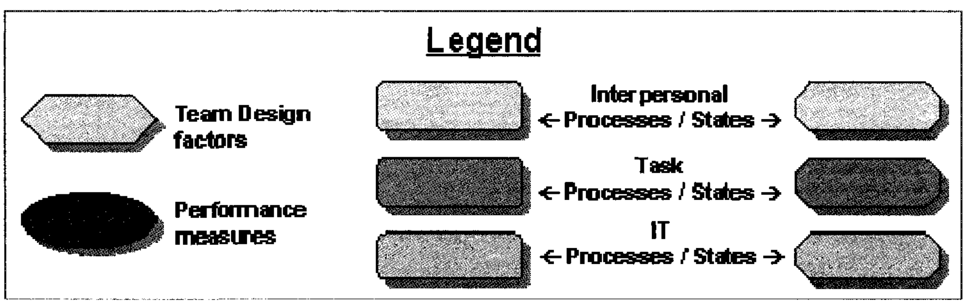
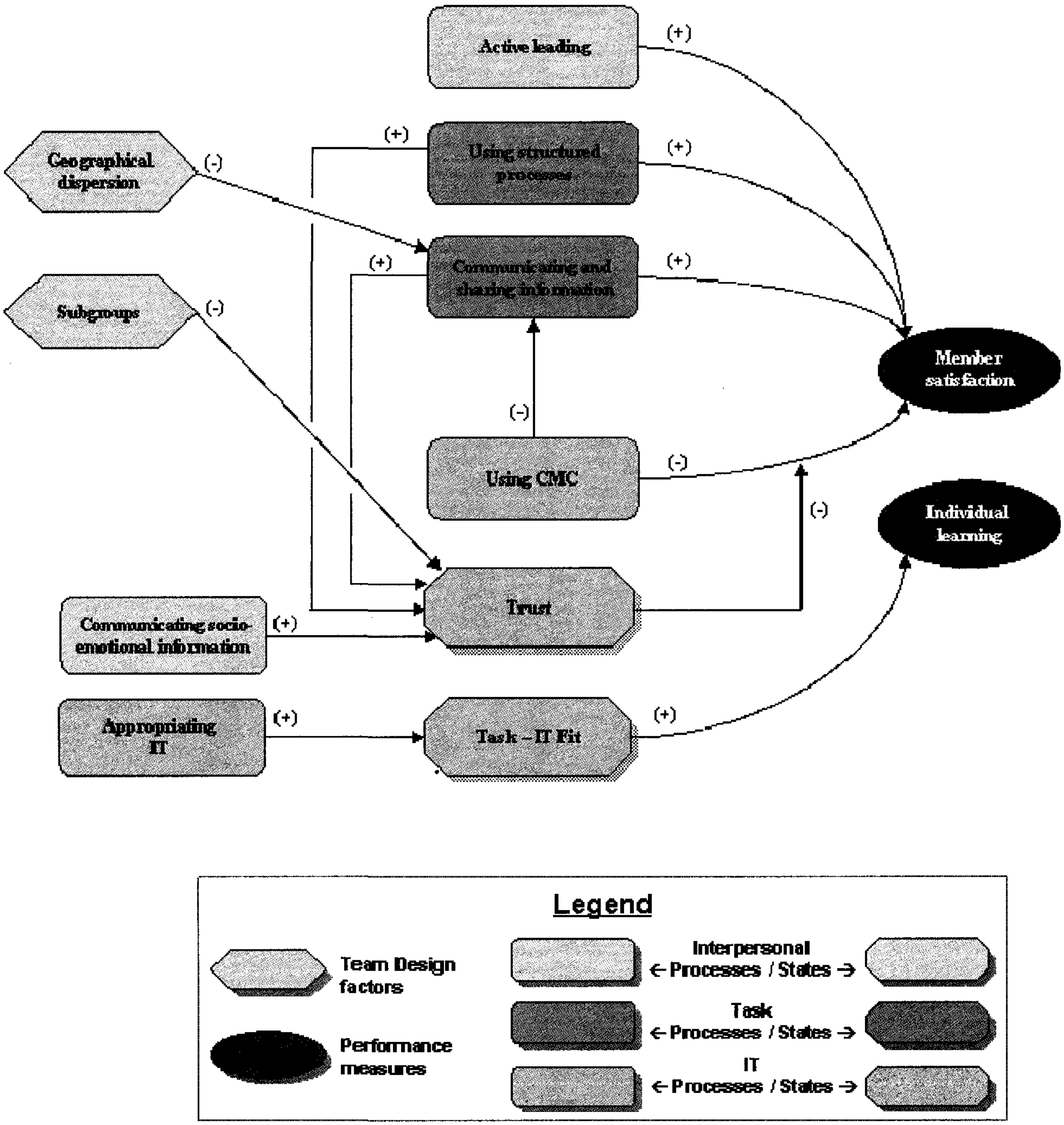


Figure 4. Personal Development: Antecedents of Member Satisfaction and Individual Learning



Appendix 1- List of Articles

Author(s)	Year	Academic journal
1- Smith and Vanacek	1990	Journal of MIS
2- Gallupe and McKeen	1990	Information and Management
3- Cass et al.	1992	Information and Management
4- Walther and Burgoon	1992	Human Communication Research
5- Turoff et al.	1993	MIS Quarterly
6- Hollingshead et al.	1993	Small Group Research
7- Zack	1993	Information Systems Research
8- O'Connor et al.	1993	Small Group Research
9- Chidambaram and Jones	1993	MIS Quarterly
10- Orlikowski and Yates	1994	Administrative Science Quarterly
11- Galegher and Kraut	1994	Information Systems Research
12- Straus and McGrath	1994	Journal of Applied Psychology
13- Walther	1995	Organization Science
14- Zack and McKenney	1995	Organization Science
15- Ocker et al.	1995-96	Journal of MIS
16- Chidambaram	1996	MIS Quarterly
17- Hightower and Sayeed	1996	Information Systems Research
18- Aiken and Vanjani	1997	Information and Management
19- Walther	1997	Human Communication Research
20- Warkentin et al.	1997	Decision Sciences
21- Burke and Aytes	1998	HICCS
22- Jarvenpaa et al.	1998	Journal of MIS
23- Dennis and Kinney	1998	Information Systems Research
24- Ocker et al.	1998	Journal of MIS
25- Warkentin and Beranek	1999	Information Systems Journal
26- Weisband and Atwater	1999	Journal of Applied Psychology
27- Moon	1999	Journal of Experimental Psychology: Applied
28- Jarvenpaa and Leidner	1999	Organization Science
29- Burke and Chidambaram	1999	MIS Quarterly
30- Lind	1999	IEEE Transaction on Professional Communication
31- Kayworth and Leidner	2000	European Management Journal
32- Tan et al.	2000	IEEE Transaction on Professional Communication
33- Robey and Khoo	2000	IEEE Transaction on Professional Communication
34- Majchrzak et al.	2000	Information Resources Management Journal
35- Majchrzak et al.	2000	MIS Quarterly
36- Maznevski and Chudoba	2000	Organization Science
37- Sole and Applegate	2001	ICIS proceedings
38- Yoo and Kanawattanachai	2001	International Journal of Organizational Analysis
39- Schmidt et al.	2001	Decision Sciences
40- Montoya-Weiss et al.	2001	Academy of Management Journal
41- Mortensen and Hinds	2001	International Journal of Conflict

		Management
42- Malhotra et al.	2001	MIS Quarterly
43- McDonough III et al.	2001	Journal of Product Innovation Management
44- Lurey and Raisinghani	2001	Information and Management
45- Cramton	2001	Organization Science
46- Kayworth and Leidner	2001	Journal of MIS
47- Andres	2002	Team Performance Management
48- Baker	2002	Information Resources Management Journal
49- Morris et al.	2002	Information Resources Management Journal
50- Huang et al.	2002	Decision Support Systems
51- Burgoon et al.	2002	Journal of Communication
52- Kanawattanachai and Youngjin	2002	Journal of Strategic Information Systems
53- Douglas and McGarthy	2002	Group Dynamics: Theory, Research, and Practice
54- Postmes et al.	2002	Group Dynamics: Theory, Research, and Practice
55 Thompson and Coovert	2002	Group Dynamics: Theory, Research, and Practice
56- Colquitt et al.	2002	Journal of Applied Psychology
57- Sole and Edmonson	2002	British Journal of Management
58- Mortensen and Hinds	2002	Distributed Work
59- Ahuja et al.	2003	Management Science
60- Ahuja and Galvin	2003	Journal of Management
61- Massey et al.	2003	Journal of MIS
62- Piccoli and Ives	2003	MIS Quarterly
63- Thompson and Coovert	2003	Group Dynamics: Theory, Research, and Practice
64- Sarker and Sahay	2003	Journal of the Association for Information Systems
65- Aubert and Kelsey	2003	Small Group Research
66- Pauleen	2003-04	Journal of MIS
67- Zolin et al.	2004	Information and Organization
68- Paul et al.	2004	Journal of MIS
69- Panteli	2004	Information and Organization
70- Balthazard et al.	2004	DATA BASE for Advances in Information Systems
71- Yoo and Alavi	2004	Information and Organization
72- Jarvenpaa et al.	2004	Information Systems Research
73- Kirkman et al.	2004	Academy of Management Journal
74- Majchrzak and Malhotra	2004	Journal of Knowledge Management
75- Piccoli et al.	2004	Information Technology & People
76- Breu and Hemingway	2004	Journal of Information Technology
77- Baba et al.	2004	Journal of Organizational Behavior
78- Hinds and Mortensen	2005	Organization Science
79- Majchrzak et al.	2005	Information Systems Research
80- Walther	2005	Journal of Communication
81- Im et al.	2005	Information Technology & People
82- Sarker et al.	2005	IEEE Transactions on Professional Communication

83- Cramton and Webber	2005	Journal of Business Research
84- Panteli and Davison	2005	IEEE Transactions on Professional Communication
85- Beranek and Martz	2005	Team Performance Management
86- Chudoba et al.	2005	Information Systems Journal
87- Wilson et al.	2006	Organizational Behavior and Human Decision Processes
88- Sivunen and Valo	2006	IEEE Transactions on Professional Communication
89- Anawati and Craig	2006	IEEE Transactions on Professional Communication
90- Sivunen	2006	Group Decision and Negotiation
91- Hardin et al.	2006	Small Group Research
92- Polzer et al.	2006	Academy of Management Journal
93- Haas	2006	Organization Science
94- Gibson and Gibbs	2006	Administrative Science Quarterly
95- Krebs et al.	2006	Small Group Research
96- Andres	2006	Information Resources Management Journal
97- Staples and Zhao	2006	Group Decision and Negotiation
98- Belanger and Watson-Manheim	2006	Group Decision and Negotiation
99- DeLuca and Valacich	2006	Information Technology & People
100- Kirkman et al.	2006	Journal of Applied Psychology
101- Lee et al.	2006	Communications of the ACM
102- Lee-Kelley	2006	International Journal of Project Management
103- Metiu	2006	Organization Science
104- Nandhakumar and Baskerville	2006	Information Technology & People
105- Powell et al.	2006	Information Technology & People
106- Fuller et al.	2006-07	Journal of MIS
107- Kankanhalli et al.	2006-07	Journal of MIS
108- Newell et al.	2007	Knowledge and Process Management
109- Hambley et al.	2007	International Journal of e-Collaboration
110- Hambley et al.	2007	Organizational Behavior and Human Decision Processes
111- Carte et al.	2006	Group Decision and Negotiation
112- Espinosa et al.	2007	Journal of MIS
113- Thatcher et al.	2007	Information & Management
114- Shachaf and Hara	2007	Journal of Information Science
115- Rutkowski et al.	2007	Small Group Research
116- Espinosa et al.	2007	Organization Science
117- Munkvold and Zigurs	2007	Information & Management
118- Staples and Webster	2007	Small Group Research
119- Hardin et al.	2007	Small Group Research
120- Baskerville and Nandhakumar	2007	IEEE Transactions of Professional Communication
121- Hoegl et al.	2007	Journal of Product Innovation Management
122- Kanawattanachai and Yoo	2007	MIS Quarterly

CHAPTER III (ESSAY 2): A Conceptual Framework of Knowledge Integration in Virtual Teams[6]

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ABSTRACT

Because they offer the opportunity to access and harness specialized knowledge irrespective of temporal and geographical constraints, many have suggested that virtual teams could allow distributed organizations to leverage their intellectual capital. However, the extant research indicates that the virtual context generates several challenges for the effective integration of knowledge in virtual teams. Moreover, the literature on knowledge management in virtual teams offers limited theoretical foundations for explaining how to address these challenges, and remains vague about the specific role played by information technologies in supporting knowledge work in the virtual context. This paper addresses this issue by proposing a conceptual framework of knowledge integration in virtual teams. Drawing on the knowledge-based theory and complemented with prior work on information processing, studies on coordination in work units, and the literature on shared cognition, the framework identifies three integration mechanisms enabled by information technologies and describes how the enactment on those mechanisms can influence knowledge integration effectiveness in virtual teams. The framework also outlines the role of common knowledge as a key factor leading to effective knowledge integration in virtual teams. Implications of the framework for research on virtual teams, electronic collaboration, and knowledge management in dispersed settings are discussed.

[6] This paper has been presented at the Academy of Management 2006 (Atlanta). Please do not cite without permission from the author.

Introduction

In a vast number of organizations today, specialized knowledge held by individuals represents a strategic asset, and plays a central role in the creation of business value (Argote, McEvily & Reagans, 2003; Grant, 1996a; Spender, 1996). As a consequence of globalization, corporate mergers, and inter-organizational partnerships, specialized knowledge is often spread across multiple geographical locations, thereby creating new challenges for collaborative work within and across organizations (Anand, Manz & Glick, 1998; Hansen, 1999). One particular means through which firms can leverage their knowledge asset in such context is by setting up *virtual teams* (VTs), defined as "groups of geographically and/or organizationally dispersed coworkers that are assembled using a combination of telecommunication and information technologies to accomplish an organizational task" (Townsend, DeMarie & Hendrickson, 1998: 18). Because they rely mainly on information technologies (IT) to communicate and coordinate their work (Hinds & Bailey, 2003), it is said that members of VTs can overcome the various operational constraints associated with physical and temporal dispersion and successfully perform knowledge-based projects remotely with limited face-to-face interactions (Jarvenpaa & Leidner, 1999; Malhotra et al., 2001; Maznevski & Chudoba, 2000).

Existing empirical studies, however, reveal some inconsistencies in terms of the success with which knowledge management processes can be achieved in VTs. On the one hand, some studies show that members of VTs face several communication and coordination problems that can ultimately inhibit the exchange and transfer of knowledge at the team level. Examples include failure to exchange unique knowledge (Cramton, 2001; Hightower & Sayeed, 1996; Smith & Vanacek, 1990; Sole & Edmonson, 2002; Warkentin, Sayeed & Hightower, 1997), difficulties in communicating successfully and coordinating effectively with others (Galegher & Kraut, 1994; Maznevski & Chudoba, 2000), and problems establishing mutual understanding among team members (Cramton, 2001; Sole & Edmonson, 2002). On the other hand, a series of studies by Majchrzak & colleagues (Majchrzak, Rice, Malhotra, King & Ba, 2000; Malhotra, Majchrzak, Carman & Lott, 2001; Malhotra & Majchrzak, 2004) have shown that the successful exchange, utilization, and creation of knowledge within VTs is possible, and can lead to performance levels that in some cases exceeds the standards established for collocated teams. Since a great part of the legitimacy of virtual teams lies in their potential to create bridges between distributed knowledge sources, we think it is critical to demystify the above inconsistency and devote additional efforts to identifying the key factors and mechanisms that explain how, and under which circumstances, VTs can generate value by harnessing knowledge across boundaries.

One possible explanation for the difficulty in understanding the benefits of VTs would be that the existing body of research has overlooked a critical knowledge management activity: the integration of knowledge. In fact, while the extant IS and OB research has brought significant contributions with respect to the factors that facilitate and/or inhibit the effective exchange (Cramton, 2001; Cummings 2004; Hightower & Sayeed, 1996; Majchrzak et al., 2000; Malhotra et al., 2001), transfer (Griffith, Sawyer & Neale, 2003; Sole & Edmonson, 2002), and creation of knowledge within VTs (Malhotra & Majchrzak, 2004), much less attention has been devoted to the issue of knowledge integration, which refers to *the coordinated application of virtual team* *members' specialized knowledge in the accomplishment of tasks at the team level* (Grant, 1996; Tiwana & McLean, 2005). Paradoxically, recent advances in the knowledge management literature suggest that it is the integration of specialized knowledge that most contributes to the creation of business value, and ultimately leads to the attainment and sustenance of competitive advantage (Grant, 1996a; Okhuysen & Eisenhardt, 2002; Spender, 1996). However, beyond general assertions that VTs could leverage a firm's intellectual capital across boundaries, the literature offers no comprehensive theoretical model that explains how they can do so, and remains relatively broad about the role played by IT in facilitating the integration of knowledge at the team level.

This paper addresses the above issue by proposing a conceptual framework of knowledge integration in VTs. Grounded in the knowledge-based theory (Grant, 1996a), and complemented with prior work by information processing theorists (Galbraith, 1973; March & Simon, 1958), studies on coordination in work units (Thompson, 1967; Van de Ven, Delbecq & Koenig, 1976), and the literature on shared cognition (Cannon-Bowers, Salas & Converse, 1993; Lewis, 2004; Wegner, 1987), this framework seeks to identify the main factors and mechanisms that facilitate the effective integration of specialized knowledge within VTs, and outline the role played by information technologies in supporting knowledge integration effectiveness. Therefore, we expect this paper will complement existing studies on knowledge management in VTs by describing how knowledge integration effectiveness can be achieved.

The rest of the paper is structured as follows: in the next section, the knowledge-based theory is explained and its core premises are developed; we describe how the theory is being adapted to the realm of virtual teams as we present a comprehensive framework of knowledge integration in VTs; and in the last section, implications of the study are discussed and avenues for future research are suggested.

The Knowledge-Based Theory

Overview of the theory

The knowledge-based theory originates from Robert Grant's work (1996a; 1996b) and draws upon various research domains such as the resource-based view of the firm, organizational capability literature, research on core competencies, and theories of organizational learning. At the heart of the theory is the idea that knowledge represents an organization's most strategically significant resource, and that the fundamental role of a firm is to integrate that knowledge at multiple levels (e.g., teams, work units, organization).[7] Broadly stated, knowledge integration refers to the activity of coordinating the utilization of people's specialized knowledge in organizations (Grant, 1996a). Grant's notion of knowledge integration differs from other knowledge management processes - such as knowledge creation (Nonaka & Takeuchi, 1995), knowledge transfer (Hansen, 1999; Reagans & McEvily, 2003), and knowledge sharing (Cummings, 2004) - by its emphasis on the coordinated use of specialized knowledge by organizational actors. When effective knowledge integration takes place within a given work unit, the knowledge is not merely accessed but is utilized effectively in order to foster the progression of the task at the collective level (Grant, 1996b; Tiwana & McLean, 2005). As stated by Grant (1996a), this situation is likely to enhance the

[7] Grant defines knowledge broadly, including both explicit knowledge which can be codified, and tacit knowledge which cannot (see Grant, 1996a: 377). However, because tacit knowledge is revealed through its application and explicit knowledge by communication only, Grant recognizes that the former raises more potential for sustained competitive advantage than the latter.

performance of a given work unit, and lead to the attainment and sustenance of competitive advantage.

Integration mechanisms

According to Grant (1996a; 1996b) knowledge integration effectiveness is made possible by the enactment of integration mechanisms, which represent the activities performed by organizational members to facilitate the coordinated use of knowledge at the team level. Building on prior work with respect to coordination in organizations (Thompson, 1967; Van de Ven et al., 1976), Grant (1996b) suggests four main mechanisms can be used to integrate individuals' specialized knowledge in firms. The first integration mechanism, *rules and directives*, represents the standards, protocols, and procedures that are used to regulate the interactions between individuals. Examples include the specific sets of policies, procedures, heuristics, and instructions developed through the articulation of specialists' tacit knowledge for direct application by non-specialists. The second integration mechanism is called *organizational routines*, and is defined as a "complex pattern of behavior triggered by a small number of initiating signals or choices, and functioning as recognizable unit in a relatively automatic fashion" (Grant, 1996b p. 115). As Grant (1996a) states, the essence of routines is that individuals develop organized patterns of interaction, which permit the integration of their specialized knowledge without the need for communicating that knowledge. The third integration mechanism is *sequencing*, and refers to the organization of production activities in a time-patterned sequence such that each specialist's input occurs independently through being assigned a separate time slot (Grant, 1996b). Sequencing is a relatively simple integration mechanism and, again, allows people to minimize communication. However, Grant states that sequencing may not be an appropriate mechanism for integrating knowledge when the task is complex, changing, and characterized by a high degree of interdependence. In this latter situation, a fourth integration mechanism, *problem solving and decision making groups*, appears to be a more viable option. In fact, individuals working jointly on a collective task can offer the necessary interactivity to synthesize organizational members' knowledge, build mutual understanding, and resolve ill-defined problems (Grant, 1996b).

The role of common knowledge

Another important component of the knowledge-based theory is the notion of *common knowledge*, which captures these knowledge items that are shared by organizational members, or, in other words, lie at the intersection of their knowledge sets. Different forms of common knowledge are proposed in the knowledge-based theory as being important for achieving successful knowledge integration, such as common language and vocabulary, shared literacy and familiarity with the same computer systems, commonality of specialized knowledge, shared awareness of each other's knowledge domains, shared organizational culture, shared experience, and shared behavioural norms of interaction (see Grant 1996b). According to Grant, those aspects of common knowledge allow individuals to implicitly integrate knowledge items which are *not* common between them, as outlined in the following quote:

> The benefit of knowledge integration is in meshing the different specialized knowledge of different individuals – if two people have identical knowledge there is no gain from integration – yet, if the individuals have entirely separated

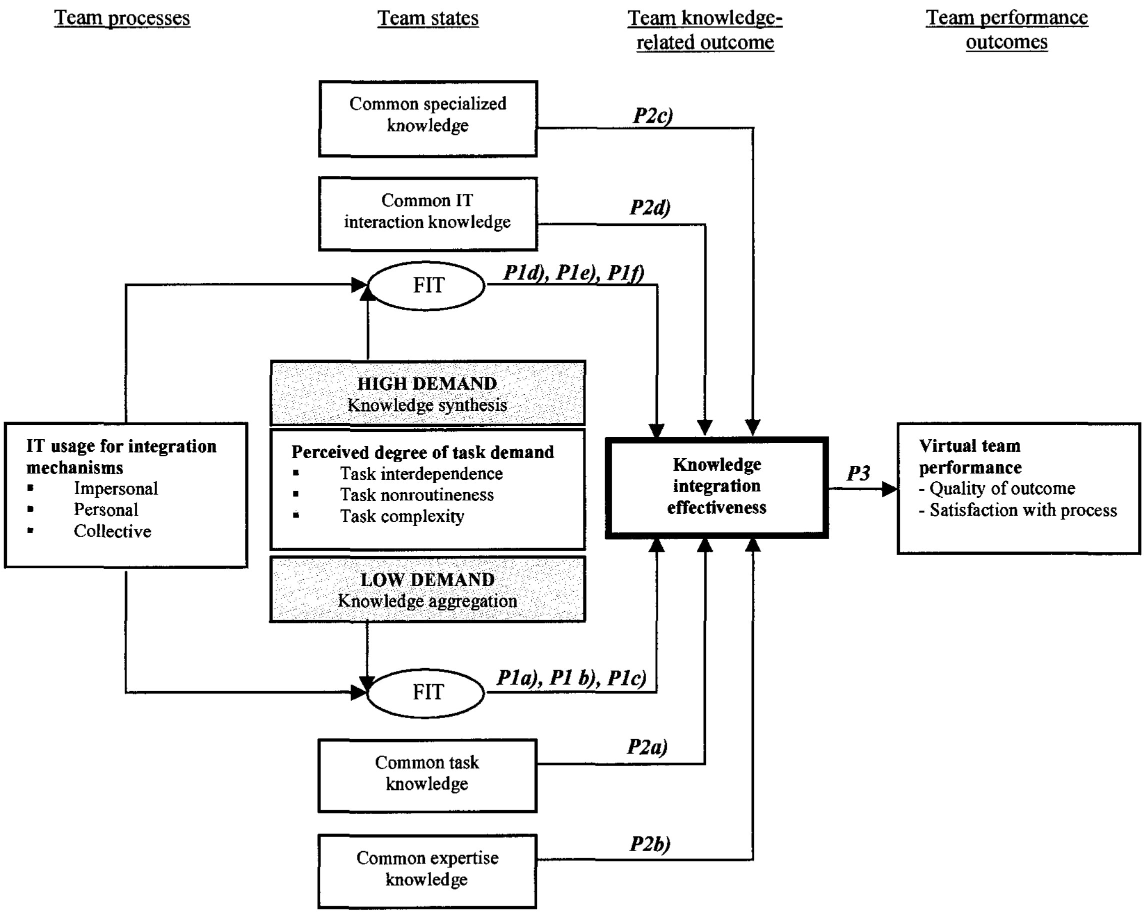
> knowledge bases, then integration cannot occur beyond the most primitive level. (Grant, 1996b: 116)

Overall, the higher the degree and sophistication of common knowledge among people, whether in the form of shared language, shared meaning, or commonality of specialized knowledge, the more successful the integration of knowledge is likely to be (Grant, 1996a).

An Conceptual Framework of Knowledge Integration in Virtual Teams

In this section, we develop a conceptual framework of knowledge integration in VTs grounded in the knowledge-based theory (Grant, 1996a), studies on information processing and coordination in work units (March & Simon, 1958; Van de Ven et al., 1976), and literature on shared cognition (Cannon-Bowers et al., 1993; Wegner, 1987). More precisely, the framework suggests that knowledge integration effectiveness in VTs is facilitated in two main ways: (1) by the "fit" between the *perceived degree of task demand* and the *usage of IT for integration mechanisms* within the team, and (2) by the development of *common knowledge* between their members. The framework also establishes a positive association between knowledge integration effectiveness and team outcomes. The key components of the framework along with the relationships that bind them together, are described next.

Figure 1. Framework of IT-Enabled Knowledge Integration in Virtual Teams



Knowledge Integration Effectiveness

In the specific context of virtual teams, knowledge integration effectiveness refers to a team's ability to successfully coordinate the utilization of their members' specialized knowledge in the accomplishment of tasks at the team level. Knowledge integration effectiveness is conceptualized as a group level phenomenon, meaning that the coordinated use of specialized knowledge is investigated at the team level. This conceptualization is consistent with the fundamental assumption of the knowledge-based theory as well as recent work on knowledge integration in work groups (Okhuysen & Eisenhardt, 2002; Tiwana & McLean, 2005), which focuses on how work capabilities (e.g. software development teams, R&D teams, product development teams, etc.) are able to harness, combine, and utilize individually-held knowledge inputs in order to generate team-level outputs.

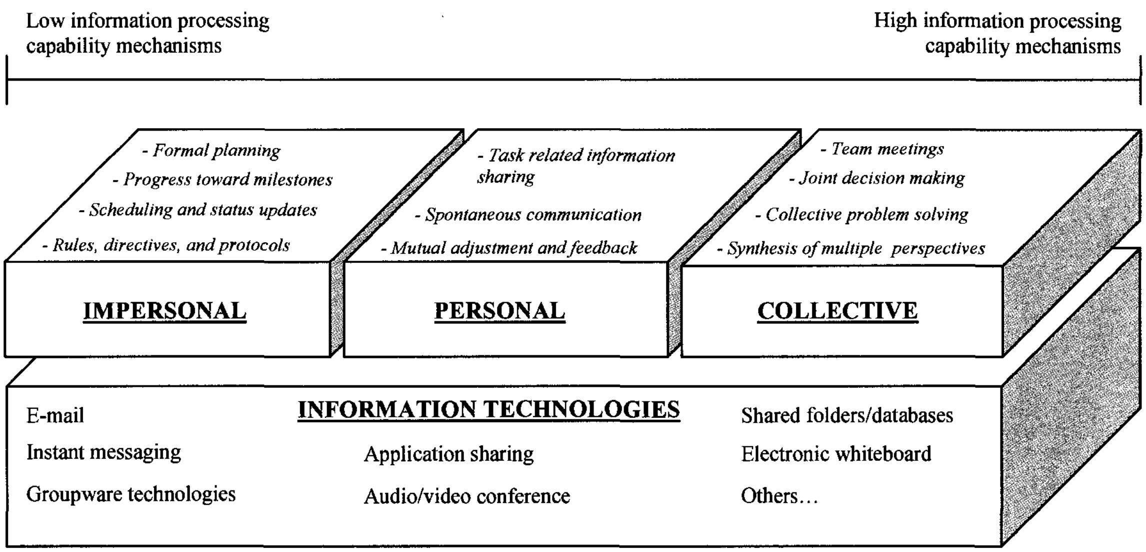
Perceived Degree of Task Demand

Prior studies on knowledge-based VTs have demonstrated that these groups can exhibit significant variability with respect to the degree of routineness, complexity, and interdependence in the tasks they perform, and that these differences can influence both the nature of knowledge integration being performed, and the effectiveness of the different strategies performed to coordinate the usage of knowledge at the team level (Malhotra & Majchrzak, 2004; Maznevski & Chudoba, 2000).[8] In the present study, *perceived degree of task demand* is used to synthesize those key characteristics of the collective task critical for the study of knowledge integration in VTs, and is defined as "the overall normal cognitive load existing within a virtual team as perceived by its members in performing their work" (adapted from Gray & Meister, 2004: 824). More precisely, perceived degree of task demand is conceptualized as a combination of three fundamental task characteristics: (1) *the degree of task interdependence*, which captures the extent to which VT members are dependent upon one another's resources and information to perform their individual jobs (Campion et al., 1993; Thompson, 1967); (2) the *degree of task non-routineness* which represents the degree of instability of the task and the variability of work processes it entails (Lawrence & Lorsch, 1967; Perrow,

[8] This observation echoes the claim made by Carlile & Rebentisch (2003), who stated that characteristics of the task - such as its degree of novelty and the amount of knowledge dependence between sources of expertise within a given work unit - are core knowledge integration challenges, and that knowledge management frameworks that fail to account for these elements are likely to be limited in terms of their inferential scope (see Carlile & Rebentisch, 2003: 1182).

1967), and *the degree of task complexity*, defined as the extent to which the collective task features many courses of action leading to multiple, possibly conflicting outcomes (Campbell, 1988). According to Gray and Meister (2004), higher levels of interdependence, non-routineness, and complexity will each increase the overall cognitive load associated with a task, which results into greater levels of perceived task demand.

Figure 2. IT Usage for Integration Mechanisms



IT Usage for Integration Mechanisms

Consistent with the knowledge-based view (Grant, 1996a), we suggest that effective integration of knowledge VTs is made possible by using IT to perform integration mechanisms, which refers to the activities accomplished by VT members to coordinate the use of their specialized knowledge at the team level. This re-conceptualization of integration mechanisms is necessary given the idiosyncratic conditions within which VT members operate, which differs from the more traditional work setting described by Grant (1996a) in his original knowledge-based theory. In fact, because they are geographically and sometimes temporally dispersed, members of VTs rely more heavily on IT to communicate and coordinate their work (Hinds & Bailey, 2003). As a result, an important portion of the activities aimed at integrating knowledge in such teams is conducted through computer-mediated communication tools (Alavi & Tiwana, 2002), which calls for the systematic incorporation of the "IT artifact" in the proposed framework. Here, three integration mechanisms are identified, namely (1) impersonal, (2) personal, and (3) collective integration mechanisms.[9] Originally proposed by Van de Ven et al. (1976) in their study on coordination in work units, these three broad mechanisms have become widely recognized in the research on the coordination within groups and work units (Gittel, 2002; Kraut & Streeter, 1995; Thompson, 1967; Van de Ven et al., 1976), and they provide a flexible yet robust framework to classify the nature of technology-supported activities performed to support the knowledge integration process in VTs. The way IT can be used to enact the three integration mechanisms is described next (see Figure 2).[10]

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[9] Although distinctions exist between the three integration mechanisms, we also maintain that they are not mutually exclusive, meaning that they can be enacted in a complementary fashion within the same virtual team.

[10] As suggested in Figure 2, no direct association is made between the type of integration mechanism and the specific information technology (e.g. electronic mail, instant messaging, application sharing, etc.) available to enact them. For example, it would be possible for virtual team members to use electronic mail systems for disseminating formal protocols - which is an example of impersonal mode of integration mechanism - or for exchanging task-related information with coworkers - which consists in the enactment of personal integration mechanism. Hence, it is not the specific technologies used to perform the mechanisms that matter most in the present framework, but rather what people actually do with the technology for enabling the coordinated utilization of knowledge at the team level.

IT Usage for Impersonal Integration Mechanism

The first IT-enabled integration mechanism is called *impersonal integration mechanism*, and refers to the usage of information technologies to enact rules and procedures, work plans, team schedules, and other formal activities aimed at coordinating the incorporation of knowledge to the collective task with limited interactions. In such instances, IT are mainly utilized to regulate the actions of team members through formal coordination behaviours (Grant, 1996a; Grant, 1996b). Examples of IT support for impersonal integration mechanism usage includes (a) obtaining information about a team's progress toward milestones, (b) setting goals, work plans, and courses of action, (c) disseminating protocols and directives that prescribe actions within the team, and (d) accessing and/or retrieving information stored in repositories of the firm's best practices for personal use by team members.[11] Using IT for impersonal integration mechanisms allows VT members to develop modularized and relatively independent patterns of work that permits the integration of specialized knowledge without the need for extensive communication (Grant, 1996a; Grant, 1996b). Overall, impersonal integration mechanism has relatively low information processing capabilities (see Figure 2), and is likely to be most effective under conditions of low task demand (Gittel, 2002; Van de Ven et al., 1976).

Information technologies can enable impersonal integration mechanisms within VTs in different ways. For example, groupware technologies that offer functionalities such as group calendars, shared agendas, task scheduling, public announcements, textboxes, and project management interfaces that captures progress toward milestones

[11] These examples represent adaptations of impersonal coordination modes traditionally proposed in the information processing literature and prior work on coordination in organizations (Daft & Lengel, 1986; Galbraith, 1973; Gittel, 2002; Thompson, 1967; Van de Ven et al., 1976).

are all good examples of IT usage for the impersonal mode of integration. In fact, these tools allow VT members to coordinate the use of knowledge by disseminating work protocols, procedures, and directives, and then to access the information anytime, from anywhere (Alavi & Leidner, 2001; Alavi & Tiwana, 2002). Another example of IT support for impersonal mechanisms is the reliance on electronic templates for creating team missions, deliverables, and meeting minutes (Malhotra & Majchrzak, 2004). These electronic documents could be exchanged via shared electronic workspaces or electronic mail, and their relatively strict, inflexible, and impersonal format is well suited for the dissemination of standardized policies and directives. Finally, another application of IT usage for impersonal integration mechanisms concerns the reliance on corporate databases and knowledge repositories within which specialized tacit knowledge has been encoded into explicit rules and directives (Alavi & Leidner, 2001; Griffith et al., 2003; Hansen & Haas, 2005). The reliance on such a pool of knowledge for obtaining standardized work procedures and guidelines remains a viable strategy for supporting knowledge integration within VTs, as it allow members to incorporate pre-existing knowledge stocks to the task at hand.

IT Usage for Personal Integration Mechanism

The second IT-enabled integration mechanism is called the *personal integration mechanism*, and refers to the usage of IT for allowing direct one-to-one vertical and horizontal informational exchanges between individuals within and outside a focal VT (adapted from Van de Ven et al., 1976). In opposition to the impersonal integration mechanism, a personal integration mechanism implies back and forth communication, spontaneous exchanges of task-related information, prompt feedback, and intensive mutual adjustments between members of VTs. Examples include the use of IT for (a) exchanging task-related information with individuals within the team, (b) working on a document or data file with another member of the team, (c) providing comments and feedback to other coworkers about aspects of their work, and (d) asking questions to someone within the team about an issue of the task that is unclear[12]. As depicted in Figure 2, a personal integration mechanism exhibits a greater level of information processing capability than the impersonal mechanism, especially because it emphasizes extensive information exchanges between individuals. According to prior studies on coordination in work groups (Andres & Zmud, 2002; Gittel, 2002; Thompson, 1967; Van de Ven et al., 1976), the value of using the personal integration mechanism increases as the task becomes more demanding.

Several information technologies can be used to perform a personal integration mechanism within VTs, starting with electronic mail systems. The prevalence of electronic mail in today's organizations makes this communication medium a viable tool for supporting the exchange of task-related information between dispersed interactants, while also facilitating mutual adjustments between individuals as they incorporate their knowledge to the collective task (Jarvenpaa, Shaw, & Staples, 2004; Malhotra & Majchrzak, 2004). Another communication medium increasingly utilized in VTs for supporting spontaneous communication are instant messaging systems, or "chat" tools. By using instant messaging, members of a VT can spontaneously ask questions to

[12] Instances of IT-enabled personal integration mechanism represent adaptations of March and Simon's (1958) concept of "feedback coordination", Thompson's (1967) notion of "mutual adjustment", Tushman & Scanlan's (1981) "boundary spanning activities", and Gittel's (2002) conceptualization of "relational coordination mode".

geographically-dispersed colleagues, share electronic files, and exchange task-related information laterally and vertically both within and outside their team (Alavi & Leidner, 2001; Malhotra & Majchrzak, 2004). Desktop videoconference applications could also be used to support lateral and horizontal interactions within VTs, as they allow individuals to engage in synchronous informational exchanges across geographical boundaries. Often coupled with application sharing tools (e.g. NetMeeting), these technologies allow interactants the possibility to simultaneously debate ideas and perspectives in a more interactive fashion.

IT Usage for Collective Integration Mechanism

The third IT-enabled integration mechanism proposed to facilitate the coordinated utilization of knowledge in VTs is called a *collective integration mechanism*, and refers to the usage of information technologies for supporting the combination and synthesis of ideas and perspectives from multiple team members. Examples include people's usage of IT for (a) discussing issues of the task with two or more members of the team, (b) pooling together opinions, ideas, and knowledge from multiple people involved in the collective project, (c) supporting team meetings, and (d) enabling joint decision making and group problem solving[13]. Through a collective mode of integration, VT members can engage in deeper clarification of key issues of the project, develop collective judgment and common frames of reference, confront perspectives and ideas with those of other people, and benefit from synergistic effects of knowledge combination. Overall, usage of IT for

[13] The collective integration mechanism is similar to the notion of group mode of coordination advanced by information processing theorists (Daft & Lengel, 1986; Van de Ven et al., 1976; Gittel, 2002). However, because synchronous collaborative work may not always be possible within virtual teams due to members' temporal dispersion, our conceptualization of IT-enabled collective integration mechanisms is broader, and includes both synchronous and asynchronous group informational exchanges.

collective integration mechanism offers high information processing capabilities (see Figure 2), and is expected to be most helpful under conditions of high task demand.

Within VTs, information technologies can enable a collective integration mechanism in different ways. For example, shared electronic workspaces that allow members of VTs to engage in synchronous and asynchronous multi-channel informational exchanges are good illustrations of IT usage for collective integration mechanism usage (Alavi & Tiwana, 2002; Malhotra & Majchrzak, 2004). According to Majchrzak et al. (2005), shared electronic workspaces for synchronous communication enable intensive back-and-forth interaction, clarification of ambiguous aspects of the collective task, and discussion amongst all team members. Other useful knowledge management systems for enabling collective integration mechanisms include tools for easy and rapid development of prototypes that can be viewed, manipulated, modified in real-time by all the team members, and saved for future use and reference (Alavi & Tiwana, 2002). Audio-conference sessions combined with electronic whiteboard systems and synchronous application sharing also represent a form of collective IT-enabled integration mechanism available for members of VTs (Malhotra et al., 2001; Malhotra & Majchrzak, 2004). Finally, discussion groups and other team repositories that allow people to comment on their teammates' contributions are also technological tools enabling the collective integration mechanism (Alavi & Leidner, 2002; Malhotra et al., 2001). By offering members of VTs the possibility to look at and synthesize comments and perspectives provided by others, these information technologies provide the team with greater information processing capabilities, and an increased opportunity to combine knowledge sources at the team level.

Table 1. Knowledge Integration under High and Low Task Demand Conditions

	Low task demand	**High task demand**
Degree of task interdependence	Few interdependencies between knowledge sources within the focal virtual team.	Many interdependencies between knowledge sources within the focal virtual team.
Degree of task non-routineness	The problem is already well defined, and causal linkages are evident between processes and outcomes.	The problem is ill-defined, and causal linkages are not evident between processes and outcomes.
Degree of task complexity	The work features few courses of action leading to non-conflicting outcomes.	The work features many courses of action leading to multiple and potentially conflicting outcomes.
Information processing requirements needed to achieve the task	Low information processing requirements. The task can be achieved without extensive communication between individuals because important aspects of its realization are known, and people's jobs are not tightly related.	High information processing requirements. The task requires frequent, spontaneous, and decentralized communication because the causal relationship between inputs and outputs are ill defined, and people's jobs are highly interrelated.
Implications for the process of knowledge integration	Successful knowledge integration at the team level is achieved by **aggregating** individual's specialized knowledge.	Successful knowledge integration at the team level is achieved by **synthesizing** individual's specialized knowledge.

Research propositions

As depicted in figure 1, we suggest that knowledge integration effectiveness in VTs is facilitated by the "fit" between the perceived degree of task demand and the level of IT usage for integration mechanisms. Implicit in this general assertion is that the impact of each integration mechanism on the degree of knowledge integration will depend on the extent to which the task is considered to be demanding for the virtual team[14]. This assumption is consistent with prior work by information processing theorists (Daft & Lengel, 1986; Galbraith, 1973; March & Simon, 1958) and the premises of contingency theory (Drazin & Ven de Ven, 1985; Venkatraman, 1989), which suggests

[14] This assertion answers recent call for research by Argote et al. (2003), who argued that more studies should be conducted using congruence frameworks in knowledge management research, especially for identifying the various conditions under which a specific knowledge management activity is most effectively conducted (see Argote et al., 2003: 577).

that successful work units establish a match between elements of their structure and their strategy[15]. It is also in line with the growing body of literature suggesting that the impacts of information technologies on group processes and outcomes should not be examined independent of the context in which they are used (Ngwenyama & Lee, 1997; Zack & McKenney, 1995). Because perceived task demand is conceptualized as the contingency factor in the present framework, the next paragraphs discuss how each IT-enabled integration mechanism influences knowledge integration in VTs under conditions of low and high task demand respectively.

Low task demand context

When virtual teams are operating in a low task demand context, few dependencies exist among team members, several aspects of the problem are already well-defined, and causal linkages are clear between task processes and outcomes (Gray & Meister, 2004; Van de Ven et al., 1976). Under such circumstances, knowledge can be successfully integrated at the team level through an **aggregation process**, meaning that an individual's specialized knowledge can be incorporated into the task in a relatively impersonal and additive fashion, with no need for extensive communication and feedback between knowledge owners (Grant, 1996a; Grant, 1996b; Malhotra & Majchrzak, 2004). In this scenario, the successful integration of knowledge is accomplished by clarifying the individual's roles and responsibilities within the team, and by providing them

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[15] For example, these literatures suggest that under conditions of low task interdependence and non-routineness, low information processing capacity approaches to coordination such as plans, milestones, rules, directives, status reports, and other informal integration strategies are deemed effective to manage informational requirements and dependencies within a given work unit (Andres & Zmud, 2001-02; Gittel, 2002; Kraut & Streeter, 1995; Van de Ven et al., 1976). Conversely, high information processing capacity approaches like organic, personal, and decentralized modes of communication and coordination are needed to achieve high work effectiveness when the task is highly interdependent and non-routine.

directives about how to incorporate their knowledge items into the collective task (see Table 1). Therefore, IT usage for an impersonal integration mechanism, which aims at prescribing specific directives to team members about how to apply their knowledge to the task, is likely to be effective under the condition of low task demand. For personal integration mechanisms, a minimal level of information sharing and mutual feedback might be desirable to make sure that knowledge inputs are appropriately incorporated into the collective task, but the relatively independent and routine nature of the task might limit the value of such mechanism. Finally, IT usage for collective integration mechanism is likely to be ineffective under conditions of low task demand because the high information processing capability inherent to this mechanism is not necessary to address the task's low information processing requirements. In fact, too much interpersonal exchanges and collective interactions may actually detract individuals from incorporating their own knowledge to the task, and lead the team to consider more perspectives than needed. Such a strategy would not only provide few benefits at the team level in terms of knowledge integration effectiveness, but could even create situations where task conflicts are likely to occur.

Although no study has explicitly looked at how different types of IT-enabled integration mechanisms influence knowledge integration in VTs depending on the task demand, we found some support in the literature for the contingency arguments described above. For example, in study of 54 effective knowledge-based VTs, Malhotra & Majchrzak (2004) found that teams performing routine tasks were able to share their knowledge successfully and create new collective knowledge by simply coordinating their work dependencies informally using task scheduling tools, electronic templates for team mission and work procedures, and other formal collaboration and coordination strategies. The authors also report that interactive and decentralized IT-enabled communication and coordination behaviours were not valuable in a routine context, which instead required the aggregation of individuals' expertise in an independent fashion. In keeping with the above arguments, the following propositions are advanced for virtual teams operating under the condition of <u>low task demand</u>:

Proposition 1a: *In a low task demand context, IT usage for impersonal integration mechanisms will facilitate knowledge integration effectiveness.*

Proposition 1b: *In a low task demand context, IT usage for personal integration mechanisms will facilitate knowledge integration effectiveness, but only marginally.*

Proposition 1c: *In a low task demand context, IT usage for collective integration mechanisms will inhibit knowledge integration effectiveness.*

High task demand context

When virtual teams are operating in a high task demand context, several dependencies of knowledge and informational resources exist, the problem at hand is characterized by a high degree of variability, and the work processes are ill-defined (Gray & Meister, 2004; Lewis, 2004). Under such circumstances, the mere aggregation of specialized knowledge is unlikely to lead to high degree of knowledge integration at the team level, in large part because people depend on each other for incorporating their own knowledge to the task, and sometimes have to negotiate with their coworkers about the way to do so. Instead, a more effective approach for integrating knowledge under high task demand is likely to follow a **synthesis process, (Table 1)** which implies the combination, blending, and merging of VT members' specialized knowledge, as well as intensive back-and-forth communication between them (Grant, 1996a; Grant, 1996b; Tiwana & McLean, 2005). Given the highly interdependent, complex, and non-routine nature of the task, the successful integration of knowledge at the team level necessitates greater interpersonal exchanges and cross-functional information sharing within and outside the focal virtual team (Cummings, 2004; Malhotra & Majchrzak, 2004). Therefore, the coordinated utilization of knowledge is achieved by combining specialized knowledge sources and blending people's perspectives in order to create team level outputs (see Table 1). Thus, we expect IT usage for personal and collective integration mechanisms should be most effective in a high task demand scenario given their emphasis on mutual feedback, intensive interaction, and their high information processing capabilities. However, IT usage for the impersonal integration mechanism is unlikely to provide the information processing capabilities required to successfully integrate knowledge at the team level.

Here again, evidence supports these arguments. For example, in a study of three internationally-distributed product development VTs, Maznevski & Chudoba (2000) found that in effective teams, a task with higher interdependence and/or complexity was associated with more frequent communication incidents at the team level. By comparison, the team that was identified as ineffective has been unable to match the information processing requirements derived from the highly interdependent and complex nature of the task with the appropriate interaction patterns of communication and coordination. Malhotra et al.'s (2001) case study of a VT performing a highly interdependent, complex, and non-routine task also supports the contingency perspective suggested in the present framework. In fact, the authors found that the exchange and combination of specialized knowledge amongst geographically-dispersed coworkers was greatly facilitated by the reliance on shared electronic workspaces within which individuals could post entries that were later viewed and assessed by all team members. Complemented with direct one-to-one and group interactions, this technology facilitated mutual adjustments between team members, and allowed the synthesis of multiple ideas and perspectives for creating team level outputs. Finally, in their field study of 54 effective far-flung teams, Malhotra & Majchrzak (2004) found that teams performing non-routine tasks had to use information technologies in a way to enable highly interactive exchanges between members, and had to engage in more frequent communication incidents both within and outside the team to insure the successful exchange and creation of knowledge at the team level. In keeping with the above observations, the following propositions are advanced for virtual teams operating in a <u>high task demand</u> condition:

Proposition 1d: *In a high task demand context, IT usage for impersonal integration mechanisms will inhibit knowledge integration effectiveness.*

Proposition 1e: *In a high task demand context IT usage for personal integration mechanisms will facilitate knowledge integration effectiveness.*

Proposition 1f: *In a high task demand context IT usage for collective integration mechanisms will facilitate knowledge integration effectiveness.*

Common knowledge

As discussed in the previous section, the knowledge-based theory asserts that the development of *common knowledge* within a given work unit represents a key enabler of knowledge integration effectiveness. Based on the literature on knowledge management (Anand, 1998; Cohen & Levinthal, 1990; Grant, 1996a), shared cognition (Brandon & Hollingshead, 2004; Cannon-Bowers et al., 1993; Wegner, 1987), and virtual teams (Cramton, 2001; Malhotra & Majchrzak, 2004; Orlikowski & Yates, 1994), four dimensions of common knowledge are proposed here as being critical for supporting knowledge integration effectiveness in VTs[16]: (1) common task knowledge, (2) common expertise knowledge, (3) common specialized knowledge, and (4) common IT interaction knowledge.

Common task knowledge

The first dimension of VT common knowledge is called *common task knowledge*, and refers to the degree of shared understanding existing amongst 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 the team has a homogeneous cognitive representation of the attributes of the task and the actions needed to foster its accomplishment (Brandon & Hollingshead, 2004). According to the literature on team mental models (Cannon-Bowers et al., 1993; Klimoski & Mohamed, 1994), effective team performance of knowledge-based groups requires that their members hold common and overlapping cognitive representations of the task requirements, procedures,

[16] The segregation of virtual team common knowledge into different dimensions is consistent with prior work on team mental models (Cannon-Bowers et al., 1993; Salas et al., 2000), which stipulates that individuals within knowledge-based groups can develop shared cognitive representations about different aspects of their team's structure, processes, and context.

and role responsibilities. 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 at the team level (Klimoski & Mohamed, 1994).

Thus far, few empirical studies have attempted to isolate the impacts of a shared representation of the task characteristics and processes on knowledge integration within VTs. However, there is evidence showing that failure to establish common understanding about the tasks' attributes and procedures can have detrimental effects on the way team members coordinate their utilization of knowledge at the team level. For example, Sole & Edmonson (2002) found that heterogeneous cognitive representations of the way to perform the collective task in VTs hamper the exchange of information between geographically dispersed individuals, and leads to sub-optimal usage of individuals' specialized knowledge. Similarly, Cramton (2001) found that the lack of mutual knowledge in regards to the salience of information exchanged within VTs 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 co-workers, Huang, Wei, Watson & Tan (2002) found that VT members who adopted a "goal setting structure" (i.e. a process structure mechanism designed to orient team members' efforts toward the common goal at any time during the project) exchanged information more efficiently than members of VTs who did not rely on such a process structure mechanism. Based on the previous findings, we argue that common task knowledge within VTs will play a central role in the process of knowledge integration.

Proposition 2a: *The development of common task knowledge will facilitate knowledge integration effectiveness in virtual teams.*

Common expertise knowledge

The second dimension of common knowledge, *common expertise knowledge*, represents the degree to which members of VTs have developed shared and accurate cognitive representations of each others' expertise domains within the team (Grant, 1996a). According to Grant (1996), knowledge integration effectiveness is facilitated when each individual in a work unit is aware of everyone else's domain of expertise. Without such a type of common knowledge, members of workgroups become more susceptible to engage in unproductive information seeking efforts (Brandon & Hollingshead, 2005; Wegner, 1987), and might overlook valuable knowledge sources residing within their own team (Lewis, 2004). Conversely, a high degree of common expertise knowledge improves the overall informational flow within a team (Grant, 1996a; Lewis, 2003), and allow people to perform tasks and subtasks that are commensurate to their respective domain of expertise (Brandon & Hollingshead, 2004; Lewis 2004), thereby optimizing the overall utilization of knowledge at the team level (Grant, 1996).

Thus far, studies that investigated the impact of common expertise knowledge in VTs remain relatively scarce. In a longitudinal study of 38 student teams spread across six different universities in four countries, Yoo & 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 the VT, and leads to increasing levels of team performance, a finding that has been also observed by Mortensen & Hinds (2002) in their study of 12 VTs in the field. Conceptual contributions by Alavi & Tiwana (2002) and Griffith et al. (2003) also suggest that a transactive memory system may play an important role in transforming potential team knowledge into usable knowledge at the team level. Hence, the development of common expertise knowledge should be an important aspect of VTs' shared cognitive basis, and a key ingredient of effective knowledge integration in such groups.

Proposition 2b: *The development of common expertise knowledge will facilitate knowledge integration effectiveness in virtual teams.*

Common specialized knowledge

While the shared awareness of teammates' expertise domains is posited as an important antecedent of successful knowledge integration in VT, the knowledge-based theory maintains that similarities in specialized knowledge grounds are also required in order to take full advantage of a work unit's intellectual capital. Here, we refer to such cognitive overlap as *common specialized knowledge*. Broadly stated, common specialized knowledge represents the degree of overlap in domain-specific knowledge grounds existing within VTs. Without some similarities in people's specialized knowledge, 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 & Rebentish (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 effective 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 knowledge integration effectiveness within VTs. 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 VT 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 development of common specialized knowledge within VTs is likely to be an important element of its shared cognitive repertoire, and a key antecedent of successful knowledge integration.

Proposition 2c: *The development of common specialized knowledge will facilitate knowledge integration in virtual teams.*

Common IT interaction knowledge

Because members of VTs greatly rely on information technologies to perform their collective task (Hinds & Bailey, 2003; Townsend et al., 1998), the knowledge they hold in respect to the way to use these technologies for supporting communication and coordination activities are likely to influence the extent to which they can successfully integrate their specialized knowledge across boundaries. Here, we define common IT interaction knowledge as the shared understanding existing within the virtual team about the way to use IT for supporting communication and coordination activities. In other words, it captures the extent to which members of VTs possess similar cognitive representations of the IT-enabled communication and coordination structure of the team. 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 communication patterns and socially-recognized interaction structures, information seeking and providing behaviours are more effectively conducted, which facilitates the effective utilization of specialized knowledge at the team level.

Contrary to the previous dimensions of common knowledge, common IT interaction knowledge has received much attention in research on VTs. 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 (2002) found that the effectiveness of knowledge sharing within VTs 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, Montoya-Weiss & Hung (2003) found that the reliance on temporal coordination mechanisms – an interaction process structure that helps 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 behaviours, which, in turn, lead to increasing levels of performance. Finally, Orlikowski & Yates' (1994) concepts of "genres of organizational communication" and "genres repertoire" are other examples of common IT interaction knowledge bases studied in VTs. 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 & 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 in the process of knowledge integration in VTs.

Proposition 2d: *The development of common IT interaction knowledge will facilitate knowledge integration effectiveness in virtual teams.*

Team outcomes

Finally, and consistent with the premises of the knowledge-based theory, the proposed framework establishes a positive relationship between the knowledge integration effectiveness in VTs and desirable team outcomes. More precisely, two broad work-related outcomes are expected when knowledge integration is done effectively, and that for VTs operating in either low or high task demand contexts: increased quality of outcome, and greater satisfaction with team processes. In fact, when VT members are effective at coordinating the utilization of their specialized knowledge and are able to do so in a way that is consistent with the team's objective, the quality of team outcomes issued from the knowledge integration process should be positively affected. Moreover, the successful integration of people's knowledge might also reflects into greater satisfaction toward the team process, in part because VT members are likely to develop feelings of personal pride and collective efficacy beliefs as their personal knowledge and the one of their teammate is successfully incorporated to the collective task.

Proposition 3: *Knowledge integration effectiveness in virtual teams will be positively associated with quality of outcomes and greater satisfaction with team process.*

Discussion

The present study complements the extant body of literature on knowledge management in VTs by outlining how, and under which circumstances, knowledge integration effectiveness can be facilitated in VTs. First, it offers a novel conceptualization of information technology grounded on the knowledge-based theory and the literature on coordination in work units, and describes how three IT-enabled integration mechanisms could facilitate the coordinated utilization of specialized knowledge in VTs. Second, the paper outlines four types of common knowledge bases likely to facilitate the integration of VT members' specialized knowledge at the team level, which constitute one of the few attempts to link research on virtual teams with the literature on shared cognition. Third, the proposed framework represents - at least to our knowledge- the first adaptation of the knowledge-based theory to the realm of VTs, and one of the few initiatives to theorize explicitly about the role of IT in supporting the activity of knowledge integration in such setting. Although further validation of the framework is needed at that stage, it still informs members and managers of VTs about the nature of IT support needed to facilitate knowledge integration effectiveness under different task conditions, and contribute to identify key aspects of VTs' cognitive structure that should be shared by its members.

In spite of the above contributions, this paper has some limitations that are worth reporting. First, the research propositions need to be tested empirically, and some room should be left for refinements and modifications. Performing interviews with VT members and managers would provide initial face validity to the framework, while a full scale field study of existing knowledge-based VTs will have to be conducted in order to establish its inferential potential. Second, the framework remains relatively vague about the specific technological features that are best suited for each integration mechanism. Although the framework focuses more on the type of IT usage made by VT members than the characteristics of these technologies, existing theories that look at specific media properties -such as media richness theory (Daft & Lengel, 1986) and media synchronicity theory (Dennis & Valacich, 1999)- could be used to draw further recommendations concerning the technology features that match appropriately each integration mechanism's purposes. Third, it is possible that other aspects of VTs' common knowledge might have been proposed here to fully grasp the multidimensional nature of this concept, and its influence on the knowledge integration effectiveness. Examples taken from the knowledge-based theory include shared literacy with computer systems, shared language, and shared culture. Even though we tried to identify those aspects of VTs' common knowledge that we believed were the most critical for facilitating knowledge integration effectiveness, future research should be conducted in order to identify other dimensions of common knowledge relevant for supporting knowledge work in VTs. Finally, it is also possible that the four dimensions of common knowledge identified in the framework may impact knowledge integration effectiveness differently under high vs. low task demand respectively. For example, common IT interaction knowledge and common specialized knowledge may be critical for VTs operating in a high task demand context because frequent computer-mediated communication and cross-functional information sharing are required for successful knowledge integration to happen. Conversely, common expertise knowledge and common task knowledge might be most helpful under a low task demand context, where less interaction is required and greater segmentation of the task is needed. Here again, future research should be conducted to identify the relative impact of each dimension of common knowledge on knowledge integration effectiveness under different task conditions. Despite these limitations, we are confident that this paper adds to the existing body of literature on KM in VTs, and provides new insight about how members of VTs can integrate effectively their specialized knowledge at the team level.

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CHAPTER IV (ESSAY 3): Knowledge Integration Effectiveness and Performance in Virtual Teams

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ABSTRACT

In today's global work context, organizations are increasingly turning to use of virtual teams (VTs) in order to access and harness the specialized knowledge of their employees across geographical and temporal boundaries. But the mere presence of specialized knowledge within VTs is not sufficient to guarantee their performance. In fact, VTs must find ways to ensure that the knowledge of their members will be integrated effectively at the team level in order to be successful at achieving their task and generate value for organizations. However, the phenomenon of knowledge integration in VTs lacks theoretical development and empirical coverage, and much equivocality persists in terms of the key drivers of knowledge integration effectiveness in such teams. To deal with this gap, we develop a model of information technology (IT)-enabled knowledge integration in VTs derived from Robert Grant's (1996a) knowledge-based theory and complemented by literature on the shared mental model and coordination in work units. The model is tested with 700 individuals working in 102 knowledge-based VTs and who use IT to coordinate the application of their knowledge inputs across distances. Results indicate that the impact of IT on knowledge integration effectiveness is fully mediated by the level of shared understanding developed within VTs about their collective task, the distribution of expertise, the IT-enabled communication structure of the team, and members' specialized knowledge domains. Consistent with the knowledge-based theory and studies on expertise coordination in organizational teams, knowledge integration effectiveness was positively associated with VT performance. Overall, these findings suggest that knowledge integration is a key knowledge management process for explaining the performance of VTs, and highlight the importance of taking into account the mediating factors that may explain the indirect effects of IT on VT outcomes. The paper ends by drawing theoretical and practical implications for the management of knowledge within VTs.

Introduction

Over the last 15 years, organizations have faced an increasing need to operate across distances (Jarvenpaa et al. 2005, Townsend et al. 1998). To be successful in such context, it is important that they adapt their structure and processes in order to benefit from the opportunities of the distributed work environment while effectively dealing with the challenges and risks it presents. One work configuration that offers such possibility is a virtual team (VT), defined herein as *a group of people who interact through interdependent tasks guided by common purpose, and who work across space, time, and organizational boundaries primarily through electronic means* (Majchrzak et al. 2005, Maznevski and Chudoba 2000). By creating and managing VTs, organizations can take advantage of their most skilled employees irrespective of their geographical location, and build pockets of expertise that span geographical, temporal, functional, cultural, and even organizational boundaries in order to achieve different types of tasks (Griffith et al. 2003, Malhotra and Majchrzak 2004, Sole and Edmonson 2002, Townsend et al. 1998). Over the last 10 years, field studies in the information systems (IS) and organizational behaviour (OB) disciplines have indeed shown that firms increasingly rely on VTs to perform various organizational tasks such as new product and software development (Malhotra and Majchrzak 2004, Sole and Edmonson 2002), business process re-engineering (Cummings 2004), research and development (Hinds and Mortensen 2005), consulting work (Majchrzak et al. 2005), and others.

One of the primary reasons explaining this interest in VTs resides in their potential for integrating knowledge across boundaries (Alavi and Tiwana 2002, Cummings 2004, Haas 2006, Malhotra and Majchrzak 2004). More precisely, the integration of knowledge refers to the process of coordinating the usage of individuals' specialized knowledge in organizations, work units, and teams (Grant 1996a, Grant 1996b, Okhuysen and Eisenhardt 2002, Spender 1996, Tiwana and MacLean 2005). By relying on information technologies (IT) to support their members' communication and coordination processes, VTs offer several opportunities for accessing, acquiring, and integrating knowledge within distributed organizations and sometimes even between organizations (Alavi and Tiwana 2002, Griffith et al. 2003, Lipnack and Stamps 1998, Malhotra et al. 2001). When effectively managed, the process of integrating specialized knowledge leads to numerous desirable team outcomes such as increased product innovation, greater process and output creativity, improved team effectiveness, and greater quality of outputs (Grant 1996a, Grant 1996b, Malhotra et al. 2001, Okhuysen and Eisenhardt 2002, Sole and Edmonson 2002, Tiwana and MacLean 2005).

However, even if the virtues of VTs for integrating knowledge across boundaries have been recognized in IS and OB research, our understanding of the antecedents of knowledge integration effectiveness in VTs remains limited. To our knowledge, Alavi and Tiwana's (2002) conceptual work remains to date the most comprehensive paper about knowledge integration VTs. In their paper, the authors present four key challenges for knowledge integration in VTs (i.e. constraints on transactive memory, insufficient mutual understanding, failure in sharing and retaining contextual knowledge, and inflexibilities of organizational ties), and discuss how knowledge management systems can be used to deal effectively with those challenges. However, the research propositions formulated by Alavi and Tiwana (2002) have not been tested empirically, which limits the inference that can be made on the basis of these propositions. In other cases, studies have addressed the issue of knowledge integration in VTs but only indirectly, since the main focus of these papers was directed towards other important yet different phenomena. For instance, in Malhotra et al.'s (2001) case study of a VT at Boeing-Rocketdyne, there was clearly effective knowledge integration taking place amongst VT members, which ultimately resulted in increased team performance (i.e. product innovation, work efficiency, and team effectiveness). However, the mechanisms that actually drove the knowledge integration process were not explicitly assessed given that the authors looked at the VT's dynamic nature through other themes and concepts such as technology adaptation, structuration of the team's taskwork activities, and IT support for knowledge sharing. Therefore, it is difficult to isolate the main drivers of knowledge integration effectiveness on the basis of their analyses. Other examples of such indirect coverage of knowledge integration in VTs include Hightower and Sayeed (1996) and Warkentin et al.'s (1997) papers on information sharing in collocated vs. virtual decision making teams (1996), and Maznevski and Chudoba's (2000) field study on VT effectiveness. In sum, IS and OB researchers have outlined the importance of knowledge integration in VTs and the potential impact of knowledge integration effectiveness on performance, but research has yet to develop and test an integrative model within which the key enablers of knowledge integration effectiveness in VTs are assessed.

To address this gap, this paper develops and tests a model of IT-enabled knowledge integration in VTs. Grounded on Robert Grant's (1996a) knowledge-based theory and complemented by literature on shared cognition (Cannon-Bowers et al. 1993, Lewis 2003, Wegner 1987) and coordination in work units and teams (Faraj and Sproull 2000, Kraut and Streeter 1995, Van de Ven et al. 1976), the model identifies two main antecedents of knowledge integration effectiveness, namely (1) IT usage for integration mechanisms enactment, and (2) the development of common knowledge between VT members. It also assesses the relationship between knowledge integration effectiveness and VT performance. By testing the model with 700 individuals from 102 VTs in a large multinational IT firm[17], the paper attempts to provide some answers to the following research questions: What are the key factors leading to knowledge integration effectiveness in VTs? What is the relationship between knowledge integration effectiveness and VT performance?

The rest of the paper is organized as follows. First, we present the theoretical background that supports our research model and hypotheses. Then, the method used to assess the research model is described. The third section presents the results of the data analyses. Finally, the last section is used to discuss the findings, contributions, limitations, and avenues for future research.

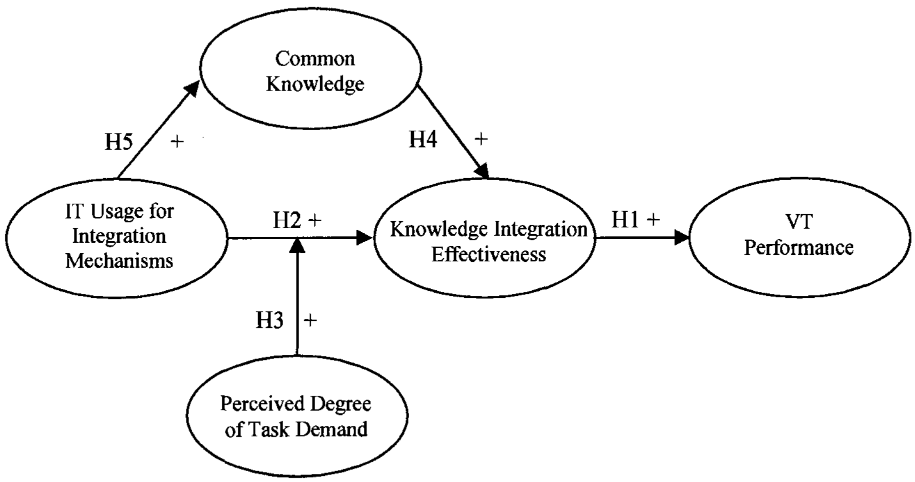
Theoretical Development and Research Hypotheses

To assess the antecedents and the effects of knowledge integration effectiveness in VTs, a model of IT-enabled knowledge integration is proposed. As depicted in Figure 1, the model suggests that knowledge integration effectiveness acts as a direct antecedent of VT performance. In turn, knowledge integration effectiveness is facilitated in two main ways. First, it is facilitated by formally managing the knowledge integration process by using IT to perform integration mechanisms. Second, by using IT to develop common knowledge between members of VTs, it then acts as a main driver of knowledge integration

[17] For confidentiality purposes, the name of the firm is not revealed.

effectiveness. In this section, we provide more details about the theoretical underpinning that supports the research model.

Figure 1. Research model



<u>The Effect of Knowledge Integration Effectiveness on VT Performance</u>

Increasingly, distributed organizations are turning towards VTs in order to perform knowledge-based tasks such as business process re-engineering, research and development, and product development tasks (Griffith et al. 2003, Hinds and Mortensen 2005, Malhotra and Majchrzak 2004). Within those teams, the mere presence of specialized knowledge is not sufficient to guarantee high performance (Faraj and Sproull 2000). For instance, several scholars have suggested that knowledge needs to be shared and transferred among members of a group to allow it to function efficiently and effectively (Cummings 2004, Griffith et al. 2003, Majchrzak et al. 2000, Malhotra et al. 2001, Malhotra and Majchrzak 2004). Cummings (2004), for example, found a positive relationship between the frequency of knowledge sharing and team performance, and also observed that this positive effect was stronger as the level of structural diversity of the team increases. In their study of a cross-functional VT, Malhotra et al. (2001) found that the exchange of knowledge by interdependent experts were key to the team's ability to generate highly innovative team outcomes. Other work by Griffith et al. (2003), Robey et al. (2000), Sarker et al. (2005), and Sole and Edmonson (2002) have emphasized the importance of fostering knowledge sharing and knowledge transfer within VTs, since it allows their members to develop a shared frame of reference that helps them bridge across functional boundaries, thereby making it more likely that valuable knowledge is not withheld by individuals. But interestingly, researchers that looked at knowledge sharing and knowledge transfer/learning within VTs have usually found that knowledge is simultaneously a valuable resource and a source of communication difficulty for VT members. In fact, studies found that geographical dispersion superimposes logistical and technological constraints that inhibit the exchange and transfer of knowledge in many ways, such as by limiting possibilities for spontaneous communication (Hinds and Bailey 2003), by constraining the exchange of unique information (Cramton 2001, Hightower and Sayeed 1996), and by making site-specific/situated knowledge difficult to re-contextualize in other settings for subsequent application (Sole and Edmonson 2002).

Another stream of research suggests that rather than being shared and transferred, knowledge needs to be integrated in a team (Grant 1996a, Grant 1996b, Tiwana and MacLean 20005), which means that each individual keeps his/her specialized knowledge but mechanisms are put in place to assure that the team optimizes the use of such knowledge and performs as a unified whole. As Barki and Pinsonneault (2005) suggest, integration is key to the functioning of organizations as it allows firms to maximize the usage of specialized knowledge (through the distinctiveness of its different work units) while acting in a coordinated way as a unified entity. Research into ambidexterity in organizations (Benner and Tushman 2003, March 1991) also suggests that integrating knowledge might help firms achieve sustained competitive advantages by helping them manage the tradeoff between exploration and exploitation. Through effective team coordination and process management, teams can foster efficiency by making sure that they optimize the exploitation of the existing skills and expertise of their members. In return, the complex linkages that unite those individuals having heterogeneous specialized knowledge offer rich opportunities for exploration of new opportunities (Grant 1996a, Gupta et al. 2006). In this paper, knowledge integration refers to the activity of coordinating the use of individuals' specialized knowledge in organizations (Grant 1996a, Grant 1996b, Spender 1996). Accordingly, effective knowledge integration within VTs is observed when those teams are successful at coordinating the usage of their members' specialized knowledge at the collective level (Alavi and Tiwana 2002, Haas 2006). The concept of knowledge integration is the core component of Robert Grant's (1996a) knowledge-based theory, which posits that employees' specialized knowledge represent the firm's most valuable resource, and that the most critical organizational activity is thus to take advantage of that knowledge by integrating it at multiple levels (e.g., teams, work units, organization, organizational networks).

The importance of knowledge integration, as opposed to knowledge sharing and transfer, can be illustrated in different contexts, such as R&D, science, management, and medicine. For instance, most coronary artery bypass grafts (CABG - a cardiovascular surgery) in Canada are performed by a team of five types of specialists, each having their own set of knowledge: a cardiac surgeon, an anaesthesiologist, at least two operating-room nurses, a drip technician, and an inhalotherapist. The key to the success of such a team does not depend as much in the ability of its members to share and learn the specialized knowledge of others, but rather, the team achieves its collective task (i.e. performing the CABG) by integrating and coordinating the specialized knowledge of all members at the team level. Integration assures that the specialized knowledge held by individuals is *utilized* in a specific order and in a way that is appropriate to match the specific requirements of the task. In the surgery team example, it means that the knowledge and expertise of the five specialists are brought to bear on the collective task during the surgery in appropriate time (e.g., that the anaesthesiologist will perform before the surgeon), and in a way that is coherent with the specifications of a CABG intervention (e.g., another type of surgery is likely to require the availability and usage of a different set of specialized knowledge and skills). For instance, it is critical that the anesthesiologist apply his/her expertise at stabilizing the patient's condition and monitoring their life signals before the surgeon acts. As the surgery progresses, each individual must perform his/her work by making sure that their respective knowledge inputs are coordinated with the inputs of all the others. As an example, fluctuations in a patient's blood pressure caused by the surgeon's manipulations might require that the anesthesiologist administers vasopressors, temporarily constraining the usage of the surgeon's knowledge. Ultimately, if the usage of each member's knowledge is coordinated effectively, the whole surgery is likely to be successful and the patient's chances of recovery will be increased. Conversely, ineffective integration of knowledge and dysfunctional coordination of knowledge inputs might cause important delays and risks during the surgery, potentially creating disastrous effects for the patient.

In light of the previous example, two main reasons can explain how and why knowledge integration effectiveness is expected to positively affect the performance of organizational teams, including VTs. First, knowledge integration effectiveness leads to a situation where both the depth and breadth of specialized knowledge are leveraged at the team level (Grant 1996a, Grant 1996b). Leveraging the depth of knowledge means that a team is able to extract the deep knowledge and expertise of each of its members (Alavi and Tiwana 2002, Tiwana and MacLean 2005). It also means that individual members of a given team devote most of their time and efforts at doing what they do best, which, according to Hackman (1987), is an important antecedent of the performance of organizational groups. In the example of the surgery room, leveraging the depth of knowledge is evidenced by the segmentation of the team's sub-tasks based on the respective expertise of each of the five categories of specialists. When the nurses, the surgeon, the anesthesiologist, the drip technician, and the inhalotherapist all perform tasks that match with their specialized knowledge domain, the team as a whole is much more likely to be effective than it would have been if its members were attempting to perform the job of another specialist. Leveraging the breadth of knowledge means benefiting from the diversity and the complementary nature of the expertise that exists within a given team. In the previous example, the success of the CABG is directly contingent upon the surgery team's ability to utilize the diverse knowledge of its members in a complementary fashion. For instance, the usage of the surgeon's expertise alone cannot lead to the success of the CABG, and the same can be said about the nurses', the anesthesiologist's, or the drip technician's knowledge. Instead, it is through the process of integrating the knowledge inputs of all team members that the surgery team can achieve its task in an effective manner. In sum, the performance of knowledge-based teams depends greatly on their ability to leverage the depth and breadth of their members' knowledge, which is exactly what effective knowledge integration is about.

Second, knowledge integration is likely to minimize waste and misuse of members' time, cognitive energy, and talent. As Grant suggests (1996a), if production requires the integration of different people's specialized knowledge, the key to work efficiency is to achieve effective integration while minimizing knowledge transfer, knowledge sharing, and cross-functional learning between individuals, which are considered to be costly activities in organizations (Kogut and Zander 1992). In fact, sharing and transferring knowledge takes time and energy away from productive work, resulting in a level of actual productivity that is less than what theoretically would be possible with optimum usage of members' knowledge (Grant 1996b, Hackman 1987). Conversely, when VT members are integrating their knowledge at the team level, they are not attempting to share or transfer their specialized knowledge with each other. Instead, what they try to do is to make sure that their knowledge inputs will be used in a coordinated fashion with the knowledge inputs of their teammates, thereby ensuring that the VT behaves as a unified work entity. In the surgery team example, it would have been very inefficient for the surgeon to transfer or share his/her specialized knowledge to the nurses or the anaesthesiologist during the surgery. By analogy, the anaesthesiologist does not need to be an expert in cardiovascular surgery to do his or her job within the surgery team. What is critical for the performance of that team is that each of its members coordinates the usage of their respective knowledge in a way that minimizes the process losses inherent to cross-functional learning, knowledge sharing, and knowledge transfer.

Although relatively scarce, empirical evidence suggests that knowledge integration effectiveness leads to increased performance in VTs. For instance, Malhotra et al.'s (2001) study of a cross-functional VT at Boeing-Rocketdyne illustrates well the beneficial impacts of knowledge integration effectiveness on VT performance. In their case study, the authors show that the effective coordination of specialized knowledge inputs owned by geographically-dispersed experts tasked with designing plans for a telecommunication satellite engine resulted in very high levels of outcome quality and innovation. Key to their performance was the team's ability to leverage the specialized knowledge of their experts and coordinate the usage of such knowledge at the team level over the course of the project. In her study of 96 transnational project teams, Haas (2006) found that the successful acquisition and application of internal and external knowledge enabled those teams to more successfully transform this knowledge into improved project performance.

In sum, VTs present many opportunities for leveraging the knowledge of dispersed individuals, but for such teams to be successful, it is critical that their members integrate their knowledge effectively at the team level (Alavi and Tiwana 2002, Faraj and Sproull 2000, Haas 2006, Malhotra et al. 2001). This leads to our first hypothesis:

Hypothesis 1: There is a positive relationship between knowledge integration effectiveness and performance in VTs.

<u>The Effect of IT Usage on Knowledge Integration Effectiveness</u>

According to tenants of the knowledge-based theory (Alavi and Tiwana 2002, Grant 1996a, Grant 1996b, Spender 1996), knowledge integration effectiveness is facilitated by relying upon integration mechanisms, which represent the strategies available in a work setting to facilitate the coordinated usage of its members' knowledge at the collective level. Essentially, the enactment of integration mechanisms ensures that the transformation of individuals' knowledge input into team level outcomes are done in a coordinated fashion and in accordance with the task requirements and specifications (Grant 1996b). The importance of managing the knowledge integration process by performing integration mechanisms is explained by the fact that in itself, the activity of integrating specialized knowledge in VTs is a complex endeavour that requires the usage of a wide array of coordination behaviours. Grant explains this complexity through the notion of hierarchy of capabilities (Grant 1996a, p. 377-378), where at the base of the hierarchy is the specialized knowledge held by individuals, and where movements upward in the hierarchy of capabilities are associated with an increasing span of knowledge being integrated. At higher levels of integration are found the capabilities which require wide-ranging cross-functional integration such as software development teams, business process re-engineering teams, and new product development teams. According to Grant (1996a), the wider the span of knowledge being integrated, the more complex the problems of creating and managing organizational capabilities. Within knowledge-based VTs, this complexity originates from at least three sources.

The first source of complexity for knowledge integration concerns the constraints that the collective task imposes to team members in terms of the sequence and timing of knowledge usage. In most teams, the application of members' knowledge has to follow a relatively specific sequence or temporal pattern, whether it must be done during a designated phase of the team's lifecycle or after/before someone else apply his or her knowledge to the task. For instance, in software development teams, the knowledge of the project manager and the business analysts who are responsible for assessing the users' requirements and clarifying the system specifications must be applied to the joint task before system architects and programmers use their design and programming skills to transform those specifications into a digital product (Kraut and Streeter 1995, Tiwana and MacLean 2005). In the same way, the usage of system testers' knowledge will follow the application of programmers' knowledge given the sequential constraints for knowledge integration that are imposed by the structure of the software development task. Therefore, to be successful at integrating knowledge within VTs, it is critical that VT members perform the integration mechanisms that will help them clarify how and when their personal knowledge must be applied to the joint task, and monitor the pacing of knowledge use over time in order to make sure that work is accomplished according to the demands of the task at hand.

The second source of complexity for knowledge integration in VTs originates from the informational dependencies that exist between individuals as they utilize their knowledge. By definition, teams are a collection of individuals that share a common goal, which implies some form of work and informational interdependencies between them (Janz et al. 1997). For knowledge integration, this means that the effective usage of the specialized knowledge held by an individual is often dependent upon the input and/or feedback of one or more other teammates (Grant 1996b). It also means that someone within the team might hold very valuable knowledge, but that the work interdependencies existing within the team makes the usage of that knowledge impossible, irrelevant, ineffective, or risky without the input of other individuals within the team. For instance, in most surgery teams, it is common practice that before the surgery starts, the anaesthesiologist synthesizes critical information about the patient's medical antecedents in order to formulate recommendations to the surgeon about how to adapt his or her surgical acts according to the patient's condition. Even though the specialized knowledge of the surgeon allows him or her to perform a wide array of medical acts, the information provided by the anaesthesiologist is important for the success of the surgery because it influences the way the surgeon will use his/her specialized knowledge. In sum, it is important that team members manage the complexity caused by the informational dependencies that constrain the effective usage of members' knowledge in VTs.

Third, integrating knowledge is a complex activity because of the coordination costs (time, efforts, cognitive strains) experienced by members of a team to understand, decide, and express how to combine their specialized knowledge together. Grant (1996a) states that because of the cognitive limits of the human brain, knowledge tends to be acquired in a highly specialized form, where an increase in depth of knowledge implies reduction in breadth. However, execution of taskwork activities requires a wide array of knowledge, and is usually done through complex combinations of the specialized knowledge of a number of individuals. While these complex linkages can become a source of value by creating novel and inimitable capabilities due to "causal ambiguity" (Grant 1996a, p. 381), important cognitive efforts must be deployed to understand and often negotiate how to establish those linkages and make sure they are mutually understood by members of a work unit/team. This complexity is acknowledged by Carlile and Rebentisch (2003), who observed that specialization establishes knowledge boundaries across domains, which, at the work unit/team level, is likely to make knowledge integration more difficult.

To address the aforementioned sources of complexity inherent to the knowledge integration process, we argue that VTs members must rely on different integration mechanisms. More precisely, we focus here on the extent to which ITs are used to perform different integration mechanisms within VTs. IT usage for integration mechanisms enactment is essential for knowledge-based VTs given that most communication and coordination behaviours within such teams are facilitated by information technologies (Hinds and Bailey 2003, Jarvenpaa and Leidner 1999). Based on the premises of the knowledge-based theory (Grant 1996a, Grant 1996b) and research on coordination in teams (Andres and Zmud 2001, Faraj and Sproull 2000, Kraut and Streeter 1995, Van de Ven et al. 1976), teams use different approaches to integrate the knowledge inputs of their members at the team level: such approaches ranging from formal/impersonal modes of integration to more informal/interactive mechanisms. Here, we propose that IT can be used to perform three main integration mechanisms that, together, form the overall level of IT usage for integration mechanism enactments taking place within VTs. Those are impersonal, personal, and collective integration mechanisms.

Table 1. IT Usage for Integration mechanisms and knowledge integration effectiveness

Sources of complexity inherent to the integration of knowledge	**IT usage for integration mechanism**	**Contribution to knowledge integration effectiveness in VTs**
Need to manage the sequence and timing of knowledge usage within the team.	Impersonal integration mechanism: *Using IT for...* - obtaining information about the team's progress toward milestones - setting goals, work plans, and general courses of action within the team - disseminating protocols and directives that prescribe people's actions within the team	Helps VT members develop modularized patterns of knowledge use Helps structure the pace of efforts and timing of knowledge use Allows the development of collective awareness in respect to the progression of the joint task and its key milestones
Need to manage interdependencies inherent to the usage of knowledge within the team.	Personal integration mechanism: *Using IT for...* - exchanging task-related information with individuals within the team jointly work on a document or data file with another member of the team - providing comments and feedback to other co-workers about aspects of their work - asking tips and advices to a teammate about an issue of the task	Ensures that work interdependencies are effectively managed when the usage of someone's knowledge requires another people's input or information Allows for mutual adjustment between VT members' as they bring their knowledge to bear on the collective task Help member learn about each others' domain of expertise and specialized knowledge domains
Need to understand, negotiate, decide, and express how to coordinate the use of knowledge within the team.	Collective Integration Mechanism: *Using IT for...* -discussing issues of the task with two or more members of the team - sharing opinions and ideas with multiple individuals involved in the collective project - supporting team meetings, and enabling joint decision making and group problem solving	Contributes to resolve equivocality within the team concerning the way to apply knowledge to the joint task Helps reach mutual agreement concerning the way to accomplish work and combine heterogeneous expertise within the team.

The *impersonal integration mechanism* refers to the reliance on rules, procedures, work plans, team schedules, and other formal activities performed to coordinate the use of knowledge within VTs (March and Simon 1958, Van de Ven et al. 1976). Impersonal integration mechanisms allow VT members to develop modularized and relatively independent patterns of work that permits the integration of specialized knowledge without the need for extensive interpersonal communication between members of a work unit (Grant 1996a, Grant 1996b). It also helps team members develop collective awareness in respect to the overall progress of the team task as well as a shared vision of the team goals and objectives, which ultimately facilitates the coordinated use of knowledge at the collective level.

The second mechanism is called the *personal integration mechanism*, and refers to direct one-to-one vertical and horizontal informational exchanges taking place between individuals within VTs in order to coordinate their use of knowledge (Kraut and Streeter 1995, Van de Ven et al. 1976). In opposition to an impersonal integration mechanism, personal integration mechanism implies back and forth communication, spontaneous exchanges of task-related information, provision of advice and feedback, and mutual adjustments between members of VTs (Gittel 2002, March and Simon 1958, Thompson 1968). The reliance on personal integration mechanisms is important for knowledge integration effectiveness because it helps ensure that work interdependencies are effectively managed when the usage of someone's knowledge requires another person's input or information. It is also useful when an individual within the team needs tips or advice from another team member before applying its own specialized knowledge to the task.

The third integration mechanism proposed here is called *collective integration mechanism*, and refers to the interdependent behaviours performed to coordinate the use of knowledge within VTs through the combination and synthesis of ideas and perspectives from multiple team members. By using a collective mode of integration, VT members can engage in deep clarification of key issues of the task, develop collective judgment and common frames of reference, and confront perspectives and ideas with those of other people in order to jointly establish how to coordinate the use of knowledge within the team.

As Table 1 indicates, the usage of IT to perform all three integration mechanisms is important for VTs because each mechanism holds a specific function to enable the successful integration of knowledge. Therefore, we argue that VTs are likely to benefit from the complementary coordinative capabilities of these three mechanisms rather than using one mechanism as a substitute for the others. This is consistent with organizational theory literature, which use the terms "additive linkages" (Van de Ven et al. 1976, p. 325) to describe how coordination mechanisms complement each other within work units and facilitate the coordination of members' work inputs at the team/work unit level (Thompson 1968, Van de Ven et al. 1976,). In their study of three VTs in the field, Maznevski and Chudoba (2000) describe how effective VTs adapt their patterns of IT-enabled coordination over time by punctuating the frequent usage of impersonal and personal approaches of integration with occasional collective integration mechanisms such as team meetings. Thus, we suggest that all three types of integration mechanisms (impersonal, personal, and collective) are important for managing the integration of knowledge in VTs.

Given the above explanations, we argue that the overall degree of IT usage for integration mechanisms will have a positive impact on knowledge integration effectiveness. This is the case because the process of integrating knowledge in VTs is complex and requires a wide array of mechanisms to be managed successfully. Because the enactment integration mechanisms help define and specify the way members of VT should incorporate their personal knowledge to the joint task, the usage of IT for enabling those mechanisms increases the likelihood that individuals' knowledge inputs will be coordinated with those of others within the team, and that this coordinated process of knowledge usage will be done according to the task specifications. In contrast, low usage of IT for integration mechanisms will inhibit knowledge integration effectiveness in many ways, such as by limiting the cues available about the status of each others' contribution in the team, by constraining members' awareness of the overall team progression towards its goals, by running the risk of duplicating VT members efforts, by inappropriately managing work interdependencies between dispersed individuals, and by creating situations where VT members' knowledge inputs are not used consistently with the task's requirements. This leads the following hypothesis:

Hypothesis 2: There is a positive relationship between the degree of IT usage for integration mechanisms and knowledge integration effectiveness in VTs.

<u>Task Demand as a Moderator of the IT usage → Knowledge Integration Relationship</u>

Studies on coordination in teams and the literature on knowledge management suggest that the impact of using IT for integration mechanisms on knowledge integration effectiveness is likely to be contingent upon the degree of task demand perceived by VT members (Carlile and Rebentisch 2003, Gittel 2002, Kraut and Streeter 1995, Malhotra and Majchrzak 2004, Van de Ven et al. 1976).

Within knowledge-based virtual teams, lower levels of task demand are characterized by few work dependencies among team members, well-defined and fairly repetitive tasks, and clear causal linkages between task processes and outcomes (Campbell 1988, Gray and Meister 2004, Lewis 2004, Van de Ven et al. 1976). Under such circumstances, an individual's specialized knowledge can be effectively incorporated to the task in a fairly additive fashion, with lesser needs for extensive communication, frequent mutual feedback, and collective decision making (Grant 1996b, Malhotra and Majchrzak 2004). Therefore, we expect that in a low task demand condition, the process of coordinating the use of knowledge can be managed effectively with lesser extent of IT usage for integration mechanisms enactment. This can also be explained by the fact that lower levels of task demand creates fewer challenges for knowledge integration and makes the overall knowledge integration process more straightforward (Carlile and Rebentisch 2003). For instance, the routine nature of a low demanding task necessitates less frequent re-definition of working plans, rules, and protocols to prescribe the actions of individuals within the team (March and Simon 1958). Similarly, lower levels of task interdependence within VTs reduces the need for IT-enabled interpersonal communication, mutual adjustments, provision and receipt of tips and feedback, and joint problem solving activities between people (Andres and Zmud 2001, Thompson 1968, Malhotra and Majchrzak 2004). Therefore, we expect that greater usage of IT for integration mechanisms will provide few marginal benefits on knowledge integration effectiveness to VT members as the degree of task demand decreases.

Conversely, high levels of task demand within VTs are characterized by several dependencies in informational resources, high degree of variability for the problem at hand, and ill-defined causal linkages between individuals' knowledge inputs and team outputs (Gray and Meister 2004, Lewis 2004). Under such circumstances, a greater level of IT usage for integration mechanisms is required in order to ensure that work interdependencies are managed appropriately and that the challenges stemming from the non-routine nature of the task are mutually understood by individuals before they apply their knowledge to the task. Given the highly interdependent, complex, and non-routine nature of a high demanding task, the effective integration of knowledge at the team level also necessitates more frequent use of IT for integration mechanisms in order to negotiate and sometimes redefine the way to use specialized knowledge within VTs. In sum, high levels of perceived task demand creates challenges for effective knowledge integration, which must be compensated by heavier IT support for integration mechanisms (Carlile and Rebentisch 2003). This leads to the next hypothesis:

Hypothesis 3: The positive relationship between the degree of IT usage for integration mechanisms and knowledge integration effectiveness in VTs will be magnified by the degree of task demand.

The Effect of Common Knowledge on Knowledge Integration Effectiveness

According to the knowledge-based view, a complementary way to facilitate the integration of knowledge in work units and teams is to develop common knowledge between individuals. More precisely, *common knowledge* captures these knowledge items that are commonly held by individuals, or, in other words, lie at the intersection of their knowledge sets (Grant 1996a, Grant 1996b). It can also be seen as the organized understanding of the relevant knowledge that is shared between team members (Klimoski and Mohammed 1994, Mohammed and Dumville 2001). According to Grant (1996b), the development of common knowledge allows individuals to tacitly integrate knowledge items which are not common between them.

Table 2. 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

The development of common knowledge within VTs is expected to positively influence knowledge integration effectiveness for four reasons. First, common knowledge enhances comprehension and interpretation of the information that is communicated between 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, 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 it less effective for team members to interrelate to each other's expertise, thereby inhibiting knowledge integration at the team level.

Second, common knowledge about the team's interaction structure and its members' expertise makes the overall process of coordinating VT 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, common knowledge allows VTs to integrate the knowledge of their members when interpersonal exchanges and explicit forms of coordination are impossible between them, 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 VT 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, 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 4: There is a positive relationship between common knowledge and knowledge integration effectiveness in VTs.

The Effect of IT on Common Knowledge Development

Because common knowledge in VTs is posited to be a key driver of knowledge integration effectiveness, the actions that can be done in order to build and maintain a high level of common knowledge are also important in the present analysis. Research on team cognition has shown that one way to develop and maintain common knowledge within teams is for their members to interact frequently with each other and perform interdependent behaviours, such as coordination and communication activities (Brandon and Hollingshead 2004, Cannon-Bowers et al. 1993, Krauss and Fussell 1990, Lewis 2004, Moreland 2000, Wegner 1987, Yoo and Kannawattanacahi 2002). In fact, through interdependent actions performed in their team setting (e.g., team training, interpersonal communication), individuals develop shared cognitive representations about numerous important facets of their collaborative process, such as peoples' respective area of expertise (Lewis 2003, Lewis 2004, Wegner 1987), team goals, objectives, and task characteristics (Brandon and Hollingshead 2004, Cannon-Bowers et al. 1993), individuals' roles and responsibilities in regards of the joint task (Cannon-Bowers et al. 1993), norms of IT usage for communication and coordination (Orlikowski and Yates 1994, Sole and Applegate 2000), and project-specific technical terms and work heuristics (Carlile and Rebentisch 2003, Malhotra et al. 2001).

Research on transactive memory systems also supports the idea that frequent interactions between teammates help them develop and maintain shared cognitive representations about the distribution of expertise within the team, and about the way that expertise is used to address the task requirements (Brandon and Hollingshead 2004, Lewis 2004, Moreland 2000, Wegner 1987). The development of communication genres and genres repertoires described by Orlikowski and Yates (1994) also supports the assumption that repeated interactions help build common knowledge within teams. In their case study of a distributed team in the field, Orlikowski and Yates (1994) observed that patterns of IT-enabled communication and coordination are defined and re-defined over time as team members interact together using IT to a point where those patterns become commonly accepted and internalized by those members, a process called "genre formation". In other words, repeated IT-enabled interaction lead to the creation and reinforcement of a common cognitive representation of the IT-enabled communication and coordination structure among team members.

Consistent with the above statements, we therefore expect that the degree of IT usage for integration mechanisms enactment will be positively associated with the degree of common knowledge development found in VTs. In fact, greater usage of IT-enabled integration mechanisms will help members of the team develop and maintain common knowledge about various aspects of the team functioning, which is reflected in our final hypothesis:

Hypothesis 5: There is a positive relationship between the degree of IT usage for integration mechanisms and common knowledge development within VTs.

Methods

Data on knowledge-based VTs were collected at a large North American firm operating in the consulting industry[18], with activities distributed in 16 different countries on 4 continents. Within that company, the reliance on VTs to conduct knowledge-based projects has become a strategic orientation, especially given the company's massive efforts for improving global service delivery across the world. In the meantime, senior executives were striving to better understand the factors affecting the performance of their VTs, and were looking towards implementing new methodologies for managing the knowledge of VT members in a more effective way.

After the study was approved at the senior executive level, a series of conference calls and face-to-face meetings were conducted with vice-presidents and business unit leaders of all nine regional branches of the company in order to discuss the goal of the study, its implications for participants, and ethical considerations raised by the research project. In exchange for two research reports and an oral presentation to senior executives, the company provided a series of lists identifying ongoing projects managed from representatives of those nine regional branches. Using those lists, we contacted the managers of each project in order to identify the ones that were performed using VTs. The following three criteria were used to identify VTs for the study: (1) members of the team must have a shared goal, (2) members of the team must be spread across two or more geographical locations, (3) the team had to be ongoing at the time of the study[19]. After selecting VTs based on those criteria, managers of the selected teams provided a list of their members using a pre-defined Microsoft Excel template file within which four

[18] Confidentially reasons prevent us from giving additional details about the firm.
[19] We excluded teams that had completed their task in order to avoid retrospection bias, which could have affected the results given the study's important use of perceptual constructs.

key information were required: (1) each VT member's first and last name, (2) their working e-mail address at the company, (3) the name of the team to which they belong[20], and (4) whether or not the person is the designated leader of the team.

Respondents

A total of 1197 personalized invitation e-mails were sent to members and leaders of 114 VTs over 6 months. Within each e-mail, three key information were inserted (1) a description of the study and its objectives, (2) the name of the team to which each individual belong to, and (3) a hyperlink leading to the first page of the online survey. For each team, two types of respondents were surveyed: (1) *team members*, who provided data about their day-to-day experience in their VT, and (2) the *designated team leader*, who answered the same survey but who also had to fill out additional questions concerning team performance and other project-level characteristics. Team members' participation was voluntary, which was communicated within the first page of the web survey along with a guarantee of confidentiality. Two reminders were sent after five (first reminder) and ten (second reminder) working days to those that did not complete the web survey at those stages.

A total of 777 individuals from 113 of the 114 targeted VTs completed their web-based survey. Among those completed surveys, 49 were dropped because too many questions were left unanswered[21]. Twenty-one participants from 4 teams were also discarded because it turned out that they were actually part of a collocated team instead of a VT. Eight other teams were also dropped from the sample because less than 30% of

[20] Managers were sometimes responsible for more than one virtual team.
[21] In the present study, a completed survey represents a survey for which the last web page was submitted. The 49 questionnaires that were dropped were, in most cases, filled with missing values. This happens when an individual browses through the questionnaire without providing any answers and then submit the last page of the survey.

the team members provided usable responses. Keeping the responses from those individuals could have been misleading given the high importance of collective-level phenomena in the research model (e.g., common knowledge, team knowledge integration effectiveness). Overall, 700 respondents (626 members and 74 team leaders) spread across 102 VTs provided usable survey data, for an acceptable rate of usable questionnaires of 58.8%.

Descriptive statistics

Within our final sample, 31.7% were female, and 49.5% 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 VT, and were members of the company for 7 years and one month. 82.8% of individuals had an undergraduate degree or higher. Individuals performed a wide range of functions within their respective VT, with the three most represented functions being system analyst/developer (43.3%), business analysts (12.2%), and database administrators (8.7%). As for the tasks performed by VTs, they represented a variety of knowledge-based tasks such as business process reengineering, product/ software development, system implementation and integration, and system maintenance. Concerning membership issues, 51.1% of the individuals reported that the designated VT was the only team they were member of and they spent an average of 66.5% of their time working for that team. The size of the teams varied between 2 to 40 members, with an average of 11 members.

Concept Operationalization and Measures

Knowledge Integration Effectiveness

In this paper, we build on Grant's (1996a) knowledge-based view of the firm and define knowledge integration as the activity of coordinating the usage of VT members' specialized knowledge at the team level. Consistent with the knowledge-based view and its recent adaptation to organizational teams (ex. Alavi and Tiwana 2002, Tiwana and McLean 2005), knowledge integration effectiveness in VTs is defined here as the extent to which a VT 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, we asked VT members and leaders five questions to obtain their perceptions of the effectiveness with which their team has been successful at coordinating the use of its members' specialized knowledge. A five point Likert scale was used to gather members' and leaders' level of agreement on five items measuring knowledge integration effectiveness.

IT Usage for Integration Mechanisms

As mentioned in the previous section, integration mechanisms refer to the activities performed by members of VTs to coordinate the usage of knowledge at the team level (adapted from Grant 1996a, Grant 1996b). Thus, the degree of IT usage for integration mechanisms represents the extent to which VT members use IT to proactively manage the process of knowledge integration by performing the three integration mechanisms defined earlier (impersonal, personal, and collective integration mechanisms). It is conceptualized as a second-order formative construct with three underlying first-order factors (indicators), namely impersonal, personal, and collective integration mechanisms. The choice of a formative conceptualization was made based on Jarvis et al.'s (2003) recommendations, who suggest that four major criteria should be observed to model formative constructs: (1) the direction of causality must be from indicators to constructs, (2) the indicators need not to be interchangeable, (3) co-variation among indicators is not necessary, and (4) the nomological net of indicators can be different (Jarvis et al. 2003). In the present case, it is the complementary nature that emanates from the combined usage of those three conceptually-distinct mechanisms that is used to define the overall degree of IT usage for integration mechanisms. Also, the usage of one mechanism does not imply that the others will be used, and each mechanism contributes in its own way to shape the overall level of IT usage for integration mechanisms. Thus, a formative conceptualization appears to be appropriate.

To measure the degree of IT usage for integration mechanisms, we adapted Van de Ven et al. (1976) and Kraut and Streeter's (1995) scales of coordination mechanisms usage in work units and teams. The major adaptation consisted in reframing existing questionnaire items and developing new ones (see procedure described next) in order to reflect the fact that within VTs, those mechanisms are mainly performed through IT. More precisely, a set of eighteen items (six for each integration mechanism) was used where each item depicts a behaviour traducing the usage of one of the three integration mechanisms. Examples of IT usage for impersonal integration mechanism include the use of IT for obtaining information about the team's progress toward milestones, setting goals, work plans, and general courses of action within the team, and disseminating protocols and directives that prescribe people's actions within the team[22]. Building on Thompson's (1967) notion of coordination by mutual adjustments, examples of IT usage for personal integration mechanism include the use of IT for exchanging task-related information between individuals within the team, providing comments and feedback to other co-workers about aspects of their work, and asking tips and advices to a teammate about an issue of the task that is unclear[23]. Examples of collective integration mechanisms enabled by IT include people's usage of IT for discussing issues of the task with two or more members of the team, sharing opinions and ideas with multiple individuals involved in the collective project, supporting team meetings, and enabling joint decision making and group problem solving[24]. By using a six point scale of extent of use (1 = never, 2 = very low extent, 6 = very high extent), members and leaders of VTs were asked to indicate to what extent they used IT to perform a series of behaviours traducing the usage of one of the three integration mechanisms.

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[22] These examples represent adaptations of impersonal coordination modes traditionally proposed in the information processing literature and prior work on coordination in organizations (Daft and Lengel 1986, Galbraith 1973, Gittel 2002, Thompson 1967, Van de Ven et al. 1976).

[23] Instances of IT usage for personal integration mechanism represent adaptations of March and Simon's (1958) concept of "feedback coordination", Thompson's (1967) notion of "mutual adjustment", and Gittel's (2002) conceptualization of "relational coordination mode".

[24] IT usage for collective integration mechanism is similar to the notion of group mode of coordination proposed by information processing theorists (Daft and Lengel 1986, Van de Ven et al. 1976, Gittel 2002), which offers members of a work unit the possibility to interact with multiple others in a synchronous fashion, and discuss issues of the task in a collective setting. However, because synchronous collaborative work may not always be possible within virtual teams due to members' temporal dispersion, our conceptualization of IT support for collective integration mechanisms usage includes both synchronous and asynchronous collective interdependent behaviours.

Common Knowledge

Common knowledge represents the organized set of knowledge items that are commonly held by individuals in respect to their team's structure and processes (Grant 1996a, Grant 1996b, Klimoski and Mohammed 1994, Mohammed and Dumville 2001). Both the knowledge-based view and shared mental model literature suggest that common knowledge is a multi-dimensional construct, which means that the shared cognitive basis of individuals within teams are likely to converge towards different yet complementary elements of a given team's structure and processes. For instance, Cannon-Bowers et al. (1993) suggest that multiple mental models are likely to co-exist within a team, thereby complementing each other and forming that team's overall shared cognitive structure. Similarly, Grant (1996b) states that different types of common knowledge fulfill different roles in knowledge integration. In the present study, we combine insights from the knowledge-based view with literature on shared mental models (Cannon-Bowers et al. 1993, Mohammed and Dumville 2001), team cognition (Brandon and Hollingshead 2004, Lewis 2003, Lewis 2004, Wegner 1987) and VT research (Cramton 2001, Malhotra et al. 2000, Malhotra and Majchrzak 2004, Maznevski and Chudoba 2000) to propose four dimensions of common knowledge that together, form the overall shared cognitive structure a VT can use to facilitate the integration of its members' knowledge. Those dimensions are (1) common task knowledge, (2) common expertise knowledge, (3) common IT interaction knowledge, and (4) common specialized knowledge. Table 2 shows how each dimension of common knowledge contributes to knowledge integration effectiveness.

The first dimension of VT common knowledge is called *common task knowledge*, and refers to the degree of shared understanding existing amongst VT members about the characteristics of the task and the way it should be conducted (adapted from Cannon-Bowers et al. 1993). According to the literature on team mental models (Brandon and Hollingshead 2004, Cannon-Bowers et al. 1993, Moreland 2000), effective team performance of knowledge-based groups requires that their members hold overlapping cognitive representations of the task requirements, procedures, and role responsibilities. The second dimension of common knowledge in VTs, *common expertise knowledge*, represents the degree to which members of VTs have developed shared cognitive representations of each others' expertise domains within the team (Anand et al. 1998, Faraj and Sproull 2000, Grant 1996a, Wegner 1987). According to Grant (1996b), knowledge integration is facilitated when each individual in a work unit or a team is aware of everyone else's domain of expertise. 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), duplicate taskwork activities (Lewis 2003), or face the risk of overlooking valuable knowledge sources residing within their own team. The third dimension of VT common knowledge is called *common IT interaction knowledge*, and represents the degree of shared understanding existing within VTs about the way to use IT for supporting communication and coordination activities. In other words, it captures the extent to which members of VTs possess similar cognitive representations of the IT-enabled communication and coordination structure of the team. Because members of VTs greatly rely on IT to perform their collective task (Hinds and Bailey 2003, Townsend et al. 1998), the common knowledge they hold in respect to the way to use these technologies for supporting communication and coordination activities between them is used to capture an important dimension of the overall common knowledge basis existing within VTs. The last dimension of common knowledge in VTs investigated in this study is *common specialized knowledge*. Broadly stated, common specialized knowledge refers to the similarities in domain-specific knowledge grounds existing within VTs. Without some overlap in people's specialized knowledge, 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 costs associated with efforts deployed for cross-functional learning (Grant 1996b, Hackman 1987). 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 among members of a work unit (Grant 1996b).

We propose that those four dimensions of common knowledge combine to form the overall degree of common knowledge a VT can rely upon in order to tacitly coordinate the use of its members' knowledge at the collective level. Common knowledge is operationalized as a second-order formative construct with four first-order factors, namely common task knowledge, common expertise knowledge, common IT interaction knowledge, and common specialized knowledge. Again, this conceptualization was chosen because it is consistent with the criteria suggested by Jarvis et al. (2003) to model formative constructs (see previous section). Indeed, a reflective conceptualization would have been misleading because the four types of common knowledge are not expected to covary together and are each contributing in a unique way to shape the development of common knowledge in VTs.

To measure common knowledge, a series of 20 questions (five for each dimension of common knowledge development) measuring the extent to which common knowledge was developed within the team in respect to the four dimensions of task, expertise, IT interaction, and specialized knowledge were asked to leaders and members of VTs using 5-points Likert scales of agreement. Consistent with Lewis' (2003, 2004) survey instrument for measuring transactive memory systems within organizational teams, questions 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.

Perceived Degree of Task Demand

Here, perceived degree of task demand refers to the normal cognitive load experienced by VT members in performing their work (adapted from Gray and Meister 2004, p. 824). Consistent with studies on knowledge-based teams by Lewis (2004), Gray and Meister (2004), and Janz et al. (1997), perceived degree of task demand is operationalized as a combination of three fundamental task attributes: (1) *the degree of task interdependence*, which captures the extent to which VT members are dependent upon one another's resources, information, and knowledge to perform their individual jobs (Campion et al. 1993); (2) the *degree of task non-routineness* which represents the degree of instability of the task and the variability of work processes it entails (Lawrence and Lorsch 1967, Perrow 1967), and *the degree of task complexity*, defined as the extent to which the collective task features many courses of action leading to multiple, possibly conflicting outcomes (Campbell 1988). We used Gray and Meister's (2004) approach for measuring the degree of task demand perceived by individuals within VTs. Pre-validated scales were available for task interdependence (Campion et al. 1993, Gray and Meister 2004) and task non-routineness (Goodhue and Thompson 1995, Gray and Meister 2004, Majchrzak et al. 2005), and therefore were used in the present study. Items for task complexity were developed based on Campbell's (1988) review of perceived and objective task complexity. Again, 5-points Likert scales of agreement were used to collect data about the three dimensions of perceived degree of task demand.

Virtual Team Performance

Given the variety of knowledge-based teams in our sample, we opted for a holistic conceptualization of team performance that covers different team outcomes such as product innovation, work excellence, product quality, the team's ability to meet the budget and delivery schedules, and others. More precisely, we assessed team performance using recent adaptations of Ancona and Caldwell's (1992) 8 items validated scale of team performance by Hinds and Mortensen (2005). To generate a single measure of team performance for each VT, only the designated leader's assessment of performance was used.

Figure 2. Measurement of Constructs

Constructs and items

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.

Team performance (leaders only)
Compared with other projects you have worked on in the past and other projects with which you are familiar, please rate your perception of performance of your team according to the following dimensions.
(Scale: 1 = poor; 3 = average; 5 = excellent)
1. Work quality
2. Work excellence
3. Technical innovation*
4. Adherence to project goals
5. Adherence to budget
6. Adherence to schedules and deadlines
7. Work efficiency
8. Overall performance

IT Usage for integration mechanisms
(Scale: 1 = never to 6 = very high extent)
Impersonal
1. Set goals, work plans, and general courses of action within the team.
2. Check milestones and delivery schedules within the team.
3. Define, update, and view team schedules and work assignments.
4. Obtain information about the team's progress toward milestones.
5. Distribute work plans and protocols to coordinate the work within the team.
6. Post information about the status of my tasks.*

Personal
1. Exchange task-related information with another team member.*
2. Ask someone within the team for tips and advice about a problem I face.
3. Provide comments to and receive feedback from another member of my team.
4. Share thoughts and opinions with another person in the team about an issue of the project.
5. Spontaneously contact another member of the team for exchanging task-relevant information and knowledge.
6. Validate aspects of my work with another individual within the team.

Collective
1. Discuss issues of the task with two or more team members simultaneously.*
2. Build consensus with teammates about important task-related issues faced within the team.
3. Support joint decision making and collective problem solving within the team.
4. Contrast and compare ideas and perspectives from many different people within the team.
5. Brainstorm ideas and opinions with multiple people involved in the collective task.
6. Interact with multiple team members simultaneously.

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.*

Team size

How many people are part of your team? ___ people, including myself

Stage of team development

Which of the following stages of team development best reflects the current stage of your team?
1- Forming / 2- Storming / 3- Norming / 4- Performing / 5 - Ending

Perceived degree of task demand

(Scale: 1 = strongly disagree; 3 = neutral; 5 = strongly agree)

Interdependence

1. I cannot accomplish my tasks without information or materials from other members of my team.
2. Within my team, jobs performed by team members are all related to one another.
3. Other members of my team depend on me for information or materials needed to perform their tasks.*
4. The team's task requires that team members rely on one another's work products to succeed.

Non-routineness

1. Our team is dealing with non-routine challenges.*
2. Our team is using a non-routine process to address the collective task.
3. Our team is addressing questions that have never been asked in quite that form before.
4. I frequently deal with unusual, one-of-a-kind things at work within this team.

Complexity

1. Our team has a complicated task to achieve.
2. This team's collective task is very complex.

*Indicates items that have been excluded from the analysis because their factor loading on their theoretical construct was inferior to .70.

Scale Development Procedure

For knowledge integration effectiveness, usage of IT for integration mechanisms enactment, and common knowledge, standardized instruments were not available and thus needed to be created. To do so, a five-step process was followed based on Churchill (1979) and Moore and Benbasat's (1991) guidelines for instrument development and validation.

The first step consisted in developing survey items based on the existing definitions and conceptualizations of the aforementioned constructs available in the literature. In the second step, the items generated were presented to a pool of four experts knowledgeable in the topic of knowledge integration and virtual teamwork. After refining the wording of the items based on the experts' feedback, a third step was to perform two rounds of card sorting (Moore and Benbasat 1991). For each round, 15 individuals were provided color-coded cards, with blue cards used for the definitions of the constructs and white cards used for the items. Then, people 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. In the fourth step, we shown the questionnaire items to three managers of existing knowledge-based VTs in the field in order to improve face validity and make sure that the items were relevant to VT members of existing organizations. After making minor adjustments to the wording of questionnaire items, a fifth step involved sending web-based surveys to a set of 60 individuals from 4 ongoing VTs at the partner organization described earlier. We received 45 usable responses, which were then 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.

Control Variables: Team size and Stage of Team Development

Two control variables were used in this study because of their potential impact on knowledge integration effectiveness, namely team size and stage of team development. For team size, we asked VT leaders to indicate the number of individuals working in their VT, including themselves. For stage of team development, a discrete variable with five stage categories were created based on Sarker and Sahay's (2003) adaptation of Tuckman's (1965) team stage development model. VT leaders were asked to indicate which of the five developmental stages best reflected their team at the time to complete the survey. A brief definition of each stage of team development was provided.

Results

Data aggregation

When one uses individual level responses to assess collective phenomena, it is necessary to demonstrate empirically the correspondence between the level of measurement and the level of the theoretical analysis. To determine whether or not aggregation of individual responses to the team level was justifiable, two statistical tests were conducted. First, an Intra-Class Correlation (ICC) coefficient was calculated for all constructs of the model excepting the two control variables and VT performance. 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[25]. The IRA assesses within-team agreement for each construct within each VT, and is useful to answer to following question: "How high is within-team agreement on a given construct within a given team?" Common

[25] $r_{WG(J)} = J\,[1 - (s_{xj}^2/\sigma_{EU}^2)]\;/\;J\,[1 - (s_{xj}^2/\sigma_{EU}^2) + (s_{xj}^2/\sigma_{EU}^2)]$

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.

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 2 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 VT members' responses to the team level is appropriate. To do so, VT members' responses were averaged for each item of the constructs to create team-level measures. Note that for virtual team performance, a team score was obtained by averaging the values on the 8 items (see Figure 2) provided by the leader of virtual teams.

Table 2. Aggregation statistics

Constructs	ICC	IRA
Usage of IT for Integration Mechanisms		
Impersonal	$.07^{**}$	.96
Personal	$.12^{**}$	.96
Collective	$.09^{**}$	.97
Perceived task demand		
Interdependence	$.18^{**}$	.91
Non-routineness	$.07^{**}$	.91
Complexity	$.15^{**}$	.97
Common knowledge		
Task	$.10^{**}$	.97
Expertise	$.08^{**}$	.95
IT	$.10^{**}$	.96
Specialized	$.03^{\dagger}$	.95
Knowledge integration effectiveness	$.07^{**}$	.98
Team performance*	N/A	N/A

Notes: No IRA and ICC were calculated for team performance because the measure on that construct was provided by the leader of the team only.
† = significant at $p = .10$, ** = significant at $p < .01$

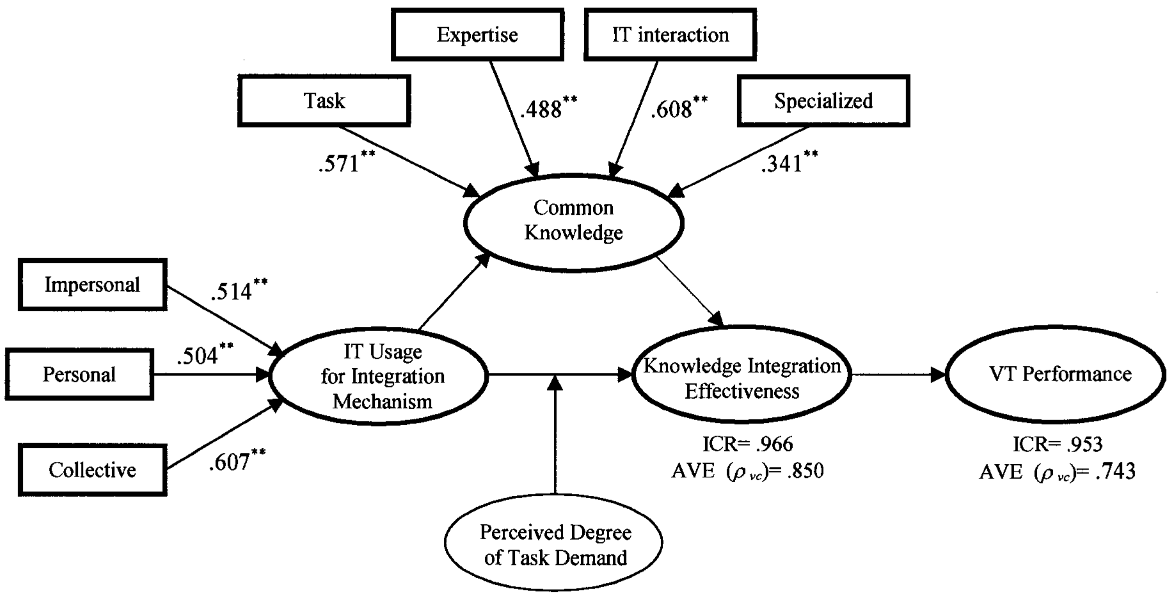
Measurement Model Assessment

The usable data collected from 102 VTs was analyzed using Partial Least Square statistical analyses (PLS). PLS is a second-generation structural equation modeling technique that is appropriate to simultaneously evaluate data and test theory that rely on latent variables, as is the case in the present study[26]. First, we assessed the overall convergent and discriminant validity of all aggregated scales. The results of PLS analyses with bootstrap set at 200 samples are shown in table 3. The loadings of indicators for reflective constructs (knowledge integration effectiveness, VT performance) exceeded the threshold value of 0.70 recommended by Nunnally (1978) and Hulland (1999). The internal consistency reliability (ICR) values for those constructs also exceeded 0.70, which provides support for convergent validity (Chin 1998, Hulland 1999). Discriminant validity was demonstrated using three sources of evidence. First, the ratio of the variance in the indicator for each relative to the overall amount of variance ρ_{vc} exceeded the threshold value of 0.5 prescribed by Fornell and Larcker (1981). Second, the square root of the shared variance between the constructs and their measures ($\sqrt{\rho_{vc}}$), shown as diagonal elements of Table 3, was greater than any inter-construct correlations found in off-diagonals of the correlation matrix. Third, we performed an exploratory factor analysis with principal components[27] including all the indicators used to measure the constructs of our research model. The factor analysis replicated the theoretical structure perfectly with all cross-loadings smaller than 0.40, which reinforces the evidence of appropriate discriminant validity across constructs.

[26] The software PLS Graph version 3.0 was used to perform the analyses.

[27] The factor analysis was conducted using a Varimax rotation and eigenvalues greater than 1 were used as threshold value for determining the optimal factorial structure. It is available upon request to the authors.

Figure 3. Measurement model



In the research model, two variables were modeled as second-order latent variables with formative underlying first-order factors, thereby generating what Jarvis et al. (2003) identified as a Type II model (p. 205). More precisely, IT usage for integration mechanisms and common knowledge development were operationalized as second-order latent variables with formative first-order factors. Following Jarvis et al.'s (2003) recommendations, we choose a formative conceptualization because the first-order dimensions of those constructs are not expected to covary and because they are not theoretically represented as manifestations of the same higher-order phenomena. Therefore, the degree of IT support for integration mechanisms usage was operationalized as a second-order latent variable with three formative first-order factors, namely impersonal, personal, and collective integration mechanisms. Similarly, common task knowledge, common IT interaction knowledge, common expertise knowledge, and common specialized knowledge were all modeled as formative first-order dimensions of common knowledge development given that variations in one dimension will not necessarily lead to changes in others. To obtain the first-order indicators for each sub-dimension, we generated factor scores in SPSS by performing factor analyses with principal components and Varimax rotation, and imported those factor scores in PLS as first-order indicators for their respective second-order factor. This procedure was used previously by Agarwal and Karahanna (2000), and is primarily attributable to the fact that PLS does not directly support second order factors. As shown in Figure 3, the weights linking first order factors with the second order factor were all significant at $p < .01$.

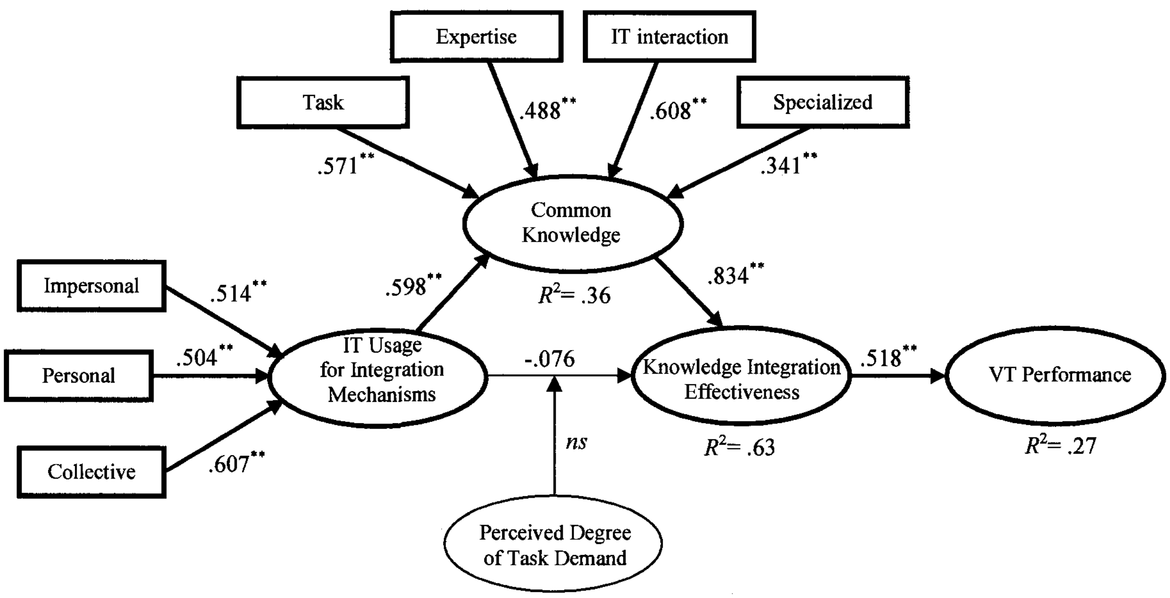
Table 3. Construct Psychometric Properties Using PLS Structural Analyses

#	Construct	Mean (1-5)	Std. dev.	AVE (ρ_{vc})	ICR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Team Size	10.956	7.686	-	-	-																
2	Stage of Team Dev.	3.798	.444	-	-	.096	-															
3	Degree of task Demand	3.399	.406	N/R	N/R	.198*	.072	-														
4	Interdependence	3.500	.545	.697	.873	.228*	.024	.760**	**.834**													
5	Non-routineness	3.022	.435	.722	.886	.124	.098	.724**	.245*	**.850**												
6	Complexity	3.676	.556	.948	.973	.113	.058	.879**	.495**	.563**	**.974**											
7	IT Usage for Integration mechanisms	4.268	.546	N/R	N/R	-.030	-.132	.225*	.310**	-.040	.220*	-										
8	Impersonal	4.313	.668	.844	.964	-.082	-.226*	.096	.247*	-.154	.090	.808**	**.919**									
9	Personal	4.465	.569	.750	.938	.045	-.030	.278**	.250*	.110	.277**	.825**	.445**	**.866**								
10	Collective	4.026	.695	.866	.970	-.028	-.070	.211*	.288**	-.035	.209*	.905**	.580**	.704**	**.931**							
11	Common Knowledge	3.865	.283	N/R	N/R	-.176†	.172†	.010	.065	-.112	.046	.565**	.439**	.484**	.514	-						
12	Task knowledge	3.863	.400	.835	.953	-.071	.231*	.009	.077	-.102	.023	.412**	.307**	.349**	.391**	.792**	**.914**					
13	Expertise	3.855	.397	.768	.930	-.152	.235*	-.035	-.015	-.026	-.041	.320**	.239*	.260**	.311**	.795**	.516**	**.876**				
14	Specialized	3.848	.285	.726	.914	-.178†	-.036	-.056	-.024	-.123	-.003	.298**	.220*	.290**	.253**	.682**	.382**	.445**	**.852**			
15	IT interaction	3.897	.399	.821	.948	-.150	.049	.092	.140	-.103	.149	.655**	.539**	.555**	.573**	.761**	.454**	.422**	.390**	**.906**		
16	Knowledge Integration Effectiveness	3.910	.394	.850	.966	-.063	.194†	.025	.088	-.080	.032	.410**	.315**	.308**	.413**	.804**	.675**	.691**	.572**	.507**	**.922**	
17	Performance	3.918	.705	.743	.953	.068	.281*	-.036	.028	-.155	.022	.176	.065	.124	.238*	.391**	.425**	.280*	.307**	.200†	.481**	**.862**

** = $p < .01$
* = $p < .05$
† = $p < .10$

It is important to specify that scale reliability is not a meaningful criterion for formative latent variables because there is no *a priori* expectation that first-order factors will correlate with each other. Therefore, consistent with Gray and Meister (2004), we did not use the average variance extracted (AVE) statistics and the index composite reliability (ICR) scores for assessing convergent and discriminant validity of the two formative constructs. Instead, we performed an exploratory factor analysis with Varimax rotation using all items for the aforementioned first-order constructs. All items loaded strongly on their theoretical construct, and cross-loadings were all under .40, thereby suggesting that discriminant validity is satisfying.

Figure 4. Structural Model



Bolded relationships display the significant effects.
** Significant at p<.01
N = 102 except for the relationship between knowledge integration effectiveness and VT performance, where n = 74.
The coefficient of -0.76 between IT usage for integration mechanisms and knowledge integration effectiveness is the one obtained for the whole sample.

Structural Model Assessment

The five 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 4. In line with the knowledge based theory, knowledge integration effectiveness significantly influenced VT performance (beta = .518; *t*-value = 7.068; $p < .01$), which provides support for Hypothesis 1. The direct impact of the degree of IT usage for integration mechanisms on knowledge integration effectiveness was not significant (beta = -.076; *t*-value = .730; *n/s*), thereby leading to the rejection of Hypothesis 2. In Hypothesis 3, we suggested that the perceived degree of task demand will moderate the relationship between the degree of IT usage for integration mechanisms and knowledge integration effectiveness. To assess the hypothesis, we tested the research model with two separate sub-samples, one including VTs operating in a low task demand context and another including VTs operating in a high task demand context. We adopted a "split sample" approach (Venkatraman 1989) because the use of multiplicative interaction terms at the item level (Chin et al. 1996) would have required a much larger sample size. It is also a manipulation that allows us to separate virtual teams into two different contexts, which can have important managerial implications. To generate the two task demand contexts, we divided the whole sample of VTs into quintiles based on the average value of task demand obtained for each team. The first and second quintiles, which included teams with task demand values ranging from 2.41 to 3.35 ($n = 40$), were used to form the set of teams operating in a low task demand context. The fourth and fifth quintiles were used to represent the high task demand context, and included VTs for which the average value of task demand ranged from 3.54 to 4.40 ($n = 42$). For both task demand conditions, the impact of IT usage for integration mechanism on knowledge integration effectiveness was non-significant once we controlled for the effect of common knowledge development, which indicates that Hypothesis 3 is not supported. Hypothesis 4 was supported, as common knowledge had a positive impact on knowledge integration effectiveness (beta = .834; t-value = 11.041; $p < .01$). Overall, 63% of the variance of knowledge integration effectiveness was explained by common knowledge. Hypothesis 5 was also supported. In fact, the PLS analysis demonstrates that IT usage for integration mechanisms had a positive and significant effect on common knowledge (beta = .598; t-value = 8.425; $p < .01$), and explained 36% of the variance of that construct. Finally, team size and stage of team development, the two control variables, had no effect on knowledge integration effectiveness.

After testing all research hypotheses, it appears that the impact of IT usage for integration mechanisms on knowledge integration effectiveness is fully mediated by the common knowledge. To provide additional validation to this full mediation argument, we performed post-hoc analyses based on Baron and Kenny's (1986) guidelines for assessing mediational models. In the first step, we tested the effect of IT usage for integration mechanisms (independent variable) on common knowledge (mediator). The effect was positive and significant (beta = .675; $t = 12.50$; $p < .01$), and 46% of the variance in common knowledge was explained by the degree IT usage for integration mechanisms. In the second step, we assessed the effect of IT usage for integration mechanisms on knowledge integration effectiveness (dependent variable). Again, the effect was positive and significant (beta = .432; $t = 4.31$; $p < .01$), and 19% of the variance in knowledge integration effectiveness was explained by the independent variable. In the third step, we tested the effect of the mediator on the dependent variable. We found that common knowledge had a strong positive impact on knowledge integration effectiveness (beta = .821; $t = 22.23$; $p < .01$), explaining 67% of the variance. Third, we performed a regression with both common knowledge and IT usage for integration mechanisms as independent variables. As suggested by Baron and Kenny (1986), full mediation holds when the independent variable has no effect on the dependent variable after controlling for the impact of the mediator, which is exactly what is depicted in Figure 4 where the structural model is assessed. In sum, the overall model testing and the post hoc analyses reveal that the impact of IT on knowledge integration effectiveness is fully mediated by common knowledge in VTs.

When looking at figure 4 and the very strong linkage between common knowledge and knowledge integration effectiveness, one might question whether or not discriminant validity was reached. To further assess discriminant validity, we generated an item-level cross loading matrix (Gefen and Straub 2005) that includes all items used for measuring common knowledge dimensions and knowledge integration effectiveness. The matrix is presented in Table 4. Although cross loadings are generally high, all items' loadings are higher on their intended construct.

Table 4. Loadings and Cross-loadings

	Common Expertise Knowledge (CEK)	Common IT Interaction Knowledge (CITK)	Common Specialized Knowledge (CSK)	Common Task Knowledge (CTK)	Knowledge Integration Effectiveness (KIE)
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**

Discussion

This paper started by arguing that the antecedents and impacts of knowledge integration effectiveness in VTs deserved deeper theoretical development and empirical validation. To address that issue, we developed and tested a model of IT-enabled knowledge integration in VTs that identifies two enablers of knowledge integration effectiveness, namely IT usage for integration mechanisms and common knowledge, and linking knowledge integration effectiveness to VT performance.

Consistent with the knowledge-based theory, we found that knowledge integration effectiveness had a positive impact on VT performance. This suggests that when VT members are able to effectively coordinate the use of their specialized knowledge at the team level, they are more susceptible to achieve higher levels of team performance. Contrary to expectations, we did not find a significant main effect of IT usage for integration mechanisms on knowledge integration effectiveness. In fact, there was no evidence suggesting that high levels of IT use for enacting integration mechanisms leads to high knowledge integration effectiveness once we controlled for the effect of common knowledge. Moreover, the degree of task demand has not emerged as a useful moderating factor that would help better understand the impact of IT on knowledge integration effectiveness. This is somehow surprising given that task demand has been found to moderate the effect of coordination mechanisms on team outcomes in numerous studies on collocated teams (e.g., Andres and Zmud 2001, Gittel 2002, Kraut and Streeter 1995). It is possible that variations in task demand conditions across teams were not stringent enough to increase the value of a greater extent of IT usage for integration mechanisms. Another explanation for the lack of significant finding could be related with the way the construct of task demand has been measured. More precisely, perceived degree of task demand was built using three task characteristics, namely task interdependence, task complexity, and task nonroutineness. It is possible that only one of these characteristics (for instance task interdependence) truly acts as a moderator of the relationship between

IT and knowledge integration effectiveness, in contrast with the aggregated scale formed of all three task characteristics. In other words, our aggregated measure of perceived task demand, although consistent with prior work on knowledge-based teams (Gray and Meister 2004, Lewis 2004), might confound the moderation analysis because its components might have different role in the model. Nevertheless, the empirical evidence suggests that IT usage for integration mechanisms positively influences knowledge integration effectiveness through a mediating variable, common knowledge.

Considering the significant percentage of variance explained in VT performance by knowledge integration effectiveness, the study shows that the examination of virtual teamwork through the lens of the knowledge-based view and its core phenomenon of knowledge integration provides a sound analysis of VT performance. This finding has implications for research on knowledge management in VTs. Thus far, most studies on knowledge management processes in VTs have focused on knowledge sharing (Cummings 2004, Majchrzak et al. 2000), knowledge transfer (Griffith et al. 2003), and knowledge creation activities within VTs (Malhotra and Majchrzak 2004, Majchrzak et al. 2005). Our research provides a complementary perspective of knowledge management activities in VTs, one that distinguishes from the above studies by its strong emphasis on the usage of specialized knowledge. In fact, while knowledge sharing and knowledge transfer frameworks are helpful to study the flow of knowledge that transits between organizational actors and the way knowledge is assimilated and learned by individuals, they do not address how knowledge items, once they have successfully transited between VT members, are being applied to an organizational task or used in combination with other knowledge inputs in order to generate team outcomes. Conversely, this idea of applying and using knowledge in a coordinated fashion within organizations is the focal point of the knowledge-based view. In the present study, this pragmatic perspective that distinguishes knowledge integration from other knowledge management processes has emerged as a valuable one to explain VT performance.

The full mediation effect of common knowledge offers some insights into the way to manage the knowledge integration process within VTs as well as interesting information about the role played by IT to facilitate this important activity. Within the teams we investigated, IT represented the main media through which communication and coordination activities were conducted, and therefore the main tool available to team members for building common grounds and shared understanding between them over time. Here, the evidence suggests that the use of IT to perform impersonal, personal, and integration mechanisms helped team members develop a shared cognitive representation about the attributes of the task and the required actions to perform in order to achieve it (common task knowledge), the distribution of expertise within the team (common expertise knowledge), the patterns of IT use for communication and coordination (common IT interaction knowledge), and the technical concepts proper to members' respective specialized knowledge area (common specialized knowledge). Then, this shared cognitive basis was used by individual members to apply their own personal knowledge to the collective task in a coordinated fashion at the team level, even though those individuals were not operating at a single work location. Because common knowledge had a strong effect on knowledge integration effectiveness, we invite researchers to look for alternative ways, beyond IT usage for integration mechanisms, to develop and maintain such common knowledge grounds within VTs. For instance, one way to extend the findings of the present research would be to look at the design characteristic of VTs (ex. functional diversity, cultural diversity, temporal dispersion) that affect common knowledge development.

Contributions, Limitations, and Future Research

This study contributes to research and practice on VTs in three main ways. First, it represents to our knowledge the first empirical demonstration of the premises of the knowledge-based theory to the realm of VTs. It extends prior conceptual contributions by Alavi and Tiwana (2002) by providing empirical evidence about the main drivers of knowledge integration effectiveness in VTs, and complements Haas' (2006) study of knowledge usage in multinational teams by looking at how team processes and states, in contrast to team composition factors, influence VT members' ability to coordinate the use of their knowledge inputs. The study also offers a set of new measures for assessing constructs relevant to knowledge-based VTs, such as IT usage for integration mechanisms, common knowledge, and knowledge integration effectiveness. Future studies on VTs that adopt a knowledge-based view of virtual teamwork might benefit from the use of those measures, refine them, and assess their role in other research frameworks.

A second contribution of this research is that it outlines the importance of accounting for key mediating factors that might explain and better contextualize the impact of IT on VT outcomes. In our study, we found that greater IT support *per se* does not automatically lead to increasing levels of knowledge integration effectiveness. Instead, what we found is that increased IT usage for integration mechanisms helps VT members develop and maintain common knowledge between them about various aspects of their team structure and processes, which then act as a strong antecedent of knowledge integration effectiveness. Stated otherwise, the resulting mediation model is helpful to explain *how* IT support affects knowledge integration effectiveness in VTs.

This research also has practical implications for leaders and members of VTs. At the broadest level, it shows that integrating knowledge in VTs is a critical organizational activity, for it is positively associated with the performance of existing knowledge-based teams in the field. It also suggests that distributed organizations that seek to leverage their intellectual capital through the use of VTs should manage the activity of knowledge integration on at least two different but complementary levels. The first level consists of performing the team processes that facilitate knowledge integration, which in the present case implied the reliance on three IT-enabled integration mechanisms. The second level concerns the team states that also facilitate knowledge integration, which we covered in the present analysis by the multidimensional construct of common knowledge. We recommend that managers of knowledge-based VTs adapt their teamwork protocols, methodologies, and internal training programs, if any, in such a way to rely on the IT-enabled integration mechanisms identified herein, and stimulate the development of common knowledge between geographically-dispersed coworkers.

The paper has some limitations that are worth mentioning. First, the cross-sectional research design makes all inference about causality impossible. Second, the fact that data was obtained from a single company can limit our ability to generalize the findings. However, the causal structure implied in our research model is well supported by the theoretical stances we drew upon as well as prior empirical studies that have built upon input-process-output frameworks of small group research (Guzzo and Dickson

1996). Regardless, a greater ability to generalize could be obtained by replicating key elements of the research models in other contexts using longitudinal designs, which we think should be a primary focus for future research on VTs. Third, the study only looked at the integration mechanisms usage that are supported by IT, which might only capture a subset of the behaviours that were enacted to facilitate the knowledge integration process in VTs. It is possible that some individuals coordinated their work using direct face-to-face interactions when teammates were at a same work location. However, 80% of the teams we surveyed reported that more than 50% of all communication and coordination activities they performed were mediated through information technologies, which suggests that IT usage for integration mechanisms represented a significant proportion of all integration mechanisms used by VT members. We think more research should be conducted on the complementary nature between IT-enabled and non IT-enabled integration mechanisms. Fourth, we did not incorporate into our model a measure of team virtualness (Kirkman and Mathieu 2005) that would discriminate VTs based on the nature of their members' distribution across time zones, functional units, sites, and other structural dimensions used to create indexes of team virtualness. Therefore, most of the conclusions drawn from our analyses can only be contextualized to a relatively broad VT context, one where team members are spread across more than one physical location. We encourage that future studies look at how findings obtained in the present research can be affected by varying levels of team virtualness.

Conclusion

For years now, IS and OB researchers have outlined the potential for VTs to leverage and integrate knowledge in distributed organizations. Yet, the scarcity of theoretical frameworks and empirical studies on the antecedents and impacts of knowledge integration effectiveness in VTs limits our understanding of the phenomenon. In this study, we developed and tested a model of IT supported knowledge integration effectiveness in VTs, and looked at the relationship between knowledge integration effectiveness and VT performance. By doing so, this research contributes to the current body of research on knowledge management in VTs by providing an empirical demonstration of the key drivers of knowledge integration effectiveness in such teams.

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CHAPTER V. Synthesis and Conclusion

Synthesis of the Dissertation

For some years now, virtual teams have captured the interest of both researchers and practitioners of several disciplines such as Information Systems, Management, and Organizational Behaviour. They do so in large part because they offer rich opportunities to leverage a firm's intellectual capital by bridging across geographical, temporal, functional, and cultural boundaries (Maznevski and Chudoba 2000, Townsend et al. 1998). Yet, best practices for the effective management of virtual teams remains to be defined, and the phenomenon of virtual team performance still deserves greater theoretical development and empirical investigation. Our goal in this dissertation was to play an active part in the stream of research on virtual teams by writing three complementary essays, where each provides a specific look at the phenomena of VT performance. The combination of those three essays offers a valuable synthesis of the current body of research on VT performance as well as new insights concerning the way to leverage specialized knowledge in such teams. The next paragraphs provide a brief summary of each essay.

Essay 1: Integration and Synthesis of the Empirical Research on VT Performance

In the first essay, an integrative model of virtual teams has been developed and used to synthesize the extant empirical literature on virtual team performance. The goal was to integrate the growing body of research on virtual teams into a manageable set of findings describing the key direct and indirect drivers of virtual team performance. The model proposed was built in such a way to be flexible enough to capture the most critical dimensions of virtual teams and explore in details how those dimensions interact together and influence different measures of team performance. Using a validated approach for reviewing the empirical literature (Webster and Watson 2002), we synthesized the empirical findings from 86 journal publications into a set of findings that outline the main antecedents of virtual team performance. Overall, this paper provides structure to research on virtual team performance, informs managers about some best practices for the management of virtual teams, and suggests some critical avenues for future research on virtual team performance.

Essay 2: A Conceptual Framework of Knowledge Integration in Virtual Teams

In the second essay, a theoretical framework of IT-enabled knowledge integration in VTs has been developed. This framework is anchored on the knowledge-based view of the firm (Grant 1996a, Grant 1996b), a theoretical stance that provides insight into the way to coordinate the use of individuals' specialized knowledge in organization, and discusses the benefits of this activity for sustained competitive advantage and work unit performance. To contextualize the use of the knowledge-based view to the virtual team environment, we relied on well-established frameworks of small group effectiveness (Cohen and Bailey 1997, Hackman 1987), literature on shared cognition and team mental models (Brandon and Hollingshead 2004, Cannon-Bowers et al. 1993, Salas et al. 2000, Wegner 1987), and studies on team coordination (Faraj and Sproull 2000, Kraut and Streeter 1995, Van de Ven et al. 1976). The framework identifies two main antecedents of knowledge integration effectiveness, namely IT usage for integration mechanisms and common knowledge, and suggests a positive relationship between knowledge integration effectiveness and virtual team performance. The main contribution of this essay lies in its theoretical value to research on virtual teams, as it provides a new integrative framework of knowledge integration effectiveness that builds on complementary theoretical stances relevant to the management of knowledge in virtual teams.

Essay 3: Knowledge Integration Effectiveness and Performance in Virtual Teams

In the third essay, an empirical test of the conceptual model of IT-enabled knowledge integration (second essay) is developed. The model was tested in a large multinational firm operating in the IT consulting industry who relies heavily on virtual teams to conduct important knowledge-based tasks such as software development, information systems integration, and business process re-engineering. To do so, a cross-sectional web survey was used to gather information from 700 individuals spread across 102 virtual teams about their use of IT to perform different integration mechanisms, the level of common knowledge developed within the team, the effectiveness with which their team has been able to integrate the knowledge of its members, the performance of their team, and other team level phenomena. The results show that the relationship between IT usage for integration mechanisms and knowledge integration effectiveness is fully mediated by the degree of common knowledge developed amongst members of virtual teams, but is unaffected by the degree of task demand perceived by individuals. Consistent with the knowledge-based view, we found that knowledge integration effectiveness was positively associated with leaders' assessment of virtual team performance. This essay contributes to research and practice on virtual teams in several ways. For instance, it is the first empirical assessment of the premises of the knowledge-based theory to the context of virtual teams. It also addresses a gap in the current research on knowledge management in virtual teams by identifying important team-level processes and emergent states acting as antecedents of knowledge integration effectiveness in virtual teams. Practitioners might also benefit from the findings of this study by adapting their teamwork methodologies, protocols, and leadership approaches in such a way to ensure the development and maintenance of common knowledge within the virtual teams for which they are responsible.

Theoretical and Practical Contributions

Theoretical contributions

This dissertation has several contributions for research in virtual teams. First, the review of the empirical literature on virtual team performance provides a much needed structure to a stream of research that has grown significantly over the last fifteen years, but that has also remained very diversified in terms of the topics investigated, the theoretical stances used to assess them, and the conclusions drawn in terms of key drivers of virtual team performance. Therefore, this dissertation makes the growing body of research on virtual team performance more accessible, both in terms of the conceptualization of virtual teams and the key factors that influence their performance. Second, the review section also underlines the importance of two generic principles for research on virtual team performance: (1) the criticality of differentiating between the various types of performance, and (2) the need for integrating the antecedents of those types of performance. For instance, our review informs researchers that design factors, emergent processes, and emergent states are often intertwined, and that one change in some of those components might have an impact on the others, and ultimately influence the performance of virtual teams. Researchers who develop new models and frameworks of virtual teams should be aware of the potentially complex relationships between antecedents of performance, and take more informed decisions to control for the effect of intervening variables and contextual factors acting on the main components of their models.

Another theoretical contribution consists in offering a new perspective of virtual teamwork that focuses explicitly on the coordinated use of knowledge inputs within such teams, which is referred herein as a knowledge-based view of virtual teamwork. This focus on knowledge usage shifts away from most of the work done to date on knowledge management in virtual teams, which have mainly looked at other important phenomena such as knowledge sharing (Cramton 2001, Cummings 2004, Majchrzak et al. 2000, Malhotra et al. 2001), knowledge transfer (Griffith et al. 2003, Sole and Edmonson 2002), and knowledge creation (Malhotra and Majchrzak 2004, Majchrzak et al. 2005). Each of those activities has its own set of potentially distinct success factors, and our study complements research into the aforementioned knowledge management processes by identifying key antecedents of knowledge integration effectiveness in virtual teams. In that sense, it brings additional breath to research on knowledge management in virtual teams, and does so by positioning the phenomenon of knowledge integration effectiveness as a main driver of virtual team performance.

Directly in line with the previous contribution, this dissertation is likely to benefit virtual team research by introducing new measurement scales for constructs relevant to the study of knowledge-based virtual teams, such as IT usage for integration mechanisms, common knowledge, and knowledge integration effectiveness. The process of developing those measures was made in accordance with established scale development methodologies used in the IS discipline (i.e. Churchill 1979, Moore and Benbasat 1991), which ultimately lead to the creation of measures having satisfactory psychometric properties. Those measures could be re-used in other research models in areas such as computer-mediated teamwork, team cognition and shared mental models, knowledge management, and of course virtual teams.

Practical contributions

This dissertation also has implications for managers and members of existing virtual teams in the field. For example, the review of the empirical literature on virtual team performance shows that the design properties of virtual teams can have important effects on team performance *via* team processes and states. More precisely, it was found that members' geographical, temporal, and functional dispersion combined with computer-mediation creates a context where the development of desirable emergent processes and states (e.g., effective communication and information sharing, absence of conflicts, shared understanding) become difficult. This suggests that managers should be aware of the potential consequences of the structural choices they make when they create virtual teams, and then take appropriate actions to attenuate the detrimental effects of team design characteristics as the team evolves.

Another practical contribution derived from the review of the empirical literature on virtual team performance concerns the way leaders of virtual teams could apply the findings of the review to their specific project objectives. By selecting the performance outcomes that they value the most given the nature of their team's work, leaders of virtual teams could use the model 'backwards', and look at the key teams processes and states that directly relates to those performance measures. In doing so, they can adapt the way they manage their team in order to make sure that the key team processes and states affecting those focal measures of performance will be taken into account carefully.

One practical contribution that emanates from the second and third essays is to position the phenomenon of knowledge integration effectiveness as a critical activity for distributed organizations that rely on virtual teams to perform knowledge-based tasks. In fact, we provided theoretical justification and empirical demonstration that knowledge integration effectiveness is positively associated with the performance of virtual teams. It means that firms that seek to extirpate the full value of their members' knowledge irrespective of their geographical location might do so by trying to optimize the coordinated use of their knowledge at the team level. To achieve that end, four dimensions of common knowledge relevant for knowledge integration effectiveness were identified, namely common task knowledge, common expertise knowledge, common IT interaction knowledge, and common specialized knowledge. We suggest that managers of virtual teams put special emphasis on the development and maintenance of those four aspects of virtual teams' shared cognitive basis. In the third essay, we found that the usage of information technologies to perform three integration mechanisms acted as a direct antecedent of common knowledge. In light of that finding, managers might consider implementing work protocols and methodologies that will facilitate the development of common knowledge through IT use.

Avenues for Future Research

We would like to conclude this dissertation by discussing some themes that we think would present insightful avenues for future research on virtual teams. The first area where we think more research is needed concerns the types of performance measures for which empirical findings are available. More precisely, we found that the empirical evidence about virtual team performance is heavily biased towards productivity-related dimensions of performance (quality of outcomes, creativity and innovation) and member satisfaction with team process. Conversely, less empirical support exists concerning the antecedents' team viability, individual learning, and personal development within virtual teams. Given the prevalence of virtual teams in the workplace, we suggest that researchers should devote more efforts to identify the key antecedents of those measures of performance that have, over the years, received little empirical coverage.

Second, although our integrative model of virtual team performance has outlined the importance of assessing bi-directional relationships between emergent processes and emergent states, we noticed that the empirical evidence is again biased towards a specific part of the model, namely the impact of emergent team processes on emergent states. However, much less is known concerning the impact of emergent states on team processes, and about the way such effects resonate into the performance of virtual teams. Examples of research questions that could address this gap include the following: *Do virtual teams with a high level of shared understanding require the same type of technology support than teams with a low level of shared understanding? Do teams with well established norms of IT use exhibit the same patterns of IT-enabled communication and coordination? Does the level of interpersonal trust within virtual teams reduce the* *need to formally control VT members' activities?* Those questions are examples of issues that would provide a more profound understanding of the role of emergent processes as a key antecedent of virtual team performance.

Given the strong influence of common knowledge on knowledge integration effectiveness, a third avenue for future research should consist in identifying other antecedents of this important construct. In our study, we limited our assessment of such antecedents to a single team process, namely IT usage for integration mechanisms. Even though we explained a significant proportion of the variance in common knowledge (i.e. R^2 = 36%), we think other factors beyond IT usage for integration mechanisms could potentially facilitate the development of common knowledge in virtual teams. 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 common knowledge development. Also, other factors associated with the interaction structure of the team might have an influence on common knowledge development, 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.

Concluding Remarks

Realizing this dissertation has been a great opportunity to generate some knowledge about key aspects of virtual teams and uncover important methodological issues inherent to research. We end this dissertation by providing some general thoughts and implications concerning the management of virtual teams and virtual teams research in general.

At the broadest level, this dissertation shows promising avenues for the future of virtual teams and their strategic role in distributed organizations. In fact, it has been found that the specialized knowledge held by distributed employees of a large multinational company can be leveraged effectively using virtual teams when the appropriate mechanisms are used to manage the work relationships of those individuals. Thus optimizing the integration of that expertise through the reliance on virtual teams should be seen as a fundamental activity in distributed organizations. Initially, this argument has been used as a main motivation for conducting this dissertation, and it has been later confirmed by the vast interest manifested by the managers of the partner organization who were involved in this research project. At the time of writing this dissertation, research reports are being disseminated to business unit leaders of the partner company, and the empirical findings are expected to be used in order to generate a set of best practices for the effective management of virtual teams. More precisely, managers intend to build on the conclusions of this dissertation to adjust, revise, and complement their existing teamwork methodologies and frameworks in order to be more effective at delivering worldwide services to their clients using virtual teams. This is a good example of an important practical contribution that directly emanates from the results of this dissertation, which represents a great source of personal satisfaction and a strong feeling of accomplishment.

On a different note, we found that conducting research about virtual teams triggers methodological challenges that deserve to be discussed. For instance, it became apparent to us that in spite of the prevalence of virtual teams at the partner organizations and the paramount importance of their global approach of delivering consulting services, the concept of virtual teamwork was not as widely understood as we expected among their managers. In several occasions, it has been necessary to explain in details the meaning of virtual teams, what they are, and what they are not. For instance, some managers had a wide conception of virtual teams that included working approaches such as telework and communities of practices. In the same vein, it was often difficult for managers to establish the boundaries of virtual teams when large projects were conducted using multiple virtual teams. Those situations needed to be clarified during communication sessions with managers of virtual teams in order to adjust our sampling strategy in the best possible way.

Another important learning point is related to the usage of an online survey, which also created some methodological concerns that are worth reporting. For instance, in order to avoid situations where respondents would have discarded our electronic mail invitations on the basis that they perceived this invite as unapproved solicitation, a thorough communication plan had to be developed by our research team and sponsored by top managers of the company. Although it has required important investments in time and energy, this communication plan has been very useful to stimulate the interest of the research project across the company.

To deal with the above methodological challenges, it is fair to say that the most critical success factor of this research project has been the strength of the partnership established with the participating company and the positive climate within which this project took place. In fact, some managers of the partner firm invested a large amount of time and efforts to help us manage critical phases of the project such as internal communication with business unit leaders and virtual team managers, identification of virtual teams for the study, and the creation of tailored research reports. At all time, the interests of both parties (researchers and practitioners) were taken into account and respected with great professionalism. Considering today's challenges of conducting research in real organizational settings, it is clear that a strong and healthy relationship with a large distributed firm such as the one we worked with remains a priceless asset. But ultimately, the most interesting aspect of this research endeavour consisted of the mutual learning process that took place between practitioners and researchers throughout the project. In fact, some managers mentioned that they were excited and proud to play a part in an academic research project, and others were extremely happy to receive professional advices from academics in order to help them improve the effectiveness of their current and future virtual teams. From a research perspective, this project has been an extremely rich opportunity to cumulate data about the performance enablers of "real" virtual teams, and has allowed us to establish strong ties with a well-established company of the consulting industry, which might lead to other research projects in the near future.