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Table of Contents

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Combining Technologies' Properties to Cope with Uncertainty:
Lessons from the Military

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ABSTRACT

This article investigates how teams aim at harnessing Information and Communication Technologies (ICTs) to coordinate under uncertainty. An explorative case study analyses the way NATO Special Forces use text-chat in Afghanistan. The findings suggest that team members combine basic material properties, knowledge processes and knowledge types to cope with various forms of uncertainty. Such combinations might trigger the emergence of unexpected biases which, in turn, generate mitigated final results. Building on the authors' findings, they develop a model of ICTs' uses based on the concepts of emergence and combination.

KEYWORDS:

Case Study, Information and Communication Technology, Knowledge Management Process, Technologies' Properties, Uncertainty

1. INTRODUCTION

Scholars widely acknowledged that Information and Communication Technologies (ICTs) provide organisations and teams with additional capabilities to manage organisational issues (Zack and McKinney, 1995; Pickering and King, 1995). Considered as "technologies of coordination" (Ciborra, 1993, p. 63), ICTs are likely to support organisations' decision making procedures and knowledge management processes (Li and Ye, 1999; Dewett and Jones, 2001; van den Hoof and Huysman, 2009). In particular, it has been suggested that ICTs provide teams with technological solutions to face various forms of uncertain – namely ambiguous, equivocal, vague, fuzzy or dissonant – situations (Daft and Weick, 1984; Daft and Lengel, 1986; Zack, 1994; Gittel and Weiss, 2004; Cronin and Weingart 2007; Weick and Sutcliffe 2007). Despite extensive research on the nature and logics of ICTs capabilities within organisations (see Merali et al., 2012 for a survey), we suggest there is still a need to improve our understanding of how teams make use of ICTs to manage various forms of uncertainty.

This article examines how teams aim at harnessing the capabilities offered by ICTs to handle the various forms of uncertainty which shape their daily work environment. To study the addressed research question, we conduct an explorative case study in the field of military operations. We focus on operations in Afghanistan as they represent the opportunity for the NATO forces to use a bundle of new and sophisticated ICTs. Our case study analysis indicates that ICT's uses emerge as the outcome of individuals' daily experimentations with the technology. We therefore contend that technology uses are emerging phenomena resulting from the interaction between users and a number of socio-material properties attached to the technology, including knowledge processes, knowledge types, and knowledge structures. As a result, it is suggested that the "making" of technological uses is rooted in

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a situated process (Orlikowski, 2000) consisting in combining socio-material properties in order to mitigate the effects of uncertainty on teams' coordination and decision-making.

We begin by describing the ways ICTs enable teams to manage uncertainty, including ambiguity. Then, we present the research method and develop a single explorative case study, focusing on the uses of text-chat during military operations in Afghanistan. Finally, we elaborate on a model of ICTs' uses relying on emergent combinations of practices, and discuss its main implications for scholars and managers.

2. CHARACTERISING UNCERTAINTY AND KNOWLEDGE MANAGEMENT TECHNOLOGIES: CORE CONCEPTS

Investigating how teams' members use ICTs to deal with uncertainty involves getting deeper into the interplay between users' creativity and technological opportunities. Next sections discuss the concept of uncertainty and identify core functions and knowledge processes attached to ICTs.

2.1. On the Various Forms of Uncertainty

Complex systems are made up with a variety of elementary units or components interacting in a complex way and collectively producing behaviours that appear to be fundamentally unpredictable (Simon, 1969). Building on Cilliers' (1998) contribution, Chapman (2007, p. 1071) indicates that social, physical, biological and artificial complex systems share common attributes:

- Their architecture is constituted by a large number of elements.
- These elements (or components) interact dynamically and non-linearly.
- They are linked together through feedback relationships.
- Each element is ignorant of the behaviour of the whole system.
- The latter operates far from equilibrium according to historical time processes.

Complex systems do not exhibit clear-cut boundaries, their architecture (e.g., systems' elementary units and the relationships among them) remaining fuzzy as interdependencies and interactions among units multiply in the face of changing – internal and external – conditions (Dekker et al., 2011). In addition, complex systems are likely to exhibit emergent behaviours which, in turn, enable them to adapt to environmental perturbations and preserve their functional integrity and identity (Holland et Miller, 1991).

Examples of complex systems embrace modern organisations, particularly military ones[1]. Indeed, organisations are made up with a variety of elements, including individuals and teams, technologies, departments and divisions, routines and capabilities that interact and get coordinated to deliver specific outcomes (e.g., goods and services). In that view, required knowledge to behave as an _haracter and organising entity is distributed across multiple elements, comprising human, time, space, material and immaterial resources. Within this framework, many scholars consider that "organizations are open systems that process information from the environment" (Daft and Weick, 1984, p. 284). However, since modern organisations' environment is – at least – partly-unpredictable (i.e., not "analyzable" in the words of Daft and Weick, 1984) organisations confront important challenges related to information gathering, coordination and decision making.

Within complex _haracterizes_ environments, organisations might lack relevant information about their environment and even when they obtain information, they may be unable to interpret it unambiguously. Daft and Lengel (1986, p. 559) suggest that "information processing in organizations is conceptually more than simply obtaining data to reduce uncertainty; it also involves interpreting equivocal situations." In other words, organisations might not be capable of identifying the components of a given situation and/or establishing clear relationships between them, and even if they could, they might also fail to make sense of what they know, and interpret the situation unambiguously. What results from the foregoing discussion of the organisations as complex information-processing systems is that _haracterizes_ settings are likely to exhibit uncertainty (Weick, 1979; Eisenhardt and Martin, 2000; Daft and Lengel, 1986; Zack, 2001; Weick and Sutcliffe, 2007).

According to Brown and Utterback (1985, p. 304-305), there are a number of approaches to uncertainty in organisation studies. For example, the authors mention Duncan (1972), who considers uncertainty as a measurable variable involving the interplay between a decision-making agent and its external environment. Broadly, scholars put particular emphasis on both information regarding environmental complexity and dynamism, and decision makers' perceptive and cognitive capabilities (Ross et al., 2013).

We therefore discriminate between two forms of uncertainty: information-based and cognition-based. Information-based uncertainty _haracterizes situations in which decision-makers do not possess exhaustive and complete information sets regarding the architecture and evolution of the internal and external environment. Under uncertainty, decision makers lack information. As Ross et al. (2013, p. 966) argue, "uncertainty can be thought of as being the inverse of information". This form of uncertainty is linked to the intricacy of the internal and external interactions between teammates and other teams constituting organisations, and their environment as a whole (Adler et al., 2011). In particular, it includes situations of incomplete and imperfect information regarding:

1. The number of actors involved in coordination and decision-making,
2. The geographical dispersion of their activities, and
3. The integration of contingent behaviours within plans and decisions.

Cognitive-based uncertainty emerges when decision-makers lack the knowledge required to make sense of – and perfectly anticipate on – the consequences of their decisions on the internal and external environment. This form of uncertainty is based on individuals' and teams' perceptive and interpretative shortcomings and (potential) failures (Conin and Weingart, 2007). These failures are often due to a dissonance among the variety of psychological states (e.g., stress, emergency, crisis) and models making up cognitive structures shared by organisations' teams and team-mates. It also refers to communication failures when formal and informal relationships and knowledge exchanges between individuals within and across teams require rich interactions and strong knowledge-sharing mechanisms (van den Hoof and Huysman, 2009). This cognitive form of uncertainty is likely to generate misunderstandings and coordination failures.

Within this framework, acquiring more information about a situation tends to mitigate the effects of informational uncertainty. However, accumulating information does not prevent decision-makers from being affected by cognitive forms of uncertainty. Weick et al. (2005) suggests that confronting cognitive forms of uncertainty (e.g., ambiguity, equivocality) require individuals and organisations to make sense of the internal and external environment, the latter being necessarily shaped by individuals' and organisations' agency and interpretative capacities. It follows that mitigating the impacts of uncertainty requires at least two interrelated processes: (1) accumulating information about internal and external environment and (2) developing individual and collective knowledge to reduce perceptive and interpretative biases.

Since they play a major role in storage, transformation, dissemination and creation of both information and knowledge (Lloria, 2008), information and communication technologies (ICTs) are likely to affect the way teams cope with these two forms of uncertainty.

2.2. Handling Uncertainty from Knowledge Management Technologies

In providing information treatment, storing and access as well as communication facilities, ICTs can be seen as facilitators of information and knowledge generation as well as collective sense-making (Cecez-Kecmanovic, 2004; Gorry, 2009). For example, in promoting effective discussions on problem solving, Web 2.0 tools allow reducing cognitive-based uncertainty: decision making among team is supported through joint knowledge-intensive processes, which enable members to capture, share and convert different conceptual schemes into action (Shen et al., 2012).

In the literature, many classifications seek to associate knowledge management strategies and processes to a set of dedicated technologies (Venters, 2010). For instance, Zack (1999) displays a model built on two knowledge processes: integrative and interactive. Integrative knowledge process refers to management of existing stocks and sequential flows of explicit (declarative) knowledge. Explicit knowledge is codified, documented, transferred and easily shared. Decision-support technologies, such as up-grading databases, on-line management information systems, tactical navigation aids, provide useful resources to integrate and manage explicit knowledge. Decision-support tools allow teams to:

1. Store and retrieve large amounts of knowledge,
2. Combine and reconfigure knowledge so as to create new knowledge, and
3. Use decision models stored as expert systems (Power and Sharda, 2007; Godé and Lebraty, 2013).

The second knowledge process is called interactive by Zack, concentrating primarily on supporting interactions among individuals holding tacit (procedural) knowledge. Accumulated from experiences and actions, tacit knowledge is difficult to articulate and share. Communication technologies, such as text-chat, email, video-teleconferencing, generate interactive knowledge processes in allowing teammates to share a part of their tacit knowing. They support (1) communication across time and geographical location with greater precision to target groups and (2) participation and control in networks (Huber and Crisp, 2003). As collaborative and communication tools, such technologies make the conversion of tacit knowing into explicit knowing easier, and reduce the probability of misinterpretations to emerge.

Drawing on Nonaka and Takeuchi's (1995) knowledge life-cycle, Marwick (2001) develops another typology, relating appropriated technologies to each phase of the SECI spiral:

- Groupware for socialisation since tacit knowledge is usually shared by means of face-to-face communication;
- Externalisation can be efficiently support by on-line discussion forum which turns into explicit knowledge the participants exchange;
- Simulation system assists internalisation in helping them better understand the explicit knowledge obtained; and finally
- Combination – which is the one best process supported by ICTs, Marwick (2001) argues, due to the fact that it only deals with explicit knowledge – can be usefully sustained by audio and visual capturing technologies.

For their part, Alavi and Leidner (2001) and Alavi and Tiwana (2003) focus on the potential of Information Technologies in successfully supporting creation, storage, transfer and application of knowledge in organisations. What the authors call Knowledge Management Systems (KMS) refer to "a class of information systems [...] developed to support and enhance the organizational processes of knowledge creation, storage/retrieval, transfer, and application" (Alavi and Leidner, 2001, p. 114). KMS are considered as tools to create an infrastructure for knowledge management processes. In this way, collaboration support systems are appropriate tools to enhance knowledge creation process in facilitating integration among participants and combining their individual knowledge. In addition, data warehouses and data mining fit with the knowledge storage and retrieval process, in converting and analysing large volume of raw data into interlinked information. The knowledge transfer process is also supported by technologies which enable transfer between individuals, individuals and knowledge repositories and between these repositories, as communication support systems and web-portal. Finally, expert-systems or decision-support systems assist the knowledge application process, which refers to the use of knowledge for decision-making and problem solving.

As such classifications point out, the interplay between technologies and knowledge may be investigated in terms of knowledge processes and technologies' properties (Kimmerle et al., 2010). However, although their deep interest, these typologies tend to establish a rather deterministic link between knowledge and ICTs, primarily addressing the question of their alignment. In doing so, they promote a linear cause-effect relationship, from which technology constantly produces the predicted (or near predicted) effect (Orlikowski, 1992), neglecting other key elements such as users' motivations and needs (Baskerville and Dulipovici, 2006). Technologies are just a part of the story, organisational structures and routines as well as work practices being equally relevant. In that way, understanding the role played by technologies to mitigate the effects of uncertainty and sustain knowledge processes requires turning more attention to "technology-in-use" (Tyre and Orlikowski, 1994, p. 98) that is users' efforts to apply technologies to their environment. Such a perspective gives the opportunity to closely apprehend the way users adapt and appropriate technology to their specific and contextualised needs. It also revealed the potential gap between technologies as they have been conceptualised by designers and as they are concretely used and transformed in situation.

This article draws upon a theoretical framework in line with the "practice lens" (Orlikowski, 2000) and the socio-materiality of technologies (for example, Leonardi and Barley, 2008; Vieira da Cunha and Orlikowski, 2008; Leonardi, 2011). As Orlikowski argues: "Through their regularized engagement with a particular technology (and some or all of its inscribed properties) in particular ways in particular conditions, users repeatedly enact a set of rules and resources which structures their ongoing interactions with that technology" (Orlikowski, 2000, p. 407). Technologies are socially constructed through individual and collective uses. They are not viewed anymore as a part of a process in which work practices become more knowledge efficient thanks to classifications and others typologies. They both support and transform social practices and knowledge flows in the situated action. Moreover, the socio-materiality perspective insists on the fact that technology is a material artefact, reconciling the material property of ICTs with the social needs of users. This realignment of the social and material view of technology allows asking how "knowledge practices are shaped by the affordances and constraints of material features within the social construction of reality" (Venters, 2010, p. 163). Such a theoretical framework leads concentrating on the uses of ICTs teams develop in situ to handle informational and cognitive-based uncertainty.

In the next section, we report a case study that we designed and deployed to meet the ways military teams use Internet technologies during operational missions. The rest of the paper describes the technology, its experimentation on war theatre, and its main managerial and theoretical outcomes.

3. CASE SETTING AND METHOD

In Afghanistan, NATO forces are involved in two distinct and running parallel operations: (1) Enduring Freedom is a U.S.-led coalition action supporting counterterrorism after 9/11 events and (2) the International Security Assistance Force (ISAF) is intended to bring stability in Afghanistan and to prevent the emergence of terrorist cells in the region. Through these operations, the main coalition goal is to pass Afghanistan's security over to its people.

In the Afghan theatre, NATO forces face asymmetric fights against a highly dissimilar adversary. The tactical situation changes in accordance with nonlinear dynamics and unexpected contingencies. Given these circumstances, collection and process of the right information at the right time are of the highest importance. Massively implemented in the weapon systems and command centres, ICTs play a crucial role when enabling to share and deal with a significant amount of information ever seen. The Afghan theatre has been an opportunity for NATO forces to improve a new model of warfare, called Network Centric Warfare (Alberts and Hayes, 2003). It consists in exploiting Internet technologies in order to collect and disseminate real-time information, being available to military teams anywhere at any time. Internet technologies gather various web-based tools as modern collaboration systems (text-chat, email, video-teleconferencing, Voice over Internet Protocol), computer decision-support aids (Tactical navigation aids, automated interfaces to training and simulation systems) and up-grading databases (modification, filtering, and storage of graphics, text files, tactical environment and target data).

Our case especially investigates usages of one of the components of Internet technologies, namely chat (Conversational Hypertext Access Technology) or tactical chat. Tactical chat is a real-time, multi-participant tool for textually communicating among military units. It sustains synchronous conversations in a lightly manner. Messages are sent over a networked server called Internet Relay Chat (IRC), which also represents a set of communication protocols. Anyone with a computer, a network connection, and compatible tactical chat software is able to communicate textually with others teams dispersed on the battlefield. Even if NATO forces have used tactical chat since 1990s, it outpaced other systems in Afghanistan (in particular voice communication), to become the main communication path, particularly when circumstances hamper information that would usually pass over radio or phone traffic. For instance, during Iraqi operations (Operation Enduring Freedom), there was just one IRC server in the Navy's Fifth Fleet that average 300 chat users; in 2006, during Afghanistan operations, fours servers where installed, supporting around 3000 navy users and 400 chat rooms (Eovito, 2006).

U.S. Army, US Navy as well as French and U.S. Special Forces especially experiment the benefits of tactical chat during Close-Air Support (CAS) missions. CAS consists of an air action against hostile targets which are in close proximity to friendly forces. Being targeted by enemy ground fire, war-fighters act under time-sensitive pressure and hostility. Supporting real-time and secured communication, tactical chat has rapidly become the main channel of communication and information gathering.

As Scarborough asserted: "A number of military [...] management practices might directly improve a number of perceived or actual weaknesses in business management" (Scarborough, 1993, p. 271). In effect, military organizations run within highly demanding environments, where time pressures are severe and errors only tolerated at minimum rates. Tactical Internet is used by the military as an effective set of decision-making and coordination technologies which enables dispersed teams to achieve tactical goals within highly austere conditions. As such, our case study provides significant insights for a variety of distinctive organizational contexts (medical health care, fire brigades, sport teams, nuclear plants, etc.) within which responsiveness and adaptability are decisive success factors (see for example Thomas et al., 2001; Faraj and Xiao, 2006; Bouty et al., 2012).

We based our research on two different contracts funded by the French ministry of Defence. The first one, produced between 2005 and 2006, focused on the Network Centric Warfare (NCW) doctrine. The ministry gave us mandate to explore the impacts of Internet Technologies on NATO military organizations (especially US forces) in terms of structural and technological changes. We were expected to come up efficient results and issues, the latest in order to prevent French forces from problematical conditions. The second contract, carried out between 2009 and 2010, concentrated on the introduction of French weapons' systems (for example, the fighter aircraft Rafale) and Information systems (for example, the NATO tactical data links called Liaison 16) into the networked environment. We designed our case study from data collected during these two researches and scientific monitoring we pursue ever since.

We conducted an extreme single case study (Yin, 2003), allowing us "to explore a significant phenomenon under rare or extreme circumstances" (Eisenhardt and Graebner, 2007, p. 27). The single-case study is appropriated when observers have access to a phenomenon that was previously inaccessible. For its part, the extreme case is well-suited for revealing detailed information and getting a point across in unusual and especially problematic circumstances, which activate a variety of actors and basic mechanisms (Flyvbjerg, 2006). Military organizations represent an environment difficult to get into, and a rare opportunity to analyse the way military teams manage complexities from technologies on the battlefield.

To design our case study, we used mixture data collection methods to achieve triangulation (Table 1) and enhance confidence in our findings (Eisenhardt, 1989):

- We selected interviews dedicate to Internet technologies on the battlefield. Relying on a semi-structured interview guideline, we first conducted three collective interviews (between three and six people) within the French Air Force, Naval and Army command-in-chief in 2006. The interviews lasted between 4 and 6 hours. Officers described their experiences in the Afghan theatre, either within tactical command and control centres, or in the field. We especially focused on the introduction and usages of Internet technologies and tactical chat. Our goal was to understand how these technologies affected their work practices, fitted – or not – with their needs and the ways they handled them. Their testimonies were valued since they all shared command and/or field missions with US and British forces. As such, even if we have not had the opportunity to meet other NATO officers, we gathered relevant information. Three years later (2009), three follow-up individual interviews were achieved - two with French air force and one with French army officers back from the Afghan theatre – to confirm or contradict intermediate results. Collective and individual interviews were transcribed and checked for accuracy. These verbatim being classified, the rest of the paper presents some interviews' extracts from US professional reviews and reports.
- Next, reviews of professional journals were performed from 2005 to today. The main reviews are: Parameters, Military Review, Naval War College Review, Joint Force Quarterly, Air & Space Power Chronicles, Rand review. We also gathered and analysed institutional and doctrinal documents, published on line. For instance: thesis from the Naval Postgraduate School, reports from the Air Land Sea Applications Center, the Command and Control Research Program and the US Department of Defense, Chairman of the Joint Chiefs of Staff Instructions as well as

Table 1. Description of collected data

Quality	Quantity	Period of Collection
Collective interviews French Air Force, Naval and Army command-in-chief	3	Over 2006
Individual interviews French Air Force officers	2	January 2009
Individual interview French Army officer	1	February 2009
Professional reviews	6 sources	From 2005 to today
Doctrinal reports	10 sources	From 2005 to today
After Action Reports French and US forces	7	From 2005 to today
Briefings NATO standardization of information systems	2	2006
Meetings French special forces	2	2006 and 2010
NATO workshop Science and Technology Organization (STO)	1	2011

several classified manuscripts. Further, we analysed After Action Reports (all classified) from American and French officers in Afghanistan, which balanced the "official" viewpoints provided by doctrinal records.

- Finally, observations shadowing were achieved during:
  - Two briefings concerning NATO standardisation of information systems (especially communication devices) and their current uses in theatre,
  - Two meetings of French Special Forces reporting their recent experiences in Afghanistan and
  - One workshop planned by the NATO Science and Technology Organization (STO), Systems concepts and integration panel, in 2011. This workshop was concerned in advancing knowledge with regard to the integration of Internet technologies across the spectrum of platforms and operating environments.

All of these data collection methods allowed us to gather an important amount of data. In order to examine how teams make use tactical chat to manage various forms of complexity, we investigated the "continuous interplay between data and concepts" (Van Maanen, 2007, p. 1149), exploiting our data to question established theory and move on towards new knowledge and some kind of theoretical understanding. Seeking to give sense from our data, we combined three different analysis strategies – narrative, grounded theory and synthetic – as described by Langley (1999). We have recourse to narrative strategy to organize our data and clarify sequences across levels of analysis. Grounded theory (Strauss and Corbin, 2008) involved the systematic comparison between our data in order to gradually elaborate and refine our categories. Finally, synthetic strategy allowed us to reflect upon our data analysis, and construct a model from identified regularities.

We first transcribed data collected from tape-recorded and written interviews, and structured our observations and field notes. From that raw material, we organised our analysis in two main steps: coding and writing monographs. Concerning the coding, analysis of the interviews, observations and field notes was conducted using NVivo8 software. We completed our analysis in a bottom-up perspective to foster the emergence of our categories. During the whole coding process, we followed an iterative and comparative approach in order to identify regularities. Concerning the second step of data analysis, a monograph was produced for each interview and sent to interviewees. Feedback allowed us to refine our observations and go deeper into our understanding of the tactical chat usages.

4. CASE STUDY FINDINGS

The data analysis reveals two first level themes, which can be detailed in second level categories. First, to manage uncertainty, we observed that final users of tactical chat develop adaptive uses through the implementation of a combinative process. More particularly, they turned a communication tool into coordination and decision/execution-support systems, articulating technological properties to fulfil their needs. Second, we report unexpected information and cognitive biases resulting from final users' appropriation of technology, mainly due to information dependencies and perceptive issues.

4.1. Revealing Tactical Chat's Coordination Processes

Let us start with an example of tactical-chat uses as being observed on the battlefield. During a recent deployment in Afghanistan, a Special Forces team was notified that a forward ground element was taking fire. It requested Close Air Support (CAS), using the dedicated tactical chat room to report to the command and control centre (C2). Thanks to grid location and threat details passed by Special Forces, C2 used multi-chat rooms in order to send two fighter aircrafts overhead and plan their refuelling. Aircrafts' pilots received the updated tasking and achieved the mission in a fraction of time it would have required using the voice communication method. While Special Forces wait for the aircraft, they simultaneously receive and process tactical information which is shared by commanders in real-time, and can be potentially used to (re)allocate air assets (adapted from classified French after action reports and vignettes provided in MTTP – DoD, 2009).

As this example states, tactical chat is primarily used by teammates to coordinate each other's during phases of preparation of missions. Teams' members and command and control officers send and ask detailed information and, if needed, adjust the conduct of missions in real time. Teams-on-the-ground receive detailed orders related to tasks they have to achieve. All these actors aim at sharing a variety of information related to the current tactical situation and its potential changes. This information can be: pictures collected from Unmanned Air Vehicles (UAV or drones) drones, weather forecasts, targets identification, etc. Interactions between users take place within various chat-rooms, which are single forum with users communicating for a specific purpose or function (see Figure 1).

At first implementing as a communication tool in order to support logistics planning, tactical chat grew from the bottom up to become a coordination artefact; today, it is used to coordinate tasks, collect and distribute information to multiple groups, both up and down echelons. This means there was no initial standards or design effort towards coordination. War-fighters "unofficially" deployed these uses when they realised that chat could sustain much more than logistical conversations (Naval Post-Graduate School after action report).

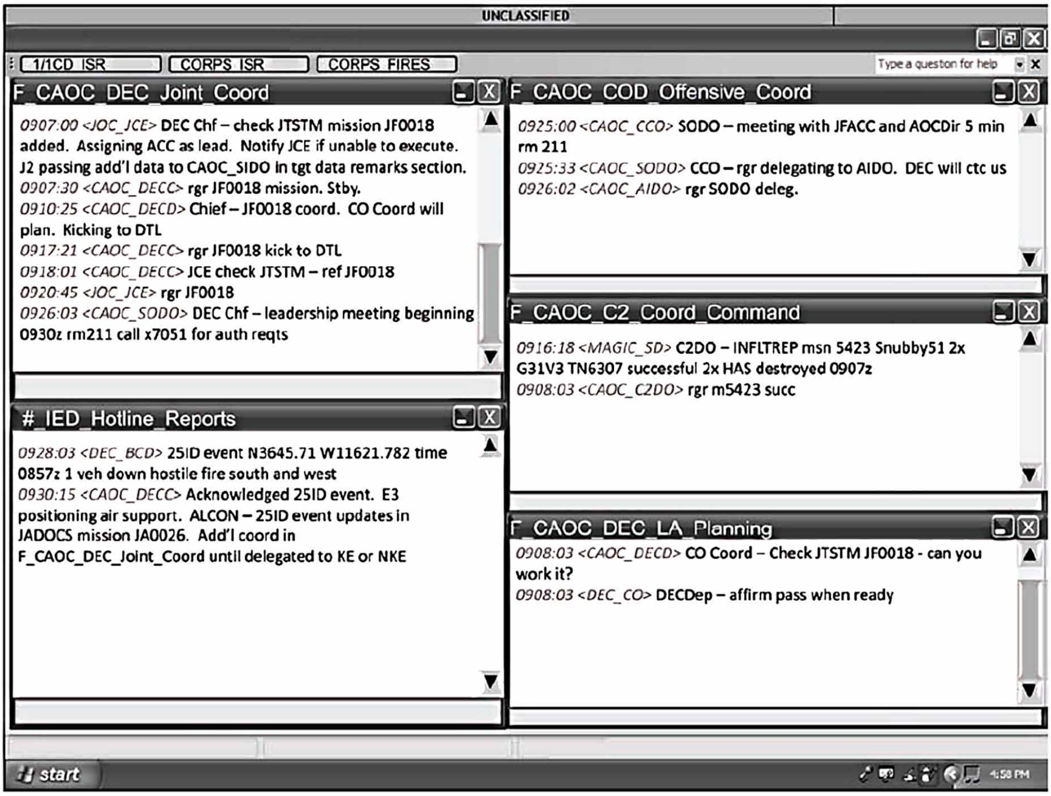
The development of chat "as-practice" makes coordination uses to come up thanks to material properties identified and combined by users to fulfil their needs. The first material property is concerned with the multiplicity of chat rooms allows users to obtain what they call the "Common operational picture". That is a visual picture of the unfolding battlefield which shows to participants the locations and movements of unit troops on the ground, along with extra real-time information. There are three basic types of chat rooms: (1) officials' ones, which are approved and consist of command chat rooms. They are permanent and dedicated to specific missions; (2) "unsanctioned chat rooms are those created by users to temporarily augment official rooms and facilitate discussion outside of the approved tactical chat structure" (MTTP – DoD, 2009, p. 14); finally, (3) users can conduct private chat, commonly called "whisper". Private chat allows discussions apart from officials and unsanctioned chat rooms. It is often used as a detailed coordination space, a team-to-team coordination way of doing. Multiple chat rooms allow users to obtain information from heterogeneous sources and to efficiently apprehend movements of troops. As an officer deployed with the Task-Force 50 explained: "Chat was awesome. Chat [was] like getting 20 new radios and being able to work all at once" (Abridged report – DoD, 2008, p. 9).

A second material property is that tactical chat serves as a kind of database. Indeed, chat is able to automatically create a record of the conversations that users can refer back to for clarification or even review later for after action analysis. Such a recording property provides a continual sharing and learning platform. As one user stated, "the chat is better because it gives history, and you can watch things unfold in near-real time" (Abridged report – DoD, 2008, p.8). During the debriefing phases, chat enables remote war-fighters and commanders to exchange personal experiences and opinions. It provides them with the opportunity to collectively discuss coordination successes and failures, even criticise tactical choices. These formal and informal exchanges trigger conceptual knowledge sharing.

Lessons from the Afghan theatre show that war-fighters have adapted tactical chat properties to their operational needs and constraints. From an oriented web-based tool enabling synchronic communications, remote users have developed a complete coordination system, allowing both information processing and knowledge sharing.

Notwithstanding growing opportunities offered by tactical chat, its impact is far from being perfect. Users also report significant issues related to the exploitation of coordination uses. In particular, perceptive and interpretative users' capacities could be disturbed. For example, conversational pauses during chat exchanges can be misinterpreted, and introduce unwarranted confusion in coordination. When a team fails to answer to a text message, the sender may misinterpret this lack of response as a disagreement with its statement while it is just as likely that the message receiver was concentrated on another task (Scott et al., 2006). These situations are more likely to occur since chat introduces

Figure 1. Five chat rooms of tactical chat (MTTP – DoD, 2009, p. 32)



additional tasks to be accomplished. These tasks are related to collecting, processing, and interpreting a growing quantity of information. In this case, users must interrupt their current activities and clarify the situation. This requires additional effort and may be disruptive if information is provided at an inopportune moment (Eovito, 2006). Therefore, coordination costs increase and can affect mission effectiveness. These illustrations highlight the limits of tactical chat's coordination uses and the unexpected cognitive biases emerging from operators' technological uses.

4.2. Developing Text-Chat's Decision/Execution Processes

Together with the coordination process, tactical chat has been progressively used to transmit and execute orders. As an execution tool, the ability to send information and exchange knowledge to a large base of users in different rooms facilitates the timely and accurate dissemination of commands. For example, tactical chat is today used for targeting the enemy and receiving clearance to fire. Rather than talking several minutes with different command centres to initiate fire, military teams on the ground use tactical chat to request clearance in a matter of seconds.

As we can see in Table 2, a fire mission request ("Immediate fire mission") is sent at 03h31.27 to the Control and Reporting Centre (CRC) which works to deconflict the airspace. When the CRC reports that the space is clear ("Resolute all clear) at 03h31.57, the fire mission is completed ("complete") at 03h32.04. The whole process will take less than one minute.

Tactical chat supports the decreasing of target execution timeline by enabling decision made on real time information from multiple sources. Moreover, the system reduces misunderstandings of the command intent since users have it written before them; time is saved from clarifications and

Table 2. Example of a fire request and executed

[03:31:27] <2/1BDE_BAE_FSE> IMMEDIATE Fire Mission, Grid 28M MC 13245 24512, Killbox 32AY1SE, POI GRID 28M MC 14212 26114, Killbox 32AY3NE, MAX ORD 8.5K [03:31:28] <CRC_Resolute> 2/1BDE_BAE_FSE, stand by - working [03:31:57] <CRC_Resolute> 2/1BDE_BAE_FSE, Resolute all clear [03:32:04] <2/1BDE_BAE_FSE> complete [03:41:23] <2/1BDE_BAE_FSE> End Of Mission [03:41:31] <CRC_Resolute> complete

http://publicintelligence.net/tactical-chat/ , 2013.

repeating questions: orders are clear, wrote in NATO code words. As a commander officer deployed in Afghanistan declared: “Because everybody had the same information available to them, they were very rarely surprised, and so when a new issue came up all the warfare commanders were working from the same baseline, you wouldn’t have to take that bring-up time to get to a decision point” ((Abridged report – DoD, 2008, p. 15). Such persistence and robustness are not provided as efficiently with other command and control means, in particular radio voice device. These technical properties make users turned tactical chat into an authoritative source.

However, we also observe that major biases are associated to such execution uses, primarily linked to information overload and dependency. Users have access to a growing quantity of useful information and knowledge, but they create conditions for information dependencies to emerge. In effect, information process and knowledge-sharing occurring in real-time, war-fighters have to remain focused and watchful in order to collect the right information at the right moment. Situation can become very stressful since teams do not want to miss out critical point. The problem is to fix the moment where users stop collecting information and concentrate exclusively on decision making and mission execution. Furthermore, the growing number of active chat rooms tends to increase quantity of useful information, leading teammates to quickly feel under pressure and overloaded by information flows. Some researches confirm biases observed in Afghanistan. Experiments into human performance suggest that subjects remain fixated on chat interfaces and ignore the decision to make and the task to fulfil as a priority in urgent and stressful situations (Cummings, 2005).

5. DISCUSSION

Our case study throws new light on the relationship between ICTs and uncertainty. Our findings indicate that team members are capable of mitigating the effects of uncertainty on coordination and decision-making by revealing and combining different material properties attached to a single technological artefact. Although this finding is definitively in line with a non-deterministic framework, it does not play down the role of managers in facilitating the appropriation of technology. Next sections aim at elaborating on a model of technological uses as the outcome of a combinatorial (and explorative) process involving various material properties and knowledge types, processes and structures. We finally discuss the main implications of the foregoing conceptual framework for practitioners.

5.1. A Combinatorial Model of Technological Uses: Implications for Scholars

The concept of combination is not new for organisation theorists. For example, the capability-based approach of the firm elaborates on the concept of “combinative capabilities” to investigate the sources of organisations’ competitive advantage and the nature and logics of innovation (see for instance Kogut and Zander, 1992; Teece et al., 1997). In the same vein, the design-oriented view of organisational and organising phenomena insists on the role played by “new organisational forms” as they enable organisations confronted to evolutionary environments to (re-)combine a variety of components (e.g., governance, technology, strategy, and capabilities) and offer competitive products and services (Daft and Lewin, 1993; Ilinitch et al., 1996). These perspectives acknowledge that a variety of tangible and intangible resources must be combined and aligned so as to provide the organisation with effective capabilities to achieve its strategic goals (Ciborra, 1996). Scholars insist on the intangible resources available inside and outside the firm's boundaries to be structured in a way that permits creative (re-) combinations (Galunic and Rodan, 1998).

The foregoing perspective considers combinations as a "meta-concept" applied to the organisation. By contrast, our contribution adopts a micro-perspective by focusing on individuals-in-teams struggling for appropriate technological uses through explorative (re-) combinations of both tangible and intangible resources. The resulting usages involve many knowledge types and processes to be combined and aligned effectively. They also involve various technological properties. The concept of combination introduced in this contribution refers to a behavioural attitude individuals adopt when they engage with the technology and explore its potentials. By multiplying the possibilities of interaction among individuals and teams and fostering the integration of a variety of information and knowledge types, the application of the combinatorial logics enables individuals to improve their capacities of achieving both routine tasks, like the production and diffusion of reports, and non-routine activities related to decision-making and coordination under conditions of uncertainty.

Building our case study findings, we suggest that the "making" of technological uses is based on the combination of three elements: socio-material properties, knowledge processes and knowledge types.

- **Socio-Material Properties:** We identify two categories of material properties attached to tactical chat which have been revealed and/or exploited by individuals: multiplication of chat rooms and information persistence. Some are likely to support decision-making processes, while other support coordination among geographically dispersed teams.
- **Knowledge Processes:** We observe that individuals combined integrative and interactive processes as they provide individuals with appropriate resources to cope with uncertainty.
- **Types of Knowledge:** Combinations involve heterogeneous types of knowledge including explicit and declarative knowledge as well as tacit and procedural knowledge, but also relational knowledge.

The foregoing combinative model goes beyond the analysis of differentiated uses of a single technology. It provides a conceptual benchmark to explore conditions of emergence, development and dissemination of technological uses providing operators and teams with additional solutions to manage uncertainty. What is interesting here is that the final functions of the technology (e.g., coordination, decision making) are not consciously incorporated during the initial design of the technology. Designers cannot predict which combinations will emerge from users' experimentation and what kind of organisational process they will support. It is also difficult to anticipate on which combinations are going to be selected, stored and employed, and which are going to be eliminated. Indeed, combinations are selected and disseminated according to their level of fitness regarding to particular tasks at work. Therefore, when a particular combination becomes adopted, it provides teams with additional operational value. Whether the cumulative development of operational value generates strategic advantage depends on their ability to capitalise on combinative technological practices.

5.2. Gaining Strategic Value from Use-Based Combinations: Implications for Practitioners

Our case study findings suggest that combinations emerging in situations support the developing of creative technological uses, some being radically unpredictable by designers, managers and even users themselves. These innovative combinations can be viewed by managers as sources of value for organisations. Basically, the nature of the value generated is twofold: operational and strategic. Operational value results from maintaining and/or enhancing the efficiency of existing organisational processes and routines. For example, since ICTs enable teams to broadly communicate, acquire wider access to information and improve self-awareness, their uses often decrease the need for hierarchical coordination and monitoring. Such structural effects might empower teams and involve performance effects due to greater concern at the individual level (Brews and Tucci, 2007). Strategic value pertains to sustaining the strategic vitality of teams through technological and organisational innovations and differentiation. The latter cannot easily be replicated since they are embedded in organisations' solutions and processes (Sanchez and Heene, 1997).

In our case study, new uses refer to the simultaneous exploitation of communication, coordination and decision-support functions associated with the technology. Our results indicate that creative combinations have provided the military with major sources of operational value. By broadening the scope and effectiveness of existing NATO's decision making routines and communication architecture, combinations had further transformed operational gains into strategic value by supporting the development of unique and hardly transmissible capabilities. The strategic advantage results from the ability of war-fighters to reconfigure tactical-chat with regard to their specific needs, at a given time. While extending the initial functions of chat through the development of new combinations, war-fighters improved their decision making, as well as their interpretative and sense-making capabilities. Subsequently, the implementation of appropriate combinations leads to a global enhancement of teams and organisational capabilities. At the same time, we also indicate that explorative combinations generate additional biases which are likely to reinforce the negative effects of uncertainty on coordination and decision-making. Unexpected combinations can thus equally result in uncertainty reinforcement depending on the particular situations involved.

The foregoing discussion raises practical implications for managers: how can they handle to capture operational and (transform it into) strategic value from the development of teams' combined uses? Beyond unexpected cognitive biases generated by combined uses, the distinction between operational and strategic values gives rise to a difficult challenge for managers. On the one hand, operational value requires focusing managerial attention on improving the efficiency of existing routines and organisational processes; on the other hand, strategic value entails concentrating on innovations and differentiation which provide organisations with competitive advantage. Therefore, managerial tasks are quite different with regard to how organisations capture strategic values from the exploitation of operational combinations. To cope with this challenge, managers must find ways to identify and nurture the operational combinations that are more likely to produce innovative solutions and competitive advantage. We claim that this involves the daily engagement of managers who should dedicate time and efforts to enable teams to develop combinatorial experimentation (enabling conditions in the sense of Orlikowski, 2002).

Major implications can be drawn from the above discussion. First, information technology's architecture must be intentionally designed so as to promote the development and dissemination of emergent technological uses. This is very different from the traditional approach to ICTs' design in which technological functionalities offered by the technology are conditioned by predefined uses. The second implication for managers is to ensure that the variety of the material properties, knowledge types and knowledge processes available to users is not bounded. This is a condition for emerging combinations to be explored and operational value to be captured. Finally, managerial attention and effort should tie toward supporting combinations that require personal engagement of final users, since individual appropriation through experimentation drive much of ICT's strategic value (Orlikowski, 2002). In this respect, the role played by managers is all but limited since they nurture those enabling conditions which support the strategic vision underlying technology-based deployment (Malhotra, 2005).

6. CONCLUSION

This article investigated how ICTs enable individuals in teams to handle the various forms of uncertainty that shape their daily work environment. Building on a case study conducted in the field of military technologies – the use of tactical-chat by NATO forces in Afghanistan – it suggested that team members combine socio-material properties, knowledge processes, and knowledge types in order to cope with informational and cognitive forms of uncertainty. The findings indicated that use-based combinations are likely to promote the development of appropriate technological uses that are likely to become sources of operational and, eventually, strategic value.

Military environment and work practices are unique; nowhere else are the consequences of team failure higher. The question of the adaptation of our results to the private sector is thus both interesting and justified. Can our "combinative" analysis of ICTs' uses be appropriate in a business context as well as a battlefield? Our contribution is a first step toward understanding of how technological uses are enacted by individuals confronted to various forms of uncertainty. It sheds light on micro-behaviours and analyses their impact on teams' decision-making and coordination ability. We expect that all teams facing with uncertainty can benefit from combining material properties attached to a single technological artefact. To do so, team managers should design a roadmap to ensure that the variety of the socio-material properties, knowledge types and knowledge processes available to users is not bounded. This is the key condition for emerging combinations to be explored and value to be captured, whether it be in military or business contexts.

REFERENCES

Abridged Report. (2008). Task Force 50 during Operation enduring freedom. US Department of Defence, Transformation case study series.

Adler, B. M., Baets, W., & König, R. (2011). A complexity perspective on collaborative decision making in organizations: The ecology of group performance. *Information & Management*, *48*(4-5), 157–165. doi:10.1016/j.im.2011.04.002

Alavi, M., & Tiwana, A. (2003). Knowledge management: The information technology dimension. In M. Easterby-Smith & M. A. Lyles (Eds.), *Handbook of organisational learning and knowledge management* (pp. 104–121). Oxford: Blackwell Publishing.

Alberts, D.S. & Hayes, R.E. (2003). *Power to the edge.* Washington D.C: Department of Defence C4ISR Cooperative Research Program.

Baskerville, R., & Dulipovici, A. (2006). The theoretical foundations of knowledge management. *Knowledge Management Research & Practice*, *4*(2), 83–105. doi:10.1057/palgrave.kmrp.8500090

Bouty, I., Godé, C., Drucker-Godard, C., Nizet, J., Pichault, F., & Lièvre, P. (2012). Coordination practices in extreme situations. *European Management Journal*, *30*(6), 475–489. doi:10.1016/j.emj.2012.03.015

Brews, P. J., & Tucci, C. L. (2007). The structural and performance effects of internetworking. *Long Range Planning*, *40*(2), 223–243. doi:10.1016/j.lrp.2007.03.006

Brown, J. W., & Utterback, J. M. (1985). Uncertainty and technical communication patterns. *Management Science*, *31*(3), 301–311. doi:10.1287/mnsc.31.3.301

Cecez-Kecmanovic, D. (2004). A sensemaking model of knowledge in organisation: A way of understanding knowledge management and the role of information technologies. *Knowledge Management Research & Practice*, *2*(3), 155–168. doi:10.1057/palgrave.kmrp.8500040

Chapman, G. (2007). Evolutionary psychology, complexity theory, and quantitative social epistemology. *Futures*, *39*(9), 1067–1083. doi:10.1016/j.futures.2007.03.013

Ciborra, C. (1996). The platform organization: Recombining strategies, structures, and surprises. *Organization Science*, *7*(2), 103–118. doi:10.1287/orsc.7.2.103

Cilliers, P. (1998). *Complexity and post-modernism: Understanding complex system*. London: Routledge.

Conin, M. A., & Weingart, L. R. (2007). Representational gaps, information processing, and conflict in functional diverse teams. *Academy of Management Review*, *32*(3), 761–773. doi:10.5465/AMR.2007.25275511

Cummings, M. (2005). *The need for command and control instant message adaptive interfaces: Lessons learned from tactical Tomahawk human-in-the-loop simulations*. Cambridge, Massachusetts: Massachusetts Institute of Technology, Humans and Automation Laboratory.

Daft, R., & Weick, K. (1984). Toward a model of organizations as interpretation systems. *Academy of Management Review*, *9*(2), 284–295.

Daft, R. L., & Lengel, R. H. (1986). Organizational information requirements, media richness and structural design. *Management Science*, *32*(5), 554–571. doi:10.1287/mnsc.32.5.554

Daft, R. L., & Lewin, A. Y. (1993). Where are the theories for the "new" organizational forms? An editorial essay. *Organization Science*, *4*(4), i–vi.

de Cunha, J.V., & Orlikowski, W. (2008). Performing catharsis: The use of online discussion forums in organizational change. *Information and Organization*, *18*(2), 132–156. doi:10.1016/j.infoandorg.2008.02.001

Dekker, S., Cilliers, P., & Hofmeyr, J. H. (2011). The complexity of failure: Implications of complexity theory for safety investigations. *Safety Science*, *49*(6), 939–945. doi:10.1016/j.ssci.2011.01.008

Dewett, T., & Jones, G. R. (2001). The role of information technology in the organization: A review, model, and assessment. *Journal of Management*, *27*(3), 313–346. doi:10.1177/014920630102700306

Eisenhardt, K. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532–550.

Eisenhardt, K., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal*, *50*(1), 25–32. doi:10.5465/AMJ.2007.24160888

Eisenhardt, K., & Martin, J. (2000). Dynamic capabilities: What are they? *Strategic Management Journal*, *21*(10-11), 1105–1121. doi:10.1002/1097-0266(200010/11)21:10/11<1105::AID-SMJ133>3.0.CO;2-E

Eovito, B. (2006). *An assessment of joint chat requirements from current usage patterns*. Monterey, California: Naval Postgraduate School.

Faraj, S., & Xiao, Y. (2006). Coordination in fast-response organizations. *Management Science*, *52*(8), 1155–1169. doi:10.1287/mnsc.1060.0526

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, *12*(2), 219–245. doi:10.1177/1077800405284363

Galunic, D. C., & Rodan, S. (1998). Resource recombinations in the firm: Knowledge structures and the potential for schumpeterian innovation. *Strategic Management Journal*, *19*(12), 1193–1201. doi:10.1002/(SICI)1097-0266(1998120)19:12<1193::AID-SMJ5>3.0.CO;2-F

Gittell, J., & Weiss, L. (2004). Coordination networks within and across organizations: A multi-level framework. *Journal of Management Studies*, *41*(1), 127–153. doi:10.1111/j.1467-6486.2004.00424.x

Godé, C., & Lebraty, J. F. (2013). Improving decision-making in extreme environment: The case of a military Decision Support System. *International Journal of Technology and Human Interaction*, *9*(2), 1–17. doi:10.4018/jthi.2013010101

Gorry, A. (2009). Technology, knowing and learning. *Knowledge Management Research & Practice*, *7*(2), 178–180. doi:10.1057/kmrp.2009.7

Holland, J., & Miller, H. (1991). Artificial adaptive agents in economic theory. *The American Economic Review*, *81*(2), 365–370.

Huber, G., & Crisp, C. (2003). Organisations, information systems impact on. In H. Bidgoli (Ed.), *Encyclopaedia of information systems* (pp. 413–426). San Diego: Elsevier Science Publishers.

Ilinitch, A. Y., D'Aveni, R. A., & Lewin, A. Y. (1996). New organizational forms and strategies for managing in hypercompetitive environments. *Organization Science*, *7*(3), 211–220. doi:10.1287/orsc.7.3.211

Kallinikos, J. (2005). The order of technology: Complexity and control in a connected world. *Information and Organization*, *15*(3), 185–202. doi:10.1016/j.infoandorg.2005.02.001

Kimmerle, J., Crees, U., & Held, C. (2010). The interplay between individual and collective knowledge: Technologies for organisational learning and knowledge building. *Knowledge Management Research & Practice*, *8*(1), 33–44. doi:10.1057/kmrp.2009.36

Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, *3*(3), 383–397. doi:10.1287/orsc.3.3.383

Langley, A. (1999). Strategies for theorizing from process data. *Academy of Management Review*, *24*(4), 691–710.

Leonardi, P. (2011). When flexible routines meet flexible technologies: Affordance, constraint, and the imbrications of human and material agencies. *Management Information Systems Quarterly*, *35*(1), 147–167.

Leonardi, P., & Barley, S. (2008). Materiality and change: Challenges to building better theory about technology and organizing. *Information and Organization*, *18*(3), 159–176. doi:10.1016/j.infoandorg.2008.03.001

Li, M., & Ye, L. R. (1999). Information technology and firm performance: Linking with environmental, strategic and managerial contexts. *Information & Management*, *35*(1), 43–51. doi:10.1016/S0378-7206(98)00075-5

Lloria, B. (2008). A review of the main approaches to knowledge management. *Knowledge Management Research & Practice*, *6*(1), 77–89. doi:10.1057/palgrave.kmrp.8500164

Malhotra, Y. (2005). Integrating knowledge management technologies in organizational business processes: Getting real time enterprises to deliver real business performance. *Journal of Knowledge Management*, *9*(1), 7–28. doi:10.1108/13673270510582938

Marwick, A. (2001). Knowledge management technology. *IBM Systems Journal*, *40*(4), 814–830. doi:10.1147/sj.404.0814

McDermott, R. (1999). Why information technology inspired but cannot deliver knowledge management. *California Management Review*, *41*(4), 103–117. doi:10.2307/41166012

Merali, Y., Papadopoulos, T., & Nadkarni, T. (2012). Information systems strategy: Past, present, future. *The Journal of Strategic Information Systems*, *21*(2), 125–153. doi:10.1016/j.jsis.2012.04.002

MTTP (2009). *Multi-Services tactics, techniques and procedures for Internet tactical chat in support of operations*. US Department of Defence, July.

Nonaka, I., & Takeushi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. Oxford: Oxford University Press.

Orlikowski, W. (1992). The duality of technology: Rethinking the concept of technology in organizations. *Organization Science*, *3*(3), 398–427. doi:10.1287/orsc.3.3.398

Orlikowski, W. (2000). Using technology and constituting structures: A practice lens for studying technology in organizations. *Organization Science*, *11*(4), 404–428. doi:10.1287/orsc.11.4.404.14600

Orlikowski, W. (2002). Knowing in practice: Enacting a collective capability in distributed organizing. *Organization Science*, *13*(4), 249–273. doi:10.1287/orsc.13.3.249.2776

Orlikowski, W. (2007). Sociomaterial practices: Exploring technology at work. *Organization Studies*, *28*(9), 1435–1448. doi:10.1177/0170840607081138

Pickering, J., & King, J. (1995). Hardwiring weak ties: Inter-organisational computer-mediated communications, occupational communities, and organizational change. *Organization Science*, *6*(4), 479–486. doi:10.1287/orsc.6.4.479

Power, D. J., & Sharda, R. (2007). Model-driven decision support systems: Concepts and research directions. *Decision Support Systems*, *43*(3), 1044–1061. doi:10.1016/j.dss.2005.05.030

Ross, T. J., Booker, J. M., & Montoya, A. C. (2013). New developments in uncertainty assessment and uncertainty management. *Expert Systems with Applications*, *40*(3), 964–974. doi:10.1016/j.eswa.2012.05.054

Sanchez, R., & Heene, A. (1997). Competence based strategic management: Concepts and issues for theory, research and practice. In R. Sanchez & A. Heene (Eds.), *Competence-based strategic management* (pp. 3–42). Chichester: John Wiley & Sons.

Scarborough, J. (1993). Revisiting the military stereotype: Take another look! *Journal of Management Inquiry*, *2*(3), 264–271. doi:10.1177/105649269323007

Scott, S., Cummings, M., Graeber, D., Nelson, W., & Bolia, R. (2006). Collaboration technology in military team operations: Lessons learned from the corporate domain. *Proceedings of theCommand and Control Research and Technology Symposium*, San Diego, CA.

Seymour, G., & Cowen, M. (2006). A review of team collaboration tools for crisis response in the military and government. *Proceedings of theCommand and Control Research and Technology Symposium*, San Diego, CA.

Shen, X.-L., Lee, M., & Cheung, C. (2012). Harnessing collective intelligence of Web 2.0: Group adoption and use of Internet-based collaboration technologies. *Knowledge Management Research & Practice*, *10*(4), 301–311. doi:10.1057/kmrp.2012.30

Simon, H. (1969). *The Science of the Artificial*. Boston: MIT Press.

Tactical Chat: How the U.S. military uses IRC to wage war. (2013) *Public Intelligence*, January 22. Retrieved from http://publicintelligence.net/tactical-chat

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capability and strategic management. *Strategic Management Journal*, *18*(7), 509–533. doi:10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

Thomas, J., Watts Sussman, S., & Henderson, J. (2001). Understanding 'Strategic Learning': Linking organizational learning, knowledge management, and sensemaking. *Organization Science*, *12*(3), 331–345. doi:10.1287/orsc.12.3.331.10105

Tyre, M., & Orlikowski, W. (1994). Windows of Opportunity: Temporal Patterns of Technological Adaptation in Organizations. *Organization Science*, *5*(1), 98–118. doi:10.1287/orsc.5.1.98

Van den Hoof, B., & Huysman, M. (2009). Managing knowledge sharing: Emerging and engineering approaches. *Information & Management*, *46*(1), 1–8. doi:10.1016/j.im.2008.09.002

Van Maanen, J., Sorensen, J., & Mitchell, T. (2007). Introduction to special topic forum: The interplay between theory and method. *Academy of Management Review*, *32*(4), 1145–1154. doi:10.5465/AMR.2007.26586080

Venters, W. (2010). Knowledge management technology-in-practice: A social constructionist analysis of the introduction and use of knowledge management systems. *Knowledge Management Research & Practice*, *8*(2), 161–172. doi:10.1057/kmrp.2010.8

Weick, K., & Sutcliffe, K. (2007). *Managing the Unexpected* (2nd ed.). John Wiley & Sons.

Weick, K. E. (1979). *The social psychology of organizing*. Reading, Mass.: Addison-Wesley.

Yin, R. (2003). *Case study research: Design and methods*. Beverly Hills: Sage Publication.

Zack, M. (1994). Electronic messaging and communication effectiveness in an ongoing work group. *Information & Management*, *26*(4), 231–241. doi:10.1016/0378-7206(94)90095-7

Zack, M. (1999). Managing codified knowledge. *MIT Sloan Management Review*, *40*(4), 45–58.

Zack, M. (2001). If managing knowledge is the solution, then what's the problem? In Y. Malhotra (Ed.), *Knowledge management and business model innovation* (pp. 16–36). Hershey, PA: Idea Group Publishing.

Zack, M. H., & McKenney, J. L. (1995). Social context and interaction in ongoing computer-supported management groups. *Organization Science*, *6*(4), 394–422. doi:10.1287/orsc.6.4.394

ENDNOTE

[1] Other examples of complex systems include financial markets, the human brain, large-scale urban areas, biological systems (e.g., ants' colony), large-scale networks (e.g., transport infrastructures or telecommunication networks), industrial facilities (e.g., nuclear plant), and complex product systems (e.g., commercial aircraft).