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Vladislav V. Fomin

Vytautas Magnus University, v.fomin@if.vdu.lt

Francois-Xavier de Vaujany

CERAG and University of Grenoble (IAE), devaujany@jae-grenoble.fr

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THEORIES OF ICT DESIGN: WHERE SOCIAL STUDIES OF TECHNOLOGY MEET THE DISTRIBUTED COGNITIVE PERSPECTIVE

Les théories de la conception des TIC :

un point de rencontre entre les approches sociologiques de la technologie et la perspective cognitive distribuée

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Vladislav V. Fomin
Dept. of Informatics
Vytautas Magnus University
LT-44404, Kaunas
LITHUANIA
v.fomin@if.vdu.lt

François-Xavier de Vaujany
CERAG and University of Grenoble (IAE)
150 rue de la Chimie
38040 Grenoble
FRANCE
devaujany@iae-grenoble.fr

Abstract

In this paper we examine the possibility to bridge theory of Distributed Cognition with popular theories of Social Studies of Technology (in particular, Actor-Network Theory and Social Construction of Technology). Responding to a recent call for revisiting the design metaphor, in this paper we aim to obtain more precise terminology for describing the phenomena of ICT design in theoretical terms. We argue that establishing correlations between the two bodies of literature adds new knowledge to a community of scholars caters for betterment of managerial practice in complex design tasks.

Keywords: design theory, distributed design, distributed cognitive perspective, Information and Communication Technology (ICT), social studies of technology (SST), social construction of technology (SCOT), actor-network theory (ANT).

Résumé (Abstract in French)

Les travaux sociologiques sur les technologies de l'information s'intéressent aux processus de conception distribués. De leur côté, les recherches sur la cognition humaine dans les processus de conception ont porté leur attention sur la cognition distribuée. Mais si ces deux courants utilisent des concepts proches pour aborder des objets de recherche assez similaires, le lien entre les deux n'a jamais vraiment été établi. C'est le but principal de cet article.

Santrauka (Abstract in Lithuanian)

Šiame straipsnyje tyrinėjama galimybė sujungti DCP (paskirstytą suvokimo perspektyvą) su gerai žinomomis technologijų socialinių studijų (SST) teorijomis. Mūsų tikslas būtų dvejų teorijų bazių bendrais teoretiniais terminais tiksliau aprašyti ICT (informacijos ir komunikacijos technologijų) projektavimą.

Аннотация (Abstract in Russian)

В данной статье мы рассматриваем возможность объединения теории распределенных познавательных процессов (DCP) с популярными теориями теории социальных исследований технологии (SST). Наша задача получить более точные теоретические термины для описания явлений при разработке сложных информационно-коммуникационных технологических систем (ICT).

Introduction

The complexity of design process in the Information Systems (IS) field has been a topic of discussion for almost two decades (Lyytinen 1987). While the IS paradigm itself has undergone a substantial change since the introduction of the discipline, reflecting the growth of IS from in-house mainframe computers to worldwide distributed network of Information and Communication Technologies (ICT) (Schneberger and McLean 2003), the theories and methods guiding design practice have remained virtually untouched (Fitzgerald 2000). Not only has the ICT environment grown complex, design process that leads to the creation of IS at virtually any level, from in-house information systems (Ramiller 2005) to national ones (Hanseth et al. 2006), have become increasingly prone to failures.

Even before IS scholar community was established¹, H.A. Simon shared his views on the complexity of design process (Simon 1977) and the ways to cope with complex systems (Simon 1962). Almost half a century since the publication of Simon's (1962) seminal article "The Architecture of Complexity", his proposed approach to harnessing complexity has been adopted in IS studies of ICT design, although not necessarily systematically. Specifically, Simon's two types of description of complex systems – the state description, and the process description – both found support in popular literatures dealing with ICT design and use. On the *process* dimension, theories of social studies of technology (SST) have recently gained popularity among scholars of the IS community (Hanseth et al. 2004; Monteiro and Hanseth 1995; Ramiller 2005; Williams 1997). On the *state* dimension, studies of cognition in human-computer interaction and ICT design have recently changed their focus from studying cognitive processes of individuals to these of distributed systems (Arias et al. 2000; Hollan et al. 2000). While the two bodies of literature deal with compatible and sometimes similar concepts and perspectives, the explicit link between them has not been established. Although there were calls to overcome the gap between "theories of power" and "theories of knowledge" (Foucault 1976), and attempts to do so (Hatchuel 2001), these contributions are scarce. Such missing link is all the more a pity as scholarly discussion in today's IS world more than ever involves both distributed cognition and distributed social processes (Orlikowski 2002).

By developing the correlations between "the sensed world and actions in the world of process" (Simon 1962, p.479) of ICT design, we aim to contribute to strengthening our understanding of design theory, and provide practical guidance for the design of ICT (Germonprez et al. 2007, p.352). Responding to recent call to renew the vocabulary of design management studies (Boland and Collopy 2004b), in this paper we attempt to juxtapose the common concepts of distributed cognition and popular SST theories in order to derive appropriate theoretical terms for describing ICT design phenomena (Hollan et al. 2000, p.181).

Distributed design in the IS domain

Design of ICT: four archetypal situations

In human cultures, almost all values inhere in designs (Baldwin and Clark 2005). In general terms, designs are the instructions that turn knowledge into things that people value and are willing to pay for (Baldwin and Clark 2005, p.3). In the jargon of social studies of technology, design is a process where various interests are translated into technological solutions as well as organizational arrangements and procedures to be followed, to make the technology work properly (Aanestad and Hanseth 2000).

Problem-solving task of design process is that of (1) requirements engineering and (2) ICT artifact implementation for consequent adoption and use by organization.

¹ The First (International) Conference on Information Systems was held in 1979.

Requirements engineering (RE) is an established scholarly and practitioners discipline (Davis 1993; Macaulay 1996), which is based on two key assumptions: “One is that requirements exist ‘out there’ in the minds of stakeholders (users, customers, clients), and they can be elicited through various mechanisms and refined into complete and consistent specifications. The second is that the key stakeholders operate in a state of goal congruence, in which there is widespread and coherent agreement on the goals of organization” (Bergman et al. 2002, p.154).

In reality, however, RE in the design process is complicated by complex nature of the organizational domain. The growing complexity of organizational domain inevitably renders the processes leading to design and implementation of ICT systems more complex, too. Systems and organizations become more and more distributed, ICT design process increasingly intertwined with use, involving more and more actors, often relying on a vaguely defined role system (De Vaujany and Fomin 2007). For instance, with non-technician people involved in the local design and management of some Intranet sub-parts, often on an unpaid basis, in parallel to their main tasks. This results in fuzzy boundaries between ICT design and use practices and other organizational practices – “it is a mistake to assume that being a consumer or being a designer would be a binary choice – it is rather a continuum ranging from passive consumer, to active consumer, to end-user, to user, to power users, to domain designer, to medium designer” (Arias et al. 2000, p.109).

Darses and Flazon (1994) suggest two kinds of design activities that can help operationalize the complex environment in which ICT design process takes place. There are design activities involving material artifact (such as cars, computers, houses) and those related to symbolic artifacts (such as plans, softwares, new theories). In both kinds of projects, cognitive and operative synchronization are at stake (Darses and Flazon 1994). The former is related to the cognitive capability of each member of the group, that of the situation, and that of a common cognitive reference points (for instance, sharing the jargon or core techniques). The latter deals with the division of tasks and overall rhythm and shape of work. Following this categorization, four archetypal design situations can be described (see Table 1).

Table 1. Four archetypal situations of collective design		
	Co-located design	Distributed design
Designers’ team with previous experience of working together	Archetypal situation 1. Typical for the 1970s: a team of designers, usually from the same company and/or IS department, develop a specific ICT-artifact through interaction in a single organizational setting. Design work is mediated by common cognitive reference points.	Archetypal situation 3. Typical for the 1990s: the advent of groupware technologies (virtual prototypes, white-board sharing, videoconferencing, e-mails, etc.) and virtual organizations, the designers involved in the IS project are share a common knowledge, but often work in a remote way. Design work is groupware-technology- and ICT-artifact-mediated
Designers’ team with no previous experience of working together	Archetypal situation 2. Typical for the 1980s: with the arrival of configurable / adaptable off-the-shelf software, ad hoc in-house design becomes less common. A work of a team of designers from a software house is complemented by the work of designers in a company. Design work is mediated by common cognitive reference points and ICT artifact.	Archetypal situation 4. Typical for the 2000s: in the era of Internet and outsourcing, numerous internal and external stakeholders are involved in the project. Common cognitive reference points are rare. Design work is artifact-mediated.

The four archetypal design situations presented in Table 1 above also reflect the evolution of design practice in the IS/ICT domain, as well as the increase in complexity, with the increment of the archetypal situation number. If situations 1 and two have received substantial attention from academia and practitioners, situations 3 and four (or

combinations of them) are clearly neglected. In situations of distributed design, which became so common in the contemporary business environment, both cognitive and operative synchronization between the design team members is extremely difficult to establish. The symbolic (intangible) nature of ICT artifacts only increases the problem, as symbolic artifacts offer more fertile grounds for flexible (or mis-) interpretation, and hence lower the coherence of common cognitive reference points. The complexity of organizational domain, and the distributed nature of design process accelerate the “struggle” of principal stakeholders for establishing own requirements as “the requirements” in a complex web solution-problem space (Bergman et al. 2002, p.168), which means that the task of discovering requirements gives precedence to such tasks as negotiation, conflict resolution, etc.

Despite the change in the ICT design practice, the IS design methods and theories have their origins in a set of concepts that came to prominence in the ten-year period from about 1967 to 1977 (Fitzgerald 2000, p.174). IS design then was mostly about in-house development of isolated systems from scratch (which corresponds to the situations 1 and two in Table 1 above). As systems were transformed from centralized mainframe computers to distributed enterprise systems, to Internet, a call for revisiting the design metaphor has been voiced (Boland and Collopy 2004a). The call is prompted by increasing complexity of the ICT environment, the design process, and inadequacy of established (and somewhat obsolete) IS design theories to cope with this multifaceted complexity.

Complexity of the contemporary (distributed) ICT environment

Today, situations of distributed design (in particular situation 4 in Table 1 above) become more and more commonplace in all kind of design activities, not only in the IS field. Co-developing multi-million budget grant applications with colleagues whom you were referred to but never met is as common as co-authoring papers in a remote way, using e-mail exchange and Skype. Car manufacturers develop new models by means of virtualization of prototypes or groupware technologies. Pharmaceutical companies more and more rely on “world of talent” - Internet-based calls-for-solution that allows involving in the company’s innovation process any number of “designers” from all over the world.

In the field of IS, the trend for distributed design has gained a strong ground with the advent of outsourcing as a common organizational practice. Many European and the U.S. companies use engineers in India to develop software for PCs, PDAs, mobiles phones, etc. Emergence of design based on service-oriented architecture (SOA), brought to the community technologies which are designed as pieces, where the designers create environments to which the users design the states of those pieces into new technologies². Although diverse in scope and application, the outlined examples of ICT design have something in common – these processes are complex and distributed across locations, individuals, and time.

Complexity here is defined in classical terms, as an attribute of the scope and number of different, but related, parts of a whole (Schneberger and McLean 2003, p.216). Thus, the complexity of a system depends on (1) a system’s number of different types of components, (2) number of types of links and (3) its speed of change (Cilliers 1998). Another important attribute of a complex system is that of self-organization realized through (4) novel features and emergent properties (Cilliers 1998, p.ix).

Modern ICT environment and its design witness an increasing rate in all four aforementioned dimensions of complexity as follows. First, the growing decentralization of ICT resulted in a phenomenon called “complexity cross” by Schneberger (1997) – the ICT environment was transformed from complex components in a simple system (a mainframe computer) to simple components in a complex system (the global ICT environment) (Schneberger and McLean 2003, p.216). Second, the distributed nature of the ICT environment requires design of interoperable products/components, as well as distributed design processes and control – i.e., interoperability and process quality standards. Third, the degree of instability (fluidity) of technology designs is increasing. A recent study on technology standards reported that only 60% of ICT standards are stable, while 27% being responsible for 90% of all the changes in standards specifications (Egyedi and Heijnen 2005). Finally, the immense size and dynamics of the ICT environment more and more often produces incompatibilities between the disparate elements of the system (Council of the European Union 2004) and innovation failures (Hanseth et al. 2006).

² We are thankful to anonymous reviewer for suggesting this example for the break-down of the user-designer dichotomy.

The distributed nature of ICT design process is established by several factors. First, designing (for) the ICT environment became a multi-player distributed activity (Fomin et al. 2004; Ives and Jarvenpaa 1991) due to the complexity of the process (Hawkins 1996; Hawkins et al. 1995) and the high stakes of establishing a “dominant design” in the ICT domain (Anderson and Tushman 1990). Second, episodes of design can not be viewed anymore as isolated, closed systems (either temporally from what precedes and followed it, or socially from its broader context), but are seen as elements of an open system of innovation “across multiple cycles of design, implementation, consumption and further enhancement and dispersed across a wide range of players; sites; phases” (Williams et al. 2005). Third, the distributed nature of the process requires integration of knowledge from a broad array of disciplines, whereas specialized knowledge workers (designers, market analysts, project managers, engineers, etc.) are dealing with only a part of the overall design architecture (Baldwin and Clark 2005; Boland et al. 1994; Steinmueller 2005).

Understanding the nature and character of distributed design, realizing its complex nature, is an important step designers must take to minimize the risk of innovation failure, i.e., the negative emergent property of design. The failure to grasp the nature of interaction between the elements, the failure to embed the correct user values in design (Baldwin and Clark 2005), is perceived as a “design problem” (Williams et al. 2005), which leads to low adoption rates (or rejection) of innovation.

Two approaches to harnessing complexity of the ICT environment

While other approaches to harnessing complexity have been offered to the managerial and scholarly communities (Axelrod and Cohen 1999), we find the two methods proposed by Simon (1962) particularly suitable for contemporary discussion on betterment of design practice. In his seminal work “The Architecture of Complexity”, Simon proposes two methods for seeking an understanding of complex systems: the *state description* and *process description* (Simon 1962, p.479). The former characterizes the world “as sensed” – provides criteria for identifying and modeling objects. The latter characterizes the world “as acted upon” – provides the means for producing or generating objects having the desired characteristics (Simon 1962, p.479). Building on these two perspectives, two separate bodies of literature gained recognition among design scholars.

On the state description dimension, the studies of human-computer interaction (HCI) focused on the design, evaluation and implementation of interactive computing systems for human use. Initially drawing on theories of individual cognition in ethnographic studies of technology use, with the increasing complexity and the distributed nature of ICT environment and objects, HCI embraced distributed cognitive perspective (DCP) (Arias et al. 2000; Hollan et al. 2000). Although dealing with tasks, the focus of DCP is rather on states, than on processes – on the environments, conditions, and implications for technology design and uses. “The theory of distributed cognition... seeks to understand the organization of cognitive system”, where *cognitive* is understood to encompass interactions between people and artifacts, as well as with resources and materials in the environment (Hollan et al. 2000, p.175; Norman 1993).

On the process description dimension, social studies of technology (SST) emerged as popular stream of research on the development and design of ICT (Allen 2004; Faraj et al. 2004; Hanseth et al. 2004; Mähring et al. 2004; Marres 2004; Monteiro and Hanseth 1995; Ramiller 2005; Williams 1997). Much of that literature draws upon either Actor Network Theory (ANT) (Latour 1997; Latour 1999), or social construction of technology research (SCOT) (Bijker 1995b; Bijker 2001). Both of these literatures share an interest in examining processes of interaction between socio-technical elements through which the technology becomes invented and introduced (Lyytinen et al. 2008, p.7). While processes are the main foci of SST, both ANT and SCOT ascribe an important role to specific state – the *closure* (Pinch and Bijker 1987), *stabilization* (Mangematin and Callon 1995) of socio-technical network around the artifact-in-making.

While it is apparent that DCP and SST literatures are dealing with the same set of concepts and share at least compatible vocabulary, surprisingly, no visible attempts to establish the correlation between the two literatures has been made. Developing such correlations would be a useful contribution to design science, as problem solving of complex tasks “requires continual translation between the state and the process descriptions of the same complex reality” (Simon 1962, p.479). Departing from and placing an emphasis on the social studies of technology, in the next sections we explore where does the process description of SST meet the state description of DCP, and how the two bodies of literature can benefit from adopting (some) theoretical terminology of each other.

The extant theories of social studies of technology (design)

The bulk of sociology of technology research draws upon either the Actor-Network Theory (ANT) (Latour 1995) or the Social Construction of Technology research (SCOT) (Bijker 2001). For a general overview and discussion of both literatures, we refer to Howcroft et al. (2004) and for overview in the context of ICT design – to Lyytinen et al. (2008). Both of these literatures share an interest in examining in a very detailed ex post manner (as opposed to abstract level of managerial ex ante analysis) social and technical interaction in which the technology-in-making becomes invented, introduced, and stabilized (Latour 1999). Both theories were heavily criticized in the past and have seen a certain convergence (Sørensen and Williams 2002). Nonetheless, they are enjoying increasing interest among IS scholars, reflected in a number of theoretical and empirical works (Boland and Schultze 1995; Fomin et al. 2003; Hanseth et al. 2004; Lyytinen et al. 2008; McGrath 2002; Ramiller 2005; Walsham 1997; Walsham and Sahay 1999).

In SCOT research, the emphasis is on the mobilization and evolution of interpretive schemes and associated engineering skills while the technology becomes invented and stabilized. Thus, the problem scope of SCOT fits that of requirements engineering (RE) during the design process, which is concerned with stabilization of problem-solution spaces (Bergman et al. 2002) and selection of one set of requirements out of the multitude of possible ones. Stabilization is achieved by a reduction of openness, in the literature also termed *closure*. Closure is “... the outcome of the interaction among the different participating, or relevant social groups, and of a process narrowing down the features and the form of available technical artifacts” (Schmidt and Werle 1998, p.159). Thus, closure processes lead to a compromise among the principals, which in turn limits the degrees of freedom for subsequent technical development, but at the same time allows to proceed to artifact implementation (Lyytinen et al. 2008).

The primary goal of SCOT is to explain why technology obtains a certain shape and how such shaping is socially conditioned. This explanation is organized around a theory of technology frames or a set of community wide shared mental schemes “composed of... the concepts and techniques employed by a community in its problem solving” (Bijker 2001, p.168). An important feature in SCOT research is to reveal conditions, called closure conditions (Pinch and Bijker 1987), that determine when and how such frames become stable. An investigator can trace backwards from a “closed” technology to situations where specific alternatives were excluded, while addressing critical challenges during technology design (Hughes 1986). This unpacking reveals the logic of why and how technological choices are made. SCOT emphasizes the criticality of sense-making during innovation, i.e., how technology frames become critical in contextualizing, interpreting and solving engineering problems (Pinch and Bijker 1987).

Actor-Network Theory seeks to understand why and how a specific design emerges as a bundle of technical and social relations. It seeks to reveal how a design artifact becomes to embody “the innovator’s beliefs, social and economic relations, previous patterns of use, legal limits, and assumptions as to what the artifact is about” (Akrich 1992).

ANT traces the designed artifact in a process of “translation” (Callon 1985) where actors become enrolled into an actor-network organized around the artifact-in-design. It leads an investigator to ask why and how did the actors’ interests become aligned (Callon 1986), what reasons did they have for entering the network and how did this change their behaviors (Akrich 1992)? In ANT a translation is defined as: “the displacement, drift, invention, mediation, the creation of a link that did not exist before and that to some extent modifies the original” (Latour 1999, p. 197). Such translation forms an event that modifies the actor network. As a consequence, each translation consists of four major phases: problematization, interessement, enrollment and mobilization (Callon 1985; Callon 1986). During the problematization stage, an actor initiating the process defines identities and interests of other actors that are consistent with the interests of the initiating actor; the interessement involves convincing other actors that the interests defined by the initiator(s) are well in line with their own interests; enrollment “involves definition of roles of each of the actors in the newly created actor-network, and convincing other actors to embrace the underlying ideas of the growing actor-network, while mobilization includes initiators’ use of a set of methods to ensure that allied spokespersons act according to the agreement and do not betray the initiators’ interests” (Mähring et al. 2004, p. 214). Usually, ANT studies organize process explanations in a sequence and represent these concepts as a means of sequentially ordering the process subordinated to the obligatory passage point metaphor (Callon 1986) – “a situation through which the heterogeneous actors involved in a project must be made to pass” (Ramiller 2005, p.57).

A number recent of studies specifically examined the usefulness of social theories of technology in studying ICT innovation and design (Allen 2004; Faraj et al. 2004; Hanseth et al. 2004; Mähring et al. 2004; Marres 2004; Ramiller 2005). Following the trend, we aim at providing critical reflections on explanatory sufficiency and the predictive helpfulness of ANT and SCOT as tools for analysis of complex design in the making process. Specifically, we argue that while ANT and SCOT offer an excellent starting point as theories for ICT design in general, both approaches suffer a number of weaknesses when analyzing complex ICT design *ax ante*. We believe that introduction of some concepts from the theory of distributed cognition to the vocabulary of theories of social studies of technology (and vice versa) can improve the explanatory power of both bodies of literature in studies of complex design processes.

Where design studies meet distributed cognition

While mainstream cognitive science is focused on the analysis of causality, encompassed by the “skin and skull” of an individual, distributed cognitive perspective (DCP) looks for cognitive processes across all three aforementioned dimensions of the distributed environment for ICT design - across the members of a social group, between internal and external environments, and through the time (Arias et al. 2000; Hollan et al. 2000; Hutchins 1990a).

Similarly to ANT and SCOT theories, DCP is concerned with how to develop coordination strategies, negotiation mechanisms, conflict detection and resolution strategies, and how internalization and externalization of social interaction (non-human agents included) becomes a major factor in the development of thinking of agents (Sun 2001, p.5). The distributed cognition approach, again following the same logic as ANT/SCOT theories, provides insights into the origins of complexity – process outcomes that are not predictable form capabilities of any individual in separation may arise in the interaction between individuals (Hutchins 1990a).

Thus, at the outlook, establishing a strategic link between the tow bodies of literature seems to be feasible. However, while sharing some concepts, DCP and social studies of technology also maintain different perspectives on other concepts (see Table 2).

Table 2. A comparison of the main concepts in DCP and ANT-SCOT		
	DCP	ANT and SCOT
The main focus	The environments, conditions, and implications for technology design and use – “the state”	The processes of interaction between socio-technical elements through which the technology becomes invented and introduced – “the process”
Distribution	Of cognition in the “network” of humans, artifacts, and knowledge	Of social processes and network “connections”
Cognition	Defined explicitly as the focal point of the analysis	Implied through the use of such concepts as “imagination”, “interest”, “inscription”, “interpretation”, etc.
Heterogeneity	Of modes of knowledge and environments	Of modalities of interactions and mutual attributions
Network composition	Knowledge – practice; a form of cognitive architecture	Actants – interests (ANT); Relevant social groups – technology frames (SCOT)
Organizations	Are seen as open, liquid constructs; The notion of network is often substituted by that of organization or sociotechnical system	
Technology	Has an interpretive flexibility, a malleability (ANT and SCOT slightly diverge on this); Technology is often distributed itself	
Design	An emergent, interactive process (whether from a social or a cognitive point of view); The frontier between designer and user is fuzzy; The result of design is never definitively stable	

Despite the similarities in terms of concepts between the two bodies of literature, as outlined in the Table 2 above, in social studies of technology, and in studies of design in particular, the connection between the design process and the distributed cognitive processes is not always well established. This may come as a surprise, as the definition of the word “design” itself implies distributed cognitive processes. Walls et al. (1992, p.36-7) in their work on IS design theory, borrow the definition of design from Fielden (1975): “Design is the use of scientific principles, technical information and imagination in the definition of a structure, machine or system to perform pre-specified functions with the maximum economy and efficiency.” This definition reflects well the scope of design activity. A theory aimed at explaining how technological design comes about must account for cognitive, because design involves the use of imagination. It also must account for social interaction and negotiation (and meaning creation), because “maximum economy and efficiency” are arbitrary and context dependant concepts. Third, the definition implicates discovery of design requirements, because the designed system must perform “pre-specified” functions. And finally, the requirements discovery process may require negotiation of competing understandings (mental maps) of the function(s)-to-be, i.e., the aforementioned cognitive and social activities must be integrated into distributed cognitive design process.

Prior studies on design have focused on one or another criteria, but all the criteria were never within a scope of a single theory or study. For example, Malhotra et al.’s (1980) study observed dialogs between a designer and his client. They argue that design is inherently a negotiation process, which consist of three interacting processes: goal elaboration, design generation and design evaluation (Malhotra et al. 1980, p.119). Their finding that “in real-world design situations, the goals are, typically, fuzzy and poorly articulated and cannot be mapped directly into properties of the design” (Malhotra et al. 1980, p.120) identifies the difficulties of sense-making in multi-actor designs.

In the complex and modular environment, a process of distributed cognition is characterized by multiple “communities” of specialized knowledge workers, each dealing with a part of an overall organizational problem (Boland and Tenkasi 1995, p.351). Paraphrasing Boland et.al (1994), the traditional image of individual designers has recently been supplemented by attempts to support design groups. “It is a discrete group decision that is being supported, not the continuous individual sense making of distributed cognition” (Boland et al. 1994, p.460). The studies of distributed cognition (Arias et al. 2000; Hollan et al. 2000; Hutchins 1990b; Norman 1991) show how individual designs and related design schemata must interrelate and have congruence for effective collaboration (Gasson 2003). Thus, a distributed cognition perspective allows to conceptualize a theory of design that permits negotiated outcomes while recognizing that each individual group member’s design understanding may be incomplete, or incongruent with the understanding of others (Gasson 2003). Explication of individual designs and artifact-mediated interactions with other actors allows the resulting collective designs [goals] to be skillfully negotiated (Dixon 1994; Easterby-Smith 1997, p.1092; Senge 1990).

A historical study of Bell’s and Edison’s inventions of the microphone (Carlson and Gorman 1990; Gorman and Carlson 1990) viewed these inventions processes in which an inventor combined abstract ideas with physical objects in the network (Gorman and Carlson 1990, p.133). Hence design is not only a dialogue (an act of speaking) that results in meaning, but also a reflection, or sense-making process (Weick 1995). A researcher must find out “what occurs in the mind of the inventor – how an individual perceives the world, takes ideas from his social and cultural milieu, and utilizes those ideas to create new technological devices” (Carlson and Gorman 1990, p.388). Carlson’s and Gorman’s term of a mental model and mechanical representation (Carlson and Gorman 1990) establishes a necessary connection between the activity (design) and the object of design – a boundary object (as design) that connects the structure and activity. The mental model combines both designs and imagined networks of actors, connecting together into the actor-network designers, the ICT artifact, users, service providers, and infrastructure (builders).

Finally, returning to the problem scope of theories of distributed cognition, that of describing and explaining the organization of cognitive systems, one can notice an important connection that DCP makes to process-focused research. Specifically, since “distributed cognition looks for cognitive processes, wherever they may occur, on the basis of functional relationships of elements that participate in the process” (Hollan et al. 2000, p.175), one may assume that DCP must be well equipped in terms theoretical concepts to account for distribution processes. This must be especially so, as designers in their work draw on knowledge bases which includes not only knowledge on design process itself, but also knowledge about artifacts, their use, and rationale for previous design decisions (Arias et al. 2000, p.86). However, building on more than a decade of studies of (distributed) cognition and artifact design, Hollan et al. (2000, pp.177,180) report that DCP lacks a method for connecting the important constituents of the “cognitive architecture”. Thus, if SST perspective, for example, may be good at “following the actor” (Latour 1993), the DCP perspective may be less so (Schlecker and Hirsch 2001).

Where the social studies of technology do not quite meet distributed cognition

While having set to explore commonalities between the two bodies of theories, potential incongruence between the two must be also explored.

Designing ICT artifacts entails novel and unexpected changes in technological capability, and actors involved in the design process hold only partial knowledge on the artifact-in-design. “When [people create something together... [they are] possessed by their own vision of the world, they simply can’t see any other way of looking at it” (Kaiser 2004, p.205). This “conceptual blindness” cannot be easily accommodated into the ANT vocabulary. While ANT allows the situation where networks are “partially translated” and/or “minimally mobilized”³, the ANT assumption that alignment of interests of involved actors is a sufficient criteria for the process to advance, ignores the fact that on the cognitive level interests may be different from these “recorded” in the process of network tracing, which may present the stumbling block to the process development when the actor(s) in question realizes the discrepancy between his/her declared and actual interests.

SCOT offers a better way to understand design process as it views it as a continual drift in framing the technology. But it suffers from the weakness that it does not well integrate ideas of individual design in its concept of technology frames. Moreover it views “technology framing” mainly as a user-related activity associated with finished designs (Pinch and Bijker 1987). Being a form of innovation, design involves surprises and unexpected discoveries, which depend on the skills and competencies of individual designers (Wood and Bandura 1989), and the way in which they frame their options for design (Garud and Karnøe 2001).

Both SCOT and ANT accounts, supposedly purposefully (Sun 2001), ignore individual cognitive aspects of design. We propose that distributed cognitive processes form a critical dimension of the design-in-making and must be accounted for in studies of complex design processes.

Cognitive distributed design in SCOT

The notion of technological frames (TF) that SCOT offers is too restrictive for studies of design-in-making. When we include a cognitive design as a unit of socio-technical analysis, TF can be applied to frame the cognitive model, but with an exception of the conceptualized/imagined artifact (the artifact does not exist at the time when technology artifact and its use are only envisioned by inventor(s)). We get into more troubles when applying the TF concept to analyze how cognitive design is being externalized and internalized by interacting social group actors.

Although technological frames are maintained by social interaction, and SCOT even extends the possibilities of its scholars by introducing the concept of inclusion in a TF: “Inclusion is ‘to what extent the actor’s interactions are structured by that technological frame’ (Bijker 1995a)” (Allen 2004, p.174). Nonetheless, the social interaction as implied in the concepts of TF and inclusion, revolves around an exemplary (already implemented) artifact (Allen 2004). This once again demonstrates that design as a distributed cognitive process is taken for granted. In the ICT development work, however, it may take years before an artifact materializes from a conceptualization in the mind of inventors into an exemplary artifact (a prototype). What “guides the practice” if there is no physical artifact? And how adequate the concept of TF is when the artifact being designed is just an intangible signaling protocol?

To be able to include cognitive distributed processes in the concept of technology frame and social interaction, SCOT must be able to cope with cognitive and physical forms, equally. By failing to do so, the structural approach fails to provide “sufficient insights of technical artifacts in development” (Monteiro and Hanseth 1995).

Cognitive distributed design in ANT

Faraj et al. (2004) make a step towards integrating an explicit cognitive element in the ANT analysis. In their view, “actors’ subjectivities – their motives, intentions, interests and prejudices – are imposed on the technological artifact they develop. Thus, users of the technology respond to designers’ original intentions as they are manifest in the artifact (Akrich 1992)” (Faraj et al. 2004, pp.188-9).

³ We are thankful to anonymous reviewer for pointing at this feature of ANT.

Inscription refers to the process of inventors' attempts to "inscribe their vision and interests into the artifact" (Faraj et al. 2004, p.189). The notion of inscription can accommodate "the innovator's beliefs, social and economic relations, previous patterns of use, legal limits, and assumptions as to what the artifact is about" (Akrich 1992). Thus, Akrich argues, an artifact never begins as a blank slate. The definition of inscription seems to open doors for including a cognitive element in the studies of design. Nonetheless, the way the concept is used, it refers to a finished design, i.e., how an existing product subsumes the designer's subjectivities. In their otherwise excellent article on evolution of web browsers, Faraj et al. use ANT to analyze designers' beliefs, but only with respect to existing technological artifacts (tangible or intangible). They fall short in unleashing the potential of "subjectivities" on the design. We see this as representative of ANT in general, where the notion of inscription is used for a "post-design" phase of artifacts life. Cognitive "subjectivities" during "design-in-making" are being back-staged in traditional ANT research.

Discussion

The process of design represents a complexity paradox. On the one hand, we recognize the increasing complexity of the system (implying an increasing likelihood of unintended emergent behavior, often referred to as design failure) and the process (implying the increasing difficulty to identify and imbed in the product all the characteristics valued by a consumer). On the other hand, the design process by definition is a process of ordering complexity, aimed at minimizing, if not eliminating, the unintended behavior and maximizing the design value to the consumer.

Contemporary managerial approaches to ICT design are coping with the complexity by tending "to overestimate the universality of work practices thus seeking order by simplification and abstraction" (Hanseth et al. 2006). The SST theories do not elaborate on distributed cognitive processes of actants, while in DCP, the processes connecting the elements of distributed design are left in shadow. Such "simplifications", while being extremely helpful in identifying or describing major components of overall design architecture (DCP) and associated design tasks (SST) ex ante (Baldwin and Clark 2005), can not accommodate all the "complexities" of *both* the process and environment.

A recent critical review on the design of ICT (Williams et al. 2005) focus on "post-design" activity, i.e., what they refer to as "innofusion" and "domestication" process. The traditional ex post orientation of the design studies is not surprising, since detailed anticipatory analysis of complex system development is not possible due to emergent properties of the latter. However, it is possible in principle – designs and design architectures are ex ante observable, hence are an appropriate focus of scientific research (Baldwin and Clark 2005). Ex ante analysis of (for) complex system development (Fomin and Blechar 2005) can be done by developing "better maps of complex designs and their architectures" (Baldwin and Clark 2005). In continuation with Simon's (1962, p.479) problem solving approach, which requires "continual translation between the state and process descriptions of the same complex reality", and answering the call for new methods for managing complex design (Boland and Collopy 2004a), we suggest that through development of correlations between the two bodies of literature, namely that of the "process description" ANT/SCOT theories and the "state description" theories of distributed cognition, more precise theoretical descriptions of design phenomena can be obtained, thus reducing the "ill-defined problem space" of design theory (Germonprez et al. 2007, p.353).

Theoretical advance: distributed cognition in the studies of design-in-making

Most of the existing literature on design offers theories, which focus on requirements engineering or discovery. "Requirements discovery" means the discovery of "particular views of the user, user activities and priorities" (Williams et al. 2005). At the later stage of design, also referred to as implementation, the discovered views must be inscribed into the artifact by designers.

Akrich (1992) describes the requirements discovery process as the following: "... When technologists define the characteristics of their objects, they necessarily make hypotheses about the entities that make up the world into which the object is to be inserted... A large part of the work of innovators is that of 'inscribing' this vision of (or prediction about) the world in the technical content of the new object" (Akrich 1992, p.208).

The introduction of DCP into the vocabulary of social studies of technology will allow for the analysis of a requirements discovery process as design-in-making, as opposed to the dominant view of design-as-domestication (Williams et al. 2005). Our view of design is subsumed within the idea of a new interpretation of the design, and the

obligation of getting others to agree to go along with it. Hence, an understanding of designer's cognitive behavior (Wood and Bandura 1989) during design needs to be expanded, along with the associated sense-making (Weick 1995) and continuous negotiation where actors' interests become aligned (Latour 1995).

DCP in the formation of “designer” and “user”

A design process in SCOT is well depicted by Bijker (2001) as a “selection” process of technological development (Pinch and Bijker 1987, p.28). A linear historical perspective is drawn, with a single engineer falling into the focus of analysis at any given time. In this constellation, we can see many “users” and their different interests, but at the same time there is only one designer or several designers working on competing technological design separately. Even if present, collective engineering is not visible in Bijker's (2001) work. This contradicts somewhat with Bijker's statement, that the concept of technological frame “is intended to apply to the interaction of various actors” (Bijker 2001, p. 172). Whereas “frames are located between actors, not in actors or above actors” (Bijker 2001, p. 172), how technological frames are structuring/ facilitating/ permitting the engineers to collaborate on a design remains unclear.

If the “dominant” view on design maintains that there is a single “inventor” and many users (which allows for interpretive flexibility, for example), the emerging view on ICT design must accommodate multiple designers (due to the scope and complexity of technology artifacts to be designed, the context in which the design takes place, and the existing infrastructure, which the designed artifact will have to fit into), and a single conceptualized, imagined, aggregated end-user (due to the reach of technology) (Callon 1986).

For Akrich, a useful method for design studies is “to follow the negotiations between the innovator and potential users and to study the way in which the results of such negotiations are translated into technological form” (Akrich 1992, p.208). The paradigm shift in ICT design domain prompts for a change of 1-to-many constellation between designer and users, as advocated by SCOT, to many-to-many – multiple innovators and users for “a continuum ranging from passive consumer, to active consumer, to end-user, to user, to power users, to domain designer, to medium designer” (Arias et al. 2000, p.109).

Williams et al. (2005), when referring to these user-consumer interactions, seems to second Simon's call for bridging the state and the process descriptions of the complex world. According to Williams et al. (2005), “‘social learning’ is ... conceived in the broadest sense to include not only knowledge flows but also interactions between actors and processes of negotiation and struggle”.

DCP and the formation of the “real world”

Conceptions, or visualizations, pertain to the realm of cognition. We see them as a part of a sense-making process (Weick 1995), which is not explicitly introduced in either ANT or SCOT. Lyytinen et al. (2008) argued for introduction of the notion of sense-making in studies of ICT design during the technology innovation process. Sense-making presents the missing bridge between the concepts of individual designers, with their “worlds”, and the proposed “trajectories” leading to those worlds on one hand, and the negotiation process to choose one out of an “indefinite number of possibilities” (Akrich and Latour 1992, p.259), on the other. “The future event is more sensible because you can visualize at least one prior set of means that will produce it. The meaning is that end is those means that bring it about” (Weick 1979, p.198).

Weick (1979, p.196) argued that visualizations are richer in detail, and thus more robust in terms of being subjected to analytical techniques, if they are thought of as having already taken place. He called this way of thinking as “future perfect thinking” (Weick 1979, p.197), and presented it as one of the forms of sense-making.

Future perfect thinking can make conceptualizations more manageable if projected is thought of as already accomplished (Weick 1979, p.199). This has two important implications for studies of design. First, in multi-designer settings, where different design alternatives are being proposed and negotiated, the easier it is to make sense of somebody else's proposed design, the smoother the negotiation process will evolve. Thus, we can assume that Weick's concept of future perfect thinking can facilitate negotiation process, because proposed trajectories (speculations) are “more manageable”. Second, in the context of complexity of ICT innovation, design is almost always modular (larger design tasks are broken down into smaller design subtasks) (Hanseth 2005 submitted; Williams et al. 2005), and thus focus on “single events”, again, will facilitate the process.

Weickian “future perfect thinking” is also a good example of how process and state descriptions are correlated and depend on each other. Design is usually done intuitively, unless the designer stumbles on “unknown” in his/her imagined design (Arias et al. 2000). Should the “unknown” be encountered, either due to the lack of the designer’s knowledge or lack of comprehension for the ideas of others in the collective engineering effort (Arias et al. 2000, p.86), the designer(s) will have to switch their activity from the “cognitive” domain to that of the communication, learning, and negotiation – namely that of the “process” domain (Lyytinen et al. 2008, p.13)

Implications for practice: generative procedures

Modular design architecture in ICT manufacturing allows to decentralize the decision-making process and hence to relieve the managerial decision-making burden. Modularizations allows a design processes to be split up and distributed amongst different groups of designers, each of which can focus on a distinct part of the whole (a module) (Steinmueller 2005).

Applications of the distributed cognitive perspective suggest that the more congruent are “communities of knowing” (Boland and Schultze 1995) involved in the design process, the less likely collaborative process will be retarded by e.g., the phenomenon of “conceptual blindness”. In this light we see the framework offered by Silverstone and Haddon (1996) as particularly suitable for managing complex design processes at a managerial level. Building on earlier research and empirical observations, Silverstone and Haddon (1996) place different concepts pertaining to design under the framework containing three interrelated dimensions “each of which is a necessary, but insufficient precondition for making sense of innovation as a dynamic social process” (Silverstone and Haddon 1996, p.45): creating the artifact, constructing the user, and catching the consumer.

Another generative principle for managing the complex design process is captured by the principle of the paradox of scales. The distinction between “simple” and “complex” system can be seen as a matter of the level of abstraction. Because complexity results from the interaction between the components of a system, the scale at which one examines/ designs/ envisions a system will project either a simple or complex picture (Brey 2003; Cilliers 1998, p.3).

Neither of the two types of tasks aggregation proposed above (also known as “black-boxing”) are novel approaches in management (Simon 1977). However, extending the management of design vocabulary to embrace DCP in combination with the traditional processes will allow to chart not only “black-boxed” task maps, but also associated knowledge maps. This is especially relevant for the design of ICT, where new designs emerge through convergence, divergence, aggregation, etc. (Hanseth 2005 submitted; Williams et al. 2005). In this kind of environment, even within the boundaries of single organization, within a single “task box” of the design process chart, two or more different communities of knowing (Boland and Tenkasi 1995) may be contained. Juxtaposing participants’ “interests” to their “cognitive subjectivities” may rid design managers of unexpected stumbling blocks.

Conclusions

The IS paradigm has undergone a substantial change during the last two decades, reflecting the growth of IS from in-house mainframe computers to worldwide distributed Internet (see Table 1 above). The theories and methods guiding design practice, however, have remained virtually untouched. Reflecting the increase in ICT complexity and the growing number of the ICT design failures, theories of social studies of technology emerged to aid analysis of complex system design processes, although focused primarily on ex post descriptions of the processes leading to important design decisions.

In this paper, we were drawing on Simon’s (1962, p.479) proposition that problem solving (in complex settings) requires establishing correlations between the process and the state descriptions of the complex reality, and the continual translation between the two states. In this context, we set to explore whether or not a correlation can be established between the process-focused theories of social studies of technologies (ANT and SCOT) and the state-focused theory of distributed cognition.

The main contributions of this work is in exploring the common reference points between the two bodies of design theory – ANT/SCOT on the one hand, and DCP on the other hand, while focusing on the former. Through this exploration, we aim to derive more precise theoretical terminology than each of the bodies of theories, when taken

separately, can provide. Renewal of design management vocabulary is needed to cater for betterment of design practice (Boland and Collopy 2004b).

Ideally, our work can also form the basis on which a theory of distribution for distributed cognitive perspective can be developed⁴. The need for enriching the DCP with process descriptions and methods has already been voiced (Arias et al. 2000; Hollan et al. 2000; Schlecker and Hirsch 2001).

The main limitation of the work is that it is exploratory in nature and falls short of applying the derived concepts to real-life case analysis. In the future work, the initial correlation of common concepts between the two bodies of literature, as shown in Table 2 above, should be further elaborated to allow for continuous translation between the two theoretical perspectives by the means of precise theoretical terminology, so that the complex reality of design process can be better understood and managed (Simon 1962).

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⁴ We are thankful to anonymous reviewer for suggesting this implication of our work.

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