Organizational Change and the Digital Economy:

A Computational Organization Science Perspective

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Abstract

E-commerce, the web, computers, and information technology in general are often viewed as a technological panacea where all that is needed is better technology to eliminate social and organizational problems, to make organizations more efficient, effective and productive, and to create an effective digital economy. Technological solutions are expected to eliminate barriers to entry, increase the amount of available information, and provide uniform access to information, people, and information based services. There can be little doubt that information technology is transforming social and economic systems, particularly commerce. However, it is still the case that the networks linking people, knowledge, and companies both enable and constrain the impact of this technology. These social and cognitive networks, along with the needs of individuals for privacy, and the needs of companies to protect core intellectual property, are at odds with the open and uniform access assumptions often made about the digital economy. As we move into a digital economy we need to understand how these networks and individual and corporate needs will influence and shape the resulting organizations and markets. Recent work in computational organization science provides guidance for assessing, measuring, monitoring, and predicting organizational change as we move into a digital economy where technological change is increasing information and access in the face of social and cognitive constraints.

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As we move into the 21st century technological advances are transforming simple objects such as microwaves, VCRs, computers, locks, and lighting systems into intelligent objects by giving them the ability to perceive their environment, process information, make decisions, act, and communicate. The integration of computers into all devices is making commerce electronic, actors artificial, spaces intelligent[1], and the social and economic world digital.

Intelligent spaces will be characterized by the potential for ubiquitous access to and provision of information among potentially unbounded networks of agents (Kurzweil, 1988). These agents will include humans, as wells as many artificial agents such as organizations, webbots, robots, and other electronic agents. These agents will act and interact in an environment of vast quantities of distributed but potentially integratable information where the interface between the analog and digital world is seamless.

Intelligent spaces have four main characteristics. First, ubiquitous access — agents (human or artificial) will have the technology for accessing or providing information wherever, whenever, and to whomever it is useful thus remotely enabling other agents to act. Second, large scale — vast quantities of information will be automatically collected and stored and processed by vast numbers of agents. Third, distributed cognition and intelligence — information, access to information, and information processing and communication capabilities (i.e., intelligence) will be distributed across agents, time, space, physical devices and communication media (Hutchins, 1991; 1995). Fourth, invisible computing — the interface between the digital world and the analog world will become seamless as computers are miniaturized, made reliable, robust and embedded into all physical devices. As spaces become intelligent and as information becomes digitized a new socio-political and economic system will emerge, the digital economy.

As spaces become intelligent there will be unprecedented increases in the size and complexity of the interaction and knowledge networks in which people (and other agents) are embedded. For humans, technology is increasing the amount of information they have access to, when they have access to information, where they have access to information, and how they can process that information. While some argue that these technology based changes will engender social equality and increased individual and organizational performance, others argue that this may not be the case (Ebo, 1998; Kiesler, 1996). In other words, people will still be people. Organizations will still be needed to overcome the limitations of individuals (March and Simon, 1958; Pew and Mavavor, 1998; Prietula and Watson, forthcoming). Coordination, communication, and the diffusion of new technologies will still center around knowing who knows who and who knows what (Wellman, 1998; Wellman, et al. 1996, Rice and Aydin, 1991, Aydin and Rice, 1992; Contractor and Eisenberg, 1990).

Turning the potential of intelligent spaces into a reality where individual and organizational performance is improved will require overcoming the digital, physical and cognitive barriers faced by people and organizations in effectively locating and working with others. If work is to be done effectively, people need to locate others who have information or resources that they need, interact, gain information, and understand the impact of that interaction. The increasing professional specialization and the increasing speed with which ideas are developed in a digital economy combine to create an unprecedented need for quickly and efficiently locating and working with others.

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[1] An information processing view of intelligence is being used. Thus any agent that can perceive its environment, acquire information, process information, make decisions, learn, and communicate is considered to be intelligent. The degree of intelligence would vary with the number , extensiveness, and quality of these capabilities the agent possesses.

Today, communication takes place in a limited environment. Digital barriers to locating information exist. Physical barriers to interaction exist. Cognitive barriers to understanding the impact of interactions exist. Overcoming these barriers will have value to both the pursuit of science and to industry. Simply instrumenting spaces to be intelligent, making computers invisible, digitizing all data, putting everything and everyone on the web, carrying out all transactions electronically, will not be sufficient to overcoming all of these barriers. Technology alone cannot create a truly digital economy (Kiesler, 1996).

In theory, instrumenting the physical world to be more intelligent enables individuals, groups and organizations to do more in less time and to connect to a widening circle of others. However, research in telework demonstrates, such technological changes by effecting greater decentralization and increased worker autonomy and mobility have engendered higher levels of productivity, improved working-time arrangements, and new employment opportunities for some; but, they have also generated increased isolation, marginalization, exploitation and stress for others (DiMartino and Wirth, 1990). It is difficult to measure productivity, performance, and effectiveness and the impact of computers and the internet on such outcomes. Nevertheless, it appears that productivity and connectivity appear to be closely tied. Thus, increasing connectivity has often had the direct effect of increasing costs and delaying productivity gains (Dutton, 1996; Anonymous, 1988).

The movement to intelligent spaces is likely to increase the complexity of the underlying interaction and knowledge networks. We expect this increase in complexity to be greater than people's ability to manage and monitor this space. This increase is often referred to as an increase in individual's infospheres (see Figure 1).

The term infosphere was coined by the military to refer to the collection of remote instruments, appliances, computational resources, as well as the agents (human and artificial) and information made accessible by these systems from a person's working environment, such as the cockpit of a plane, the bridge of a ship, or the office. Humans (and indeed all agents) are surrounded by such information spheres. For humans, their infosphere is largely determined by the type of immediately accessible technology. Thus, your infosphere is generally larger in your office, than it is in your car, when you are walking down a hallway, or when you are sitting on a mountain top.

As the physical spaces humans inhabit become more intelligent there is an expansion in each individual's infosphere. Moreover, this infosphere is less likely to change in size as the individual moves from one physical location to another (see Figure 1). In intelligent spaces, when people move, their infosphere moves with them. The knowledge available in these infospheres includes what people know, who they know, and what they know how to access. As infospheres increase in size, mobility, and accessible knowledge, the networks in which people are embedded and those to which they have access respond dynamically and become potentially unbounded. Examples of these networks are the social network (who interacts with whom), the knowledge network (who knows what), and the information network (what information is related to what other information).

Technological change may lead to non-linear rates of network change and to fundamentally different network structures (Kaufer and Carley, 1993). However, technological change will not obviate the need for networks or the fundamental socio-cognitive processes surrounding them (Wellman et al. 1996). Thus, the impact of technological change on organizations can be characterized in terms of alterations on and variations from existing forms and in terms of community creation and maintenance (Butler, 1999).

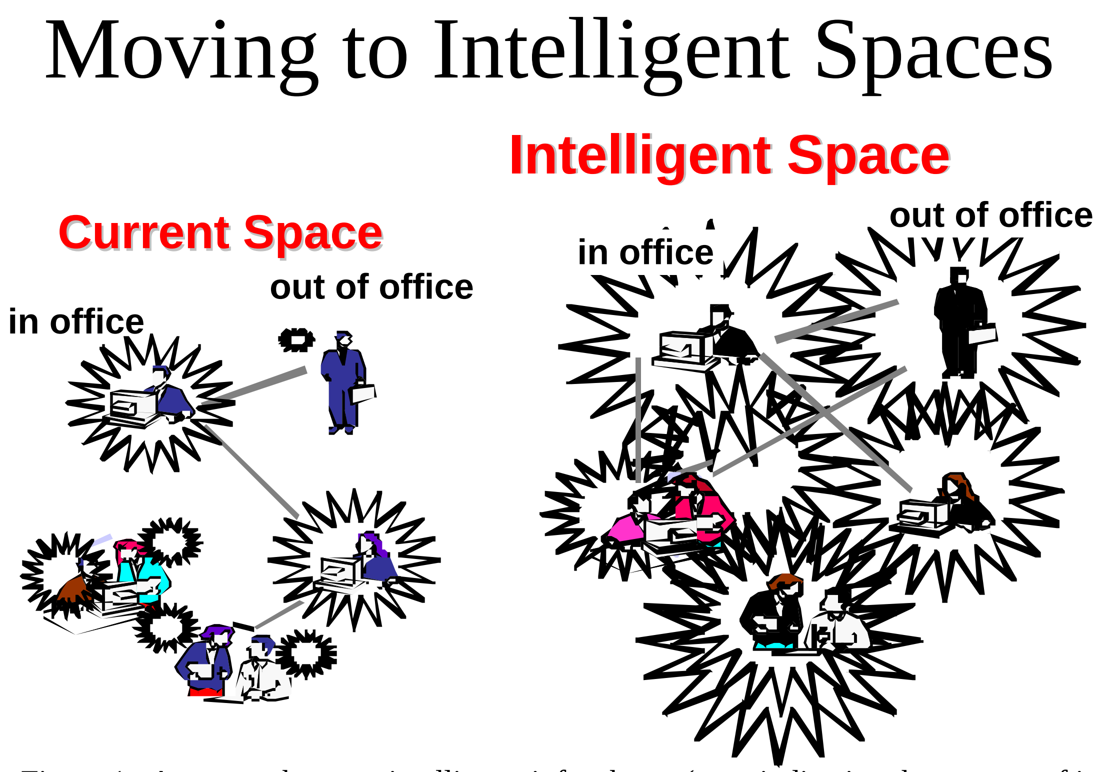

Figure 1. As spaces become intelligent, infospheres (stars indicating the amount of information the person has access to in that physical location) grow and changes occur in the interaction networks (bold lines indicating who interacts frequently with whom).

Computational Organization Science

Two adages underlie much of the research on organizations: 1) *it is who you know not what you know that matters*, and 2) *knowledge is power*. Implicitly, both adages imply that there are multiple adaptive intelligent agents whose actions and relations determine their decisions and performance and that of the organizations in which they work. However, there is a hidden conflict between these two adages with the 1st focusing on the social network and the 2nd focusing on the knowledge network.

Research on organizations that has sought to keep these networks separate has had limited success in addressing the impact of IT, e-commerce, or the web on organizations and society as we move to a digital economy. A key feature in understanding the impact of IT, e-commerce, the web, and other features of a digital economy on individual, organizational and social outcomes is the recognition that social and knowledge networks are linked in an ecology of networks and that a change in any one evokes a cascade of changes in the others. A high level view of this ecology in shown in Table 1.

Research across a large number of fields (from anthropology to computer science) has contributed to our understanding of the processes at work in each of the cells in Table 1. Nevertheless, our understanding of how the entire ecology of networks interacts and affects social and economic outcomes is incomplete, particularly as it relates to knowledge. Further, most of the measures that have been developed have been tested only on small networks (less than 5000 nodes, often less than 100 nodes). Research is needed as to which of these measures scale, and continue to provide information, when the network has many more nodes and ties.

Table 1. The Ecology of Networks in which Individuals and Organizations Reside			
	People	Knowledge	Organizations
People Tie Phenomenon Learning	**Social Network** *Who knows who* Social Structure Structural learning	**Knowledge Network** *Who knows what* Culture Individual learning	**Work Network** *Who works where* Organizational demography Turnover based learning
Knowledge Tie Phenomenon Learning		**Information Network** *What informs what* Intellectual formation Discovery	**Competency Network** *What is where* Core competencies R& D and Strategic Learning
Organizations Tie Phenomenon Learning			**Inter-Organizational Network** *Organizational linkages* Industry level structure Mimicry, transference, best practice adoption

The complexity of interactions implied by this ecology of networks, particularly when it is populated by humans and artificial agents (such as webbots) who have the ability to learn, adapt, and as a group evolve, is difficult to comprehend, let alone reason about. A new approach that has tremendous potential for improving our ability to understand, reason, and manage the digital economy is computational analysis. In particular, computational organization science is a new perspective on organizations and groups that has emerged in the past decade in response to the need to understand, predict, and manage organizational change include change that is motivated by changing technology (Carley and Gasser, 1999).

Computational organization science takes the stance that organizations are inherently complex, computational and adaptive systems composed of complex computational and adaptive agents (both human and artificial agents such as webbots, robots, and intelligent IT). Human organizations can be viewed as inherently computational because many of their activities transform information from one form to another, and because organizational activity is information-driven. This new perspective places individuals and organizations in this ecology of networks. Organizational behavior is predicted using knowledge about distribution of agents and knowledge across these networks (Cyert and March, 1963). Improved coordination and performance should be achievable by affecting the way in which people and organizations navigate within and operate on these networks.

From computational organization science perspective, organizations are synthetic agents. Within organizations, cognition, knowledge and learning reside in the minds of the participant agents and in the connections among these agents. Consequently, both individuals and organizations as agents are constrained and enabled by their positions in this ecology of networks (Granovetter, 1985).

The computational approach works synergistically with other approaches to extend and evaluate theoretical arguments in more complex, and dynamic domains such as those that characterize the digital economy. The computational approach is strongest when the underlying models are empirically grounded and embed, are driven by, or are validated against, other forms of data including detailed anthropological case studies, lab experiments, survey results, and large scale data that can be automatically collected over the web. What this means, is that multi-disciplinary teams are needed to support a modeling - theory building effort, as are data archives, model archives, and canonical task sets. Such a scientific infrastructure is necessary to increase the rate of scientific progress in this area.

Each type of scientific research has critical limitations that affect the extent to which you can generalize from the findings. For example, analyses based on surveys are limited by the way in which questions are asked, whether questions are always asked in the same order, and the sample of individuals who are questioned. Human experiments are limited by the experimental design, the subject pool, and the nature of the manipulation and controls. Computational analysis also has its limitations. In particular the assumptions made in constructing the model and the way in which the basic processes are modeled may affect the generalizability of the outcomes. For each scientific method, methodologists work to develop procedures for overcoming the limitations. For example, the use of specialized sampling procedures in survey analysis can increase the generalizability of the results. Similarly, in computational analysis, the use of Monte Carlo techniques to average out assumptions about parameter values (Balci, 1994) the use of empirical data to calibrate the model (Carley, 1999) and docking (Axtell, Axelrod, Epstein, and Cohen, 1996) two or more models with different core processes are among the techniques that are used to increase the generalizability of the findings.

Computational organization scientists seek to understand and model two distinct but complementary types of organizations (Carley and Gasser, 1999). The first type of organization is the human organization which continually acquires, manipulates, and produces information (and other goods) through the joint interlocked activities of people and automated information technologies. The second type of organization is the artificial computational organization comprised of multiple distributed agents and which exhibits collective organizational properties such as collective action and task assignment. Computational analysis is used to improve our understanding of the fundamental principles of organizing multiple heterogeneous agents and the nature of organizations as computational entities operating in this ecology of networks. Arising out of this body of work is an increased understanding of organizational change and the impact of IT. Let us consider three general findings repeatedly demonstrated by research in this area for multiple models and under a wide range of assumptions: emergent behavior, path dependence, and inevitability of change.

Emergent Behavior: Although organizational performance is dependent on the intelligence of the agents within the organization it is not determined exclusively by an aggregation of individual agent activity. Organizations in particular, and multi-agent systems in general, often show an intelligence and a set of capabilities that are distinct from the intelligence and capabilities of the composite agents (Epstein and Axtell, 1997; Padgett, 1997; Zeggelink, Stokman and van de Bunt, 1996; Kauffman, 1993; Macy, 1991; Axelrod and Dion, 1988). This means that the behavior of groups, organizations, and markets cannot be predicted by looking at the average behavior, or even the range of behaviors, of the ensemble members. Rather, the networks affecting and affected by these agents serve to constrain and enable what actions are taken when, by whom, and the efficiency of those actions. These networks and the agents' learning procedures dictate what changes can occur, are likely to occur, and will have what effect (Carley and Newell, 1996).

In order to predict the behavior of groups, organizations, or markets we need to understand the interactions and changes in the underlying networks and the way in which member learning alters these networks. Computer modeling, because it can take into account the complexities of network dynamics, facilitates accurate prediction and helps us to move from saying interesting complex behaviors will emerge to saying what behaviors will emerge. Nevertheless, research is needed on what behaviors will emerge under what conditions, and on what future scenarios are likely to occur or are infeasible given the constraints of human cognition, socio-economic policies, and the way in which the extant networks change, constrain, and enable individual behavior.

Path Dependence: Individual and organizational performance is dependent on the history of how they got to their current situation (Richardson, 1996). For individuals what they can learn is a function of what they currently know and who they know. Thus, individuals with different backgrounds learn different things when faced with the same new information; i.e., faced with the same web page you and I might learn totally different things from it. Organizational performance is determined by structure, culture and the experience of the member personnel. In particular, organizational performance is affected by the experience individuals gain working in groups as this builds both team mental models (Kim, 1993) and transactive memory of who knows what (Wegner, 1995).

This means that two organizations that start identically but differ in when they adopt new technology are likely to have dramatically different performance profiles. This means that organizations that try to improve by following the best practices of other organizations may not reap the rewards seen by the originator of the best practice. Research is needed to convert this notion of path dependence into a tool for seeing whether, and if so under what conditions, a person or organization can achieve the targeted goal. We need to be able to predict, apriori, what path to follow and how to recover from the wrong path.

Inevitability of Change: Individuals are continually learning (Newell, 1990). Whether they actively seek information, simply absorb new information told to them, or discover new ideas they learn. As individuals learn, the knowledge networks change and sometimes the information network changes. Since individuals have roles in organizations, changes in the knowledge network results in changes in the competency network. When individuals learn, that also alters whom they interact with and so the social network (Carley 1991).

Changes in the social networks or knowledge networks can lead to or be motivated by changes job network. At the organizational level such changes might be characterized as evolution or organizational adapatation (Moss, 1990). Changes in the social network, the competency network, or the job network can result in changes in the organizational network. Change, for the most part, is inevitable and as long as discoveries are possible, equilibrium is never reached. Managerial strategy thus becomes decision making about how to structure and position the firm so as to manage and profit from changes in the underlying networks. Organizational design thus becomes a dynamic process (Cohen, 1986). Thus, research is needed on how to manage change, and create an environment that controls the rate and type of change desired in these networks.

Before discussing specific results relating to the digital economy it is worth noting that the ecology of networks, described in Table 1, provides a distinctive way of classifying organizations and a representation scheme for describing organizations. A variety of schemes have existed in the past for classifying organizations, e.g., ones based on strategy (Romanelli, 1989), product service (Fligstein, 1985), or some combination of technology, coordination and control (Aldrich and Mueller, 1982). These schemes provide little guidance for how IT will be adopted by or how IT will effect organizations, how change should be managed, and how organizations will change. Computational and empirical research that has used a network approach like that in table 1 has been able to make a series of predictions about the impact of IT and changes in performance to be expected by re-engineering (see for example, Levitt, 1994).

Intelligent Spaces and the Ecology of Networks in a Digital Economy

Researchers in computational organization science employ computer models to predict, explain and manage organizations. Work in this area demonstrates that the accuracy of the predictions and the veridicality of the results depends in part on the level of detail in the models. More detailed models, more detailed predictions.

To move beyond the general findings described in the last section, which are very robust, validated, yet vague in providing specific guidance vis the digital economy, we will need to move to predictions made by specific models. One of the core areas where computational models have been used is in the area of information diffusion and belief formation.

To illustrate the level of these results the CONSTRUCT model is used (Carley, 1990; 1991, 1995, 1999). CONSTRUCT is one of the few validated computational models concerned with information diffusion that takes IT into account. CONSTRUCT is a multi-agent model of social and organizational change in which there are many heterogeneous agents all of which can be intelligent, adaptive, capable of learning, making decisions, and communicating. CONSTRUCT makes it possible to examine the impact of different types of IT on information diffusion, belief formation, and group performance. The exact processes embodied in the agent depends on whether the agent represents humans or some form of IT such as books or webbots. Using CONSTRUCT the researcher can predict change in the social network from change in the knowledge network and vice versa for a group.

The first question to address is how do we represent IT, measure IT, model IT. Research in this area has demonstrated that IT is both an agent and an agent enhancer. Most research on the social or organizational impacts of technology assume that the reason that IT does or does not effect change is because it augments or changes the information processing capabilities of humans. For example, email is seen to effect differences in communication because it enables asynchronous, high speed communication, and is archivable.

Yet, IT is also an agent. That is, IT has the ability to create and communicate information, make decisions and take action; and, as spaces become intelligent, this aspect of IT is likely to become more important. Treating IT as agent has been important in explaining the effect of previous technology (Kaufer and Carley, 1993) and has led to important new findings about the potential impact of IT. Importantly, this approach holds forth the promise of making it possible to accurately model and so predict the behavior of organizations in which humans, webbots, robots, avatars, and so forth all work together to perform various tasks (Kaplan, 1999).

Viewing IT as an enhancer led many researchers to predict that one of the core effects of email, the web, and various other IT was that they would speed things up and make interaction and knowledge networks bigger. Computer based, studies using CONSTRUCT to look at the effect of IT as enhancer and agent, suggest that the movement to intelligent spaces will have additional important effects on groups and may alter the underlying social and political order. First, to the extent that discovery is facilitated by increased information sharing then the increase in the rate of information diffusion, which is a function of the amount of information there is to diffuse, may be less than expected. Second, IT is not a panacea equally facilitating all individuals nor will it necessarily decrease the socio-economic distance between disparate groups. Rather, since individuals who know more have more ability to learn new information, since individuals who know more people have more ability to learn new information, IT has the possibility of increasing the socio-economic distance between the intellectual haves and have nots (Carley, 1995; Allstyne and Brynjolfsson, 1995). Third, IT will alter not just the rate of information diffusion but also the relative rates of diffusion.

Imagine the following scenario – a scientist makes a discovery and then wants to communicate information about it. Who will learn of this discovery first, other scientists or the general public? In a non-digital economy, where spaces are not intelligent and access is not ubiquitous, the answer is – other scientists. Historical studies of the Royal Society and the discovery of scientific ideas in previous centuries show that this was in fact the case.

Simulation studies using CONSTRUCT predict that as spaces become intelligent the new idea will diffuse much faster to both other scientists and to the general public (see Figure 2). As new communication technologies have come on the scene, the printing press, email, the web, new ideas have diffused faster. More importantly, the computational models demonstrate that the expected order in who gets what information first is very likely to change as the world becomes increasingly digitized. For example, this analysis predicts that as spaces become intelligent, the newly discovered information will diffuse to the general public before it diffuses to other scientists.

What this means is that the role of knowledge-intensive professionals is likely to change. Many professions, such as medicine, law, science and engineering have developed norms, procedures, educational programs, information checking and balance schemes based on the assumption that information peculiar to their area was first known to them (Abbott, 1988). How these will change with the presence of digital experts and ubiquitous information is an open question. For example, how will doctor-patient-nurse relationships change as patients learn about new drugs and procedures prior to the doctors?

As we develop a better understanding of how to model IT, as agent and enhancer, we will be able to use computational analysis to address these issues and to explore whether specific policies and security procedures will ensure that the right information reaches the right people in the right order to achieve the desired outcomes. Research is needed in creating computational tools for non-invasively evaluating the potential short term and long term impact of policies and procedures on access to information, changes in information flow and the consequent changes on individual, group and organizational behavior and performance. Part of this research agenda should include improved procedures, tools, and techniques for designing, building, evaluating, and teaching with computational models.

Collectively, these results and others suggest that organizations and society will need to erect barriers in and around people and knowledge. These barriers will help control information flow, maintain information superiority, and promote organizational performance. The point for research is, where and how should these barriers be erected?

Erecting barriers is not the only approach to altering the rate of information diffusion. Another approach is to encourage or discourage information seeking behavior. For example, some web proponents argue that all organizational members should be both taught and encouraged to surf-the-web so that they will be able to actively gather information that will enhance the way they do their job. Simulation studies using CONSTRUCT to explore the relative rates of information diffusion in intelligent spaces when individuals actively seek, surf, and passively receive information reveal that active information seeking does not guarantee that information will diffuse faster (see Figure 3).

The rate at which information diffuses depends on whether individuals are actively seeking out someone to tell them the new information or are on the receiving end because whomever they happen to interact with happens to tell them the new information. Actively seeking information can actually slow down the rate of information diffusion and this effect, even in an intelligent space, may be more pronounced the larger the group. Thus, if the organization's goal is to slow diffusion they might place people in larger groups, or they might encourage active searching, rather than generic surfing (Figure 3, left).

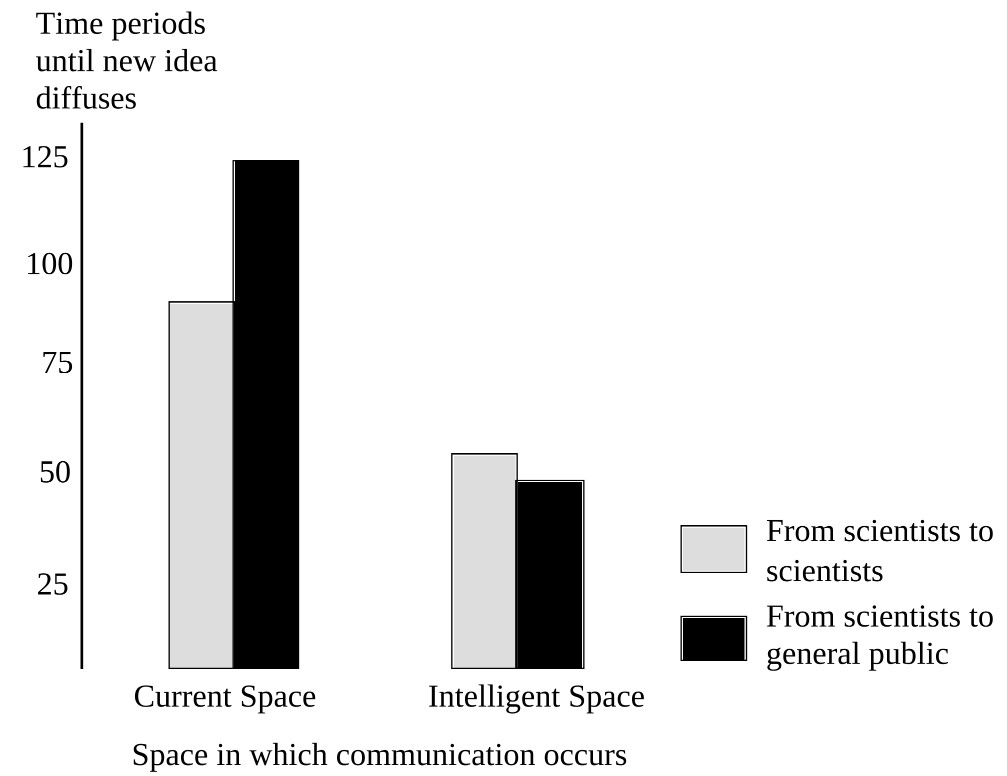

Figure 2. Communication in intelligent spaces will alter the relative rate at which information diffuses to different groups.

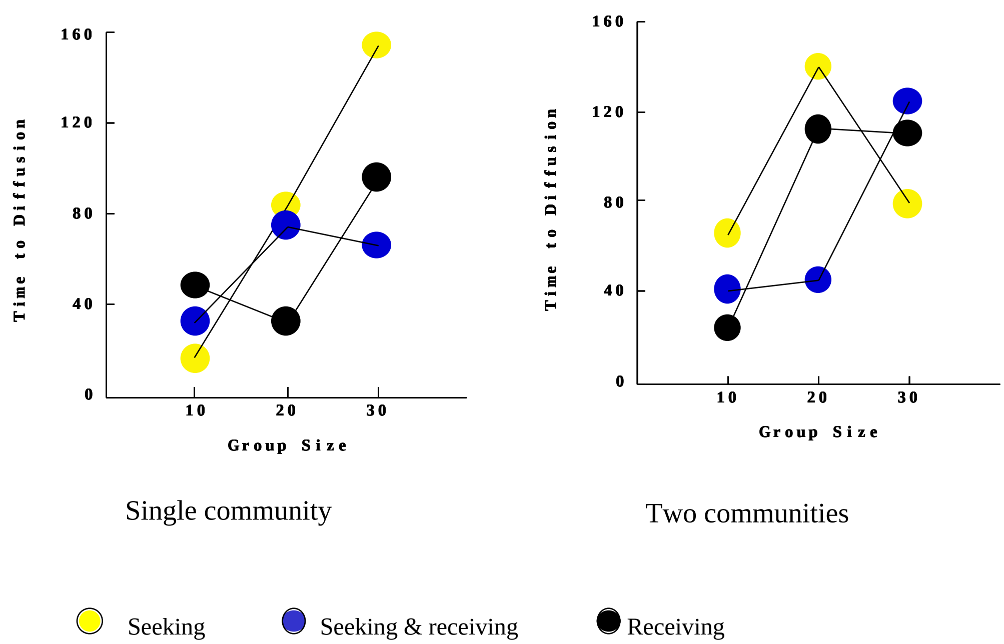

Figure 3. In intelligent spaces, group size, knowledge distribution, and procedures for learning new information, still affect who learns what when.

This assumes that information is distributed more or less randomly through the community or organization. If on the other hand, there are knowledge cliques, such as occur when the community is divided into sub-communities or the organization is divided into divisions, then a different picture emerges (Figure 3, right). The partitioning of knowledge across sub-groups slows down the rate of diffusion, even when there are no active barriers to the flow of information. This effect is strongest when individuals are passive information receivers and it is stronger the larger the number of people who are connected.

Let's put these results in the context of the web. If people and organizations put up sites more or less randomly and there is no underlying division of knowledge or people across sites, then as more sites are erected and more people actively try to find information on the web it may should take longer for new ideas to diffuse. Moreover, if on the other hand, groups in addition establish distribution lists so that information is sometimes sent to people and sometimes they seek it out, then as more sites are erected and more people start using the web the effect of size will be mitigated. On the other hand if clusters form or are constructed of people and knowledge (e.g., by similar sites linking to each other, or by sites of the same type putting up similar information) then as long as people spend at least part of the time seeking information, simply having more sites and more people on the web may not determine the rate at which new ideas diffuse. Thus while we now know that clustering networks can facilitate communication and comprehension we do not know what the optimal size, location, or composition of those clusters should be.

A popular image of e-commerce, the web, and other IT associated with a digital economy has been that it eradicates social boundaries, eliminates the role of social networks, and diminishes the importance of who knows who and who knows what in determining individual and organizational performance. The view that is emerging from computational analysis of social and organizational systems is almost the opposite (Alstyne and Brynjolfsson, 1995). A growing body of research is demonstrating that the impact of making spaces intelligent is very context dependent and that knowing the distribution of connections among people, information, and organizations is necessary for understanding the impact of different types of IT.

A growing body of research, sometimes under the rubric of small world phenomena, is demonstrating that e-commerce, the web, and IT far from reducing the role of networks in a digital economy actually require network structuring (i.e., the placement of non random connections) in the social, knowledge, organizational, and other networks if the digital economy is to be effective and efficient. Web managers for companies are often aware of this and take care in exactly how they place links in the web-based organizational network (Gant, 1998). As was seen, such structuring, depending on how people acquire information, can actually reduce search time for new information. In practical terms, putting up web pages pointing to sets of group relevant web pages should actually enable new information to diffuse faster. However, how many or which groups you should point to is not known.

Adaptive Organizations

While rapid information diffusion is valuable to organizations, performance depends not just on getting new information but in making the right decisions over sustained period of time. That is, organizations need to adopt strategies of change, do R&D, engage in alliances, and so forth to ensure high performance now and in the future as the environment changes. Much of the research in this area points out that organizations need to develop competencies, that they need to learn how to learn, and that they need to tradeoff between exploiting known competencies and exploring new options (Levinthal and March, 1981). Despite the growing body of work on organizational learning, the picture that is emerging with respect to intelligent spaces and the digital economy is woefully incomplete.

One question is, what is happening to the industry? Many studies point to increased out-sourcing and the development of new forms of organization (Pinchot, 1994; Worhington, 1997). One such new form is the "networked organization" — which is alternatively defined as a virtual organization formed through long standing linkages among a set of organizations and as an organization in which work is coordinated on an as needed bases with emergent and reforming team rather than through a strict hierarchy (Nadler, 1992; Nohira and Eccles, 1992). Data on the inter-organizational network of alliances, joint ventures, partnerships, mergers, teaming, and other forms of alliances for the past decade was gathered from newspaper data and trade journals for over 200 corporations working in the high tech industries centering around the tele-communications, electronic, and media industries (Chowdhury, 1998; Casciaro, 1999). These industries are arguable at the heart of technology development, service development, and usage for the digital economy.

These studies show that over the past decade the inter-organizational network has become increasingly structured and dense; i.e. many new organizational linkages were forming. Second, most organizations work in multiple industries so standard industry level SIC codes are not particularly useful means for classification. Third, and most intriguing, the best predictor of where organizational linkages will form is "my enemies friends are my friends too" (Chowdhury, 1998).

That is, two competing organizations were likely to link to the same third organization. These links are not sales agreements, thus it is not the case that they are buying a common commodity. What is passing through the links is expertise and knowledge. Thus one possible explanation is the shared need to know about third party information that uniquely is held by only one company (the friend of one's competitor). Another possible explanation is that when two companies link to the same third party, they can indirectly learn about the same types of things that their competitor is learning about and so stay abreast of recent developments. Fourth, over time, organizations develop a portfolio of ties in which the different sectors are represented only once (Casciaro, 1999). Further research is needed to see exactly why these linkages are forming and how long they last.

A second set of questions center around how do organizations adapt and how will a digital economy affect this adaptation? Work in computational organization science speaks to these questions (Levinthal and March, 1981; Lant, 1994; March, 1996). As in the last section, more detailed predictions and explanations require utilization of more detailed models. To illustrate the types of findings in this area the ORGAHEAD (Carley and Svoboda, 1996; Carley and Lee, 1998; Carley 1998) framework will be used.

ORGAHEAD is multi-agent model of organizational behavior and adaptation. ORGAHEAD makes it possible to examine how changes in IT and the nature of the task environment affects organizational adaptation and performance for organizations engaged in classification and situation awareness tasks. Within ORGAHEAD at the operational level individual agents learn how to get the job done through experience and communication with others. Basically, information and decisions flow up the chain of command and performance evaluations and change orders flow down. Experiential learning is modeled using standard human learning models. At the strategic level, the CEO or change agent, has the ability to attempt to predict the future (albeit faultily) and to move ahead by engaging different strategies for change (up-sizing, downsizing, redesign, retasking). The flow of strategic decisions, with the organization becoming increasingly risk averse, is captured as a simulated annealing process. Within this environment different aspects of the digital economy, such as its impact on amount and quality of information, new problems, and the rate at which decisions must be made, can be tested in isolation or collectively.

Studies using ORGAHEAD have resulted in numerous findings about adaptation and organizational change. For example, it is often asserted that IT and the web have given rise to a rapidly changing environment where there is a constant need for organizations to change what it is they are doing. One question is, should organizations change rapidly and in what way to maintain high performance in the face of these changes? Here we find that organizations that exhibit high sustained performance, the adaptive organizations, actually change less than maladaptive organizations in a rapidly changing environment. Moreover, adaptive organizations tended to be larger and with more connections in the social network or knowledge network (depending on the task environment) than their maladaptive counterparts. Whether who knows who connections can be traded for who knows what connections and under what conditions is a point for further study.

Hierarchies tend to be more robust than flatter more team like structure and so more able to withstand information errors, communication errors, and personnel turnover. This appears to be particularly true for more complex tasks involving more information. Typical claims are that in a rapidly changing environment, such as that associated with a digital economy, flatter structures such as teams are needed for more rapid response. This work suggests that such a claim overlooks the fact that in rapidly changing environments, speed is not the only important factor in effecting high performance and sustained high performance.

Learning also matters. Thus, to the extent that the fast moving world inherent in a digital economy also means that there is less time to do error checking and with more people and more information more chances of information and communication errors. Since tele-work and rapidly changing technology encourages turnover and job changes, organizations will need to adapt by finding ways of doing error checking and retaining expertise. One response is to be hierarchical, not necessarily in management but in a checks-and-balance approach; another response is to expend effort on retraining, just-in-time training, embedded training tools in technology, and employ life-long-learning approaches.

This body of computational research also suggests that adaptive organizations tend to change differently than do maladaptive organizations. For example, studies using ORGAHEAD (Carley and Lee, 1998) suggest that adaptive organizations engage in changing the network of connections — retasking, changing the knowledge network by changing who is doing what and redesign, changing the social network by changing who reports to whom. In contrast, low performance organizations spend most of their time changing the "nodes" in the network by alternate bouts of hiring and firing. Future work should examine how these changes interact with technology transfer and the migration of personnel between organizations.

Finally, adaptive organizations tend to first get the right people (hiring plus judicious firing) and then spend their time responding to the environment by altering connections. In contrast maladaptive organizations tend to engage in frequent cycles of upsizing and downsizing. These results suggest that as we move to intelligent spaces, to achieve sustained high performance, organizations should make it easy for their personnel to move between tasks, groups, departments, and divisions. Internal organizational boundaries should be treated as permeable and internal transfers as de riguer. Research is needed to suggest what tasks this approach is valuable for and whether re-design and retasking is valuable in a multi-organization systems where personnel can move between companies as well as between divisions within a single company.

Future Directions

Organizations are heterogeneous, complex, dynamic nonlinear adaptive and evolving systems. Organizational action results from interactions among adaptive systems (both human and artificial), emergent structuration in response to non-linear processes and detailed interactions among hundreds of factors. As such, they are poor candidates for analytical models. Because of the natural complexity of the object of study, existing models and theories of organization are often vague, intuitive, and under-specified. Scientific progress will be more readily achievable if the theories are more explicit and well defined. Computational theorizing helps to achieve this.

Herein, the value of computational theorizing to understand organizational change as we move to a digital economy has been explored. Computational models can be used to address organizational change in other ways as well. For example, such models can be used to demonstrate lower bounds on or the tractability of organizational information processing phenomena (e.g., minimal information necessary to reach distributed agreement or awareness or the tractability of an organizational decision or negotiation processes (Rosenschein and Zlotkinx, 1994). Experimental and empirically-based computational models can also provide computationally-plausible accounts of organizational activity (Jin and Levitt, 1996; Decker, 1996). Such models have the potential to be used as both didactic devices and managerial decision aids (Baligh, Burton and Obel, 1990; Burton and Obel, 1998).

Additional work is needed in developing computational frameworks in which these computer models of organizations, markets and societies can be rapidly developed and tested. The issues here go far beyond developing a multi-agent language. The usefulness of such frameworks will be enhanced by linking them directly to on-line databases.

Using the common representation afforded the representation scheme implicit in Table 1 enables cross model comparison and direct comparison of the predictions of the computer-based simulation model, human laboratory data, and survey data. This is making possible unprecedented levels of model comparison and validation. This common representation scheme is also leading to the development of new, more powerful and comprehensive measures of organizations that go well beyond the social network measures (Krackhardt, 1994; Wasserman and Faust, 1994) employed currently to understand the structuring of personnel networks and their impact on organizational performance. Further, the common scheme means that it will be possible to decrease the boundary between model, data and organization.

In the near future it will be possible to collect data on organizations in exactly the format needed by the computational models and since the models can generate data in a form that is directly comparable to that generated by the human organization and used by managers, HR personnel, and intelligent agents to manage, monitor, and analyze the organization. This commonality enables the computational models to be validated. Equally important from a digital economy perspective, this means the models can themselves serve as artificial agents or artificial organizations doing some of the work that might in a non intelligent space be done by humans or human organizations. It also means that the computational models can be used as virtual laboratories drawing on web-accessible data in which practitioners and scientists can conduct what-if analysis on the potential impact of new IT.

An extremely important future direction is to develop an understanding of, and tools for, change management. Little is known about what people need to effectively manage both interaction and knowledge in intelligent spaces. Will providing people with tools for integrating and visualizing knowledge (both theirs and others) actually improve the way in which people work? Will being able to analyze, visualize, and manage interaction and knowledge networks enable people, groups, and organizations, to be more effective, more productive, to reduce uncertainty, and improve performance? It is reasonable to expect that as we enter the age of intelligent spaces true productivity gains will require better tools to manage and monitor infospheres and networks.

Today, in many organizations, automation of basic processes is insufficient to eliminate inefficiencies and guarantee sustained performance. Similarly, the success in integrating distributed work activities will rest on how well the users of a network can coordinate their activities with respect to each other (Rogers, 1992). Network management involves being able to search for relevant people and knowledge, dynamically generate and evaluate the value/capability of groups of people and/or knowledge that are networked together to achieve some goal and asses the vulnerability of the system to various types of dysfunctionalities (such as loss of personnel or knowledge).

We have some understanding of the social and psychological factors involved here. However, we have few tools that can be used to aid management in thinking through these issues, or for tracking the networks in and among companies, or for automatically gathering the relevant measures. Nor do we have the infrastructure for collecting and correlating all of the known findings about human behavior that are needed to serve as an empirical foundation for such models.

Issues such as these are particularly relevant in the area of security. It is relatively easy to assume that issues of security are by and large technological issues. Encryption, firewalls, distributed computing and storage, are all seen as technological schemes to limit the free and easy access of any information to anybody at anytime.

Security, however, is also a social and organizational issue. Consider the concept of inevitable disclosure. The idea here is that if enough people that work for one company are hired by a second company, than whether or not they as individuals know trade secrets and whether or not there is any intent on the part of individuals or companies to learn knowledge peculiar to the first company, such trade secrets, such core competencies will be inevitable disclosed. This is an area fraught with research needs and policy implications.

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