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Completed Research Paper

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Abstract

The aim of this paper is to investigate the factors that influence the continuous use of collaborative technologies over time. We conducted a case study on a major telemedicine network in the U.S. The analysis of both quantitative and qualitative data suggests that integration with the regular workflow, stable availability of professionals at remote locations, and the emergence of spontaneous knowledge diffusion are associated with the success of telemedicine practices over time. Moreover, it shows that the limited awareness of the coordinating staff about the activities performed remotely reduces the use of telemedicine. However, this effect is mitigatedby the activation of telemedicine collaborations with other organizations, which belong to the same sub-networks. Based on the findings, we derive theoretical and practical implications for telemedicine and work at distance.

Keywords: Distant collaboration, telemedicine, remote work

Introduction

With the recent $838 billion economic stimulus package approved by the U.S. Senate earlier this year comes $10 billion in funding for biomedical research. This funding is expected to provide a solid foundation for substantial change in our approach to healthcare and medical education at all levels, but it has the potential to cause a change in our course in an entirely different direction. Pent-up demand for global medical services is on the verge of explosive growth. Add to this the projected shortage of medical doctors and allied health professionals worldwide, as well as an aging population, suggests that telemedicine and telehealth technologies is poised for a "change in course."

Telemedicine is defined as the use of electronic information and telecommunications technologies to support long distance clinical healthcare, patient and professional health-related education, public health, and health administration (U.S. Department of Health and Human Services, 2001). Current practices without telemedicine have been associated with problems with uncoordinated care. These include, but are not limited to: (1) *lack of effective healthcare provider and patient communication*, including follow-up communication regarding compliance, (2) *disconnect among patients, primary care physicians, and specialists* resulting in duplicated services, frequent emergency department visits for non-urgent health needs,and (3) *absence of effective channels of communication* to educate and inform physicians about national or local standards; of care (Maffei, et al., 2008).

In contrast, healthcare organizations, governments, and private companies have often touted current practices with telemedicine as a viable solution to the problems of cost containment, equitable access to specialized clinical expertise, and shortage of medical professionals. The idea that operations, diagnoses, and other consultations about medical practice can be turned into geographically distributed activities has led to "a massive investment of energy and funds into this emerging field by governments as well as private companies" (Zuiderent et al., 2003: 173). The promise that distance will no longer be an impediment to quality healthcare adds to the rhetoric that drives many telemedicine projects.

But, even though the promise of telemedicine has been heard for many years now, successful implementations that have significantly addressed such commonly perceived problems as long waiting times, lack of qualified personnel, and other ailments of the healthcare field have rarely been seen, mainly due to conflict with traditional medical practice (May, 2009). In addition, the use and adoption of telemedicine technology by the medical community has been much slower than expected (Lehoux et al., 2002; Gregg and Moscovice, 2003; May, 2009). A basic question, then, is not *if* but *how* do telemedicine programs, where health care is conducted at a distance, alter the practices and relationships between health care professionals and health care organizations? What accounts for the success of these programs over time? The aim of this paper is to investigate the factors that influence the sustained use of collaborative technologies over time.

Factors that limit the adoption of telemedicine

Telemedicine is a complex example of distant collaboration between knowledge workers and/or professional organizations, as it uses "electronic information and communication technology to provide and support healthcare when distance separates the participants" (IOM, 1996, p.1). The term telemedicine is often used to identify a wide array of services that are delivered at a distance (Bauer and Ringel, 1999). According to Taylor (1998) telemedicine services can be divided into three broad categories: (1) treatment services, where telemedicine is used to treat patients, such as tele-surgery or tele-psychiatry; (2) information or educational services, to support continuous medical education and research at distance; and (3) diagnostic or management services, where telemedicine is used to support other form of medical services at distance. Diagnostic or management services include: tele-consulting, where patients use a telemedicine service to consult a health-care worker; teleconferencing, where one or more clinicians who share responsibility for the care of a patient communicate over a video link; tele-reporting, where information about a patient (like images) is transmitted by a health care worker to be analyzed or interpreted at a remote center; and tele-monitoring, where information about a patient is collected continuously or at intervals and analyzed in a remote center.

For over a decade, an increasing number of pilot projects and telemedicine programs have been initiated around the world (Whitten and Cook, 2004; Smith, 2004). Typically, these projects and programs are privately owned or managed (e.g., NightHawk Radiology services, based in Australia), specialty specific (e.g., tele-radiology, tele-psychiatry), and have a hub and spoke structure (with one provider and many users) (Menachemi et al., 2004). Many

telemedicine networks involve organizations that do not compete for patients, or that belong to the same organization (e.g. the Veteran Affairs tele-health network).

Some studies have compared performance in traditional medical encounters with telemedicine consultations and contend that telemedicine professional and health care organizations face a number of factors that limit the adoption of telemedicine practices (Hu et al., 2002; Krupinski et al., 2002; Zuiderent et al., 2003; Hailey et al., 2004). These factors can be divided into three kinds of barriers: (1) technological, (2) organizational and administrative, and (3) individual and relational. Telemedicine technology is viewed as a technological barrier when the equipment capabilities are less than adequate for performing the required tasks. Examples of such inadequacies include system reliability problems, compatibility with existing infrastructures, and ease of use. Taylor (1998) contends that "*if a comprehensive model of a telemedicine service is to be developed, a number of other issues have to be addressed, such as how the consultation is arranged, how the specialists' time is allocated, what effect the interaction has on the patient's record and how the appropriate information is recorded*" (p. 65). These issues are addressed by a more limited number of studies, which look at organizational and individual characteristics and processes.

Organizational barriers to adopting telemedicine are related to inadequate training, formal and in formal incentive systems, difficulty in communicating the benefits to patients to reduce their reluctance (Aas, 2000; Al-Qirim, 2006; 2007), organizational resistance to change, high turnover (Krupinski et al., 2001) and poor integration of telemedicine activities with current work practices (Wyatt, 1996; Berg, 1999). Furthermore, telemedicine initiatives involve legal and administrative policies related to licensing, malpractice insurance, reimbursement for services, and patient confidentiality, not to mention filling out all of the required documents (Broens at al., 2007).Organizational characteristics are also related to the adoption of telemedicine (Hikmet et al., 2008). In their study of the Extended Tele-health Network of Quebec, Gagnon and her colleagues found that telemedicine adoption is positively associated with the small size of the hospital, the centralization of decision-making related to telemedicine, and strong managerial control of the hospital (Gagnon et al., 2005). The implication is that large hospitals with many departments in control of administrative decisions and little managerial oversight are less likely to adopt telemedicine.

Telemedicine also has a direct effect on the work of medical professionals, and on the relationships between them (Zuiderent et al., 2003). Some physicians are reluctant to alter their work practices to meet with patients at distance when they see plenty of patients face-to-face. Moreover, many physicians are reluctant to use of technologies that alter the face-to-face relationship with the patient (Mantzana et al., 2007). Physicians who already use technology in their regular work practice (e.g., radiologists) have been known to experience an easier transition to telemedicine, as compared to medical professionals who have to alter their work activities substantially (Menachemi et al., 2004). Although telemedicine can provide medical professionals with a unique opportunity for learning, it requires adequate training and experience at both the remote and local provider's sites (Robinson, et al., 2003). Paul and his colleagues (1999) found that the success of telemedicine consultations depended on the ability of the presenter or referent (i.e., the medical professional who is with the patient at the remote site and who links with the specialty physician at the local site) to use the equipments and to make sense of the cues that cannot be effectively transmitted via the telemedicine equipment.

A social perspective on telemedicine over time

Our research stems from two main considerations about previous studies on telemedicine in organizations. First, in studying adoption of telemedicine by individuals and organizations, authors typically look at technology as a reified object, or, in other words, as a "*fundamental cause of social and organizational change*" (Nicolini, 2006). For example, when studying technological barriers, authors focus on the characteristics of the equipment (the quality of the images, the usability, etc.) and look at the ways these properties affect medical professionals. An alternative view is what Nicolini calls "a social perspective on telemedicine". This perspective is coherent with a number of theoretical frameworks, like socially situated learning (Lave and Wenger, 1991), structuration theory (Orlikowski, 1992, 2000; Orlikowski and Gash, 1994), and work and occupation studies (Barley, 1986, 1996; Barley and Betchky 1994). Adopting a social perspective on telemedicine means considering that technology, actors and society need to be taken together as part of a heterogonous network or ecology instead of separate worlds. Technologies, in fact, are never neutral , "*because they carry with them the traces of their history, are an assemblage of a variety of material and human elements, and only assume a practical meaning when they are put to use in a specific social and material, i.e. situated, context*" (Nicolini, 2006, page 2).

Our second consideration is that most studies on telemedicine tend to emphasize the early stages of implementation and look at adoption or non-adoption of the technology over a short time period. Taylor (1998) underlines that much of the published work on telemedicine services reports short accounts of pilot projects and that many articles do little more than present *"preliminary results, which are by their nature inconclusive"*. These studies focus on early, short-term phases of telemedicine implementation because of a large decline in case volume shortly after implementation (Paul et al., 1999). Making a telemedicine system fully operational may be different from conducting a pilot case (Cho et al., 2008) and the issues related to the initial adoption may be different to those associated to the continuous use of the technology (Kim and Malhotra, 2005). Moreover, while the broader literature on information and communication system technology has studied information systems (IS) adoption, it has put a much lower systematic effort into investigating continuous use of IS over time (Karahanna at al., 1999; Bhattacherjee, 2001; Kim and Malhotra, 2005).

Given these two premises, the goal of this paper is to investigate the organizational and professional dynamics of distant collaboration in telemedicine networks and to study what happens when a telemedicine network of independent health care organizations co-evolves over time. We want to know how individuals and organizations successfully conduct medical work at a distance, and identifythe factors that sustain the telemedicine network over time. To address these research objectives, we developed an 8-year longitudinal case study on a telemedicine program that offers multiple services and involves different providers and users. In the next sections of this paper we describe the methodology of the study, we present the qualitative and quantitative evidence we collected, and then discuss the theoretical and practical implications for successful telemedicine outcomes.

Methodology

We conducted a case study on a major US telemedicine network of hospitals, the Southwest Telemedicine Program (STP)[1] to understand and explain its success or failure over time. Based on qualitative and quantitative data, we adopted a multiple levels analysis approach (individual, organizational, and network) to develop an in-depth picture of a single case (Provan and Milward, 1995). The case study is particularly suited to the exploratory nature of this research because it offers a unique opportunity for empirical and theoretical interpretation (Yin, 2003; Eisenhardt, 1989) and to develop an evolutionary understanding of networks (Koza and Lewin, 1999).

Research setting

The Southwest Telemedicine Program (STP) was initially funded $1.2 M by the Legislature of a state in the Southwest of the United States in 1996 for the first two years of operations. The objective was to establish various telemedicine services in eight rural communities, including geographically isolated communities, Indian tribes, and Department of Corrections rural prisons. Initially, the only hub (service provider) was the Southwest Health Sciences Center (SHSC), a leading teaching and research University institution. The headquarters of the STP is still located at SHSC and its staff is composed of doctors, technicians, and nurses who also work at the University's medical center. Leveraging the state startup funds, the Southwest Telemedicine Program succeeded in obtaining additional funding and support from many healthcare systems, state agencies, federal grant programs, and third party payers. Today, the Southwest Telemedicine network has over 130 interconnected sites, and of the original 8 spokes, 5 remain active users of the network. To date, the STP has won seven national awards as a top program, as a major provider of distance education over a telemedicine network, and for tele-health research.

The different healthcare centers involved in the STP network include (1) the SHSC and other hospitals, (2) the Department of Corrections, and (3) behavioral health sites. The services exchanged through the STP telemedicine network are continuous medical education (CME) and medical consultations (treatment and diagnostic services) in such specialties as dermatology, psychiatry, and cardiology. Continuous medical education sessions are transmitted through synchronous video conferencing (or real time) and consist mainly of grand rounds organized by the three main hubs of the network. Medical consultations are managed both in an asynchronous fashion (store and foreword) and in real time. Since tele-radiology at the STP is a well-established practice (its use is 100 times more frequent than other telemedicine services), and the consultations are managed separately by the Department of Radiology at SHSC, it was excluded from the present analysis.

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[1] To date, we did not receive permission to use the real name of the telemedicine program; STP is a pseudonym

Each site becomes a member of the network. With membership, the site is provided with standard equipment to guarantee inter-operability between all the sites. Members of the STP adopt uniform operating procedures, which are defined and assessed by an appointed evaluation unit. At every site, there is a coordinator who is in charge of planning and organizing the consultations with the hubs whenever a medical professional at the remote site requests a consultation. At the hub, there is a telemedicine coordinator, who is responsible for the scheduling process and a medical coordinator, who is in charge of allocating the appropriate medical professionals to the medical consultations that are requested by the spokes.

We chose to study the STP for several reasons. First, the STP has been in operation since 1997 and is recognized as one of the best telemedicine programs in the U.S. We can thus study the growth of telemedicine services over time. Second, STP includes many sub-specialties in medicine, behavioral health, and continuous medical education (CME) and thus offers multiple perspectives from our respondents, unlike some telemedicine programs that are specialty-specific (e.g., a telemedicine network that offers just cardiology services, Lehoux et al., 2002). Third, the STP network brings together different types of organizations such as small community hospitals, private medical centers, and large medical institutions allowing us to investigate the dynamics that this variety introduces. In order to gain access to the STP organizations, we directly contacted the STP director and proposed to start a research collaboration on the topic of networks and knowledge sharing in telemedicine. This initial contact was the starting point for the definition of a mixed-method research project.

Data collection

We used multiple data sources, both quantitative and qualitative, to increase the construct validity of this research (Huberman and Miles, 1998; Remenyi et al., 1998). The sources for our data include: (1) a database on medical consultations and continuous medical education (CME); (2) semi-structured interviews; (3) observations of consultations and training; and (4) archival data.

(1) Data on medical consultations and CME sessions. The STP tracks all medical consultations and CME sessions between the main hub of the network (SHSC) and other sites. As external researchers, we had full access to these data from 1997 to 2005.Since, at the time of data collection, the 2005 data were not complete, we do not include them here. From 1997 to 2004, the traffic with SHSC has represented, about 78% of all STP traffic. The data for each medical consultation includes the date, the location of the remote site, a code for the professional who was responsible for the consultation at the remote site and his/her degree (e.g., MD, nurse), and the department that was involved at the hub (e.g., pediatrics, diabetes). The data for the CME grand rounds offered by SHSC, includes the date, the location of the remote site, the topic of the lesson, and the number of people who attended the session.

(2) Semi-structured interviews. In 2005 we conducted semi-structured interviews in order to understand how the network evolved over time, and how concerned professionals perceived it. To begin, we first conducted five in-depth interviews with personnel responsible for operating the STP. This included the STP Director and Co-Director, the Associate Director in charge of assessment, the Associate Director in charge of administration, and the Telemedicine Coordinator. These interviews were aimed at a general understanding of the characteristics and functions of the program, the differences between the use of telemedicine with STP and face to face practice, the perspectives of the STP executive board on the evolution of services and relationships between sites, as well as the major inhibitors and facilitators in the adoption and sustainability of the program. After these initial interviews, we then asked the STP telemedicine coordinator to select member sites that presented the highest cumulative frequency of telemedicine and CME use over time. For each of these 9 sites, the STP telemedicine coordinator provided us with contact information of either the telemedicine site coordinator or the person that was considered more knowledgeable about the use of telemedicine specialties at their site. In addition to these 9 spoke sites, we also interviewed the medical directors of the three main hubs of the network. Each of these 12 interviews with the sites was scheduled through an e-mail message. The spoke site interviews were conducted by telephone and the hub interviews were done face-to-face. Each interview lasted from 45 minutes to one hour. Our questions were aimed at evaluating telemedicine use (e.g., the types of services they use, and how often they use them), as well as information about the different sites with which they interact. We were particularly interested in how telemedicine affected the knowledge and skills of the professionals, including the main inhibitors and facilitators for the sustained uses of telemedicine consultation and continuous education. Following Isabella (1990), during interviews, we asked our informants to tell us stories related to the evolution of the network and how they perceived the changes in professional activities and networks. Thus, during interviews, we were able to reconstruct the interactions each site

had with the other sites in the STP network from 1997 to 2004. A summary of the characteristics of these 12 sites in which the interviews were conducted, as well as who we interviewed is reported in Table 1.

(3) Observation of consultations and training. We triangulated the consultation data and the interviews through non-participant observations of medical consultations and training. We began our observations of the STP by participating, as external researchers, in a two-day (16 hours) training program offered by the STP to new medical organizations interested in joining the network. This training course is held at the STP main hub (SHSC) and provides a comprehensive overview of the main characteristics of the network from the legal, economic, medical, and technical perspectives. It also gives the rudimental knowledge to operate the telemedicine equipment. We later observed two consultations at the main hub. The first observation was a 4-hour demonstration of the scheduling process and a store and forward delivery of a telepathology consultation between the SHSC hub and a remote site. The second observation was a two-hour video conference related to a technical assessment issue, with four members of the STP staff and a remote site.

(4) Archival data. We reviewed the STP telemedicine procedures, grant proposals, internal reports, newsletters and job descriptions to provide us with a deeper and richer understanding of the context.

	Hub or Spoke	Dimension (# of beds)	Type of institution	Year joined the STP	Interviewee
Table 1. Data on the 12 sites where telephone (spoke) and face-to-face (hub) interviews were conducted					
1	Spoke	–	Department of Correction	1997	STP Administrator
2	Spoke	25	Medical Center	1997	TM Coordinator
3	Spoke	41	Medical Center	1997	TM Coordinator
4	Spoke	25	Medical Center	1997	TM Coordinator
5	Spoke	15	Ambulatory Care	2001	TM Coordinator
6	Spoke	–	Community Health Center	1997	Medical Coordinator
7	Spoke	44	Medical Center	1997	Psychiatry Medical Coordinator
8	Spoke	65	Medical Center	1997	TM Coordinator
9	Spoke	45	Service Unit	1997	TM Coordinator
10 SHSC	Hub	>100	Medical Center	1997	Medical Coordinator
11	Hub	>100	Medical Center	2000	Medical Coordinator
12	Hub	>100	Medical Center	2001	Cardiology Program Coordinator

Qualitative data analysis

During interviews and observations, we took notes on paper describing everything that happened, while respecting the actors' original language (Glaser, 1978). Then we coded our field following the framework depicted by Strauss and Corbin (1998) to build a grounded model. Embracing an interpretive research approach, the emerging framework stems from the continuous interplay between data analysis and literature (Strauss and Corbin, 1998). We combined this qualitative evidence with the quantitative evidence in the database. We continuously went back and forth between our field notes and the quantitative data to find support for our theoretical arguments and to detect any inconsistencies between new intuitions and our data.

Specifically, we started by reading all the field notes several times to get a thorough view of our data. We then followed a three-step coding process, similar to the one adopted by Kreiner et al. (2006) and Pratt et al. (2006). First, the two authors independently coded each field note transcript. We met to analyze batches of two or three transcripts and discuss our independent coding. This first step allowed us to agree upon emerging categories, i.e. first-order recurrent codes. For instance, some of our informants mentioned that they recurrently called colleagues belonging to

other hospitals in order to ask for advice. Some mentioned that they received requests for help from colleagues belonging to hospitals within the same group of hospitals (e.g., the Indian Health Service).

Second, each author separately grouped convergent categories at a higher level of abstraction, i.e. identified theoretical categories or 'second-order themes'. We met to compare the theoretical categories that each of us had disclosed and we reconciled disagreements through discussion. For instance, the abovementioned themes (asking advice to professionals in other hospitals, receiving requests for help from colleagues in the same sub-network[2]), together with similar ones, were grouped into the theoretical category, "asking/receiving advice to/from colleagues in the same sub-network of hospitals".

Third, each of us independently looked for aggregate theoretical dimensions as well as for the linkages between them in order to outline a coherent framework. Once again, we met a few times to explain to each other the theoretical dimensions and linkages that we had in parallel detected, to discuss discrepancies, and finally to develop a shared interpretation. Continuing the example above, "Asking/receiving advice to/from colleagues in the same network of hospitals" was one of the second-order categories grouped into the aggregate theoretical dimension, "Collaboration within sub-networks". Overall, we identified the following aggregate theoretical dimensions: continuous presence of professionals and integration with regular workflow, few critical individuals, reduced awareness, collaboration within sub-networks, continuous distant collaboration between professionals and organizations. As a final outcome of this third step, we built a grounded model that connects the different aggregate theoretical dimensions (Strauss and Corbin 1998). We also discussed our emerging results with some of our STP informants to ensure that our major conclusions were consistent with their understanding of the system.

Results

Telemedicine use over time

There were a total of 8,275 telemedicine cases that came through the SHSC hub from 1997 to 2005, with 3,088 (38%) medical specialties, 1,851 (12%) psychiatric specialties, and 3,336 (40%) CME services. Since our focus was on 9 spoke sites, we only examined the 6,869 telemedicine cases from these sites. These telemedicine data consisted of over 160 types of medical and pediatric specialties provided through the hub at SHSC. In order to deal with this wide range of services, we combined them into 20 related categories. Subsequent analyses will focus on four sub-specialties: combined clinical (15%), dermatology (30%), psychiatry (26%), and CME (29%).

All four TM sub-specialties showed a relatively steady increase in services from 1997 to 2000. From 2001 to 2004, clinical telemedicine drops off considerably, from 14% in 2000 to 7% in 2004. Similarly, dermatology drops from 19% in 2000 to 12% in 2004. Psychiatry shows an increasing trend from 2001 to 2004, as does CME. In fact, participants from 107 sites attended CME grand rounds, with 80% of them in internal medicine, psychiatry, dental medicine, surgery, nursing, and public health.

Over time, the 9 sites vary considerably in their use of telemedicine services. Figure 1 and Table 2 show that certain sites focus on one or two sub-specialties at the expense of the others. For example, Sites 1 and 2 mostly uses CME services, whereas Sites 3 and 6 are mostly used for tele-dermatology, though most of the services in Site 3 drop off over time. Site 7 is mostly used for tele-psychiatry (62%), with some CME services (35%). The remaining four sites use a combination of two sub-specialties. The data suggest that these remote sites either do not have the expertise to do all kinds of telemedicine services, or have a limited staff to handle more than one or two kinds of consultations, or decide to conduct only one sub-specialty with SHSC and the other sub-specialties with other hubs on the network.

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[2] In this paper we use the term network to refer to the whole STP, while we use the term sub-network to refer to a group of hospitals belonging to the STP and having another kind of relationship, beyond telemedicine.

Figure 1: Frequency of telemedicine sessions over time for each of the 9 spoke sites
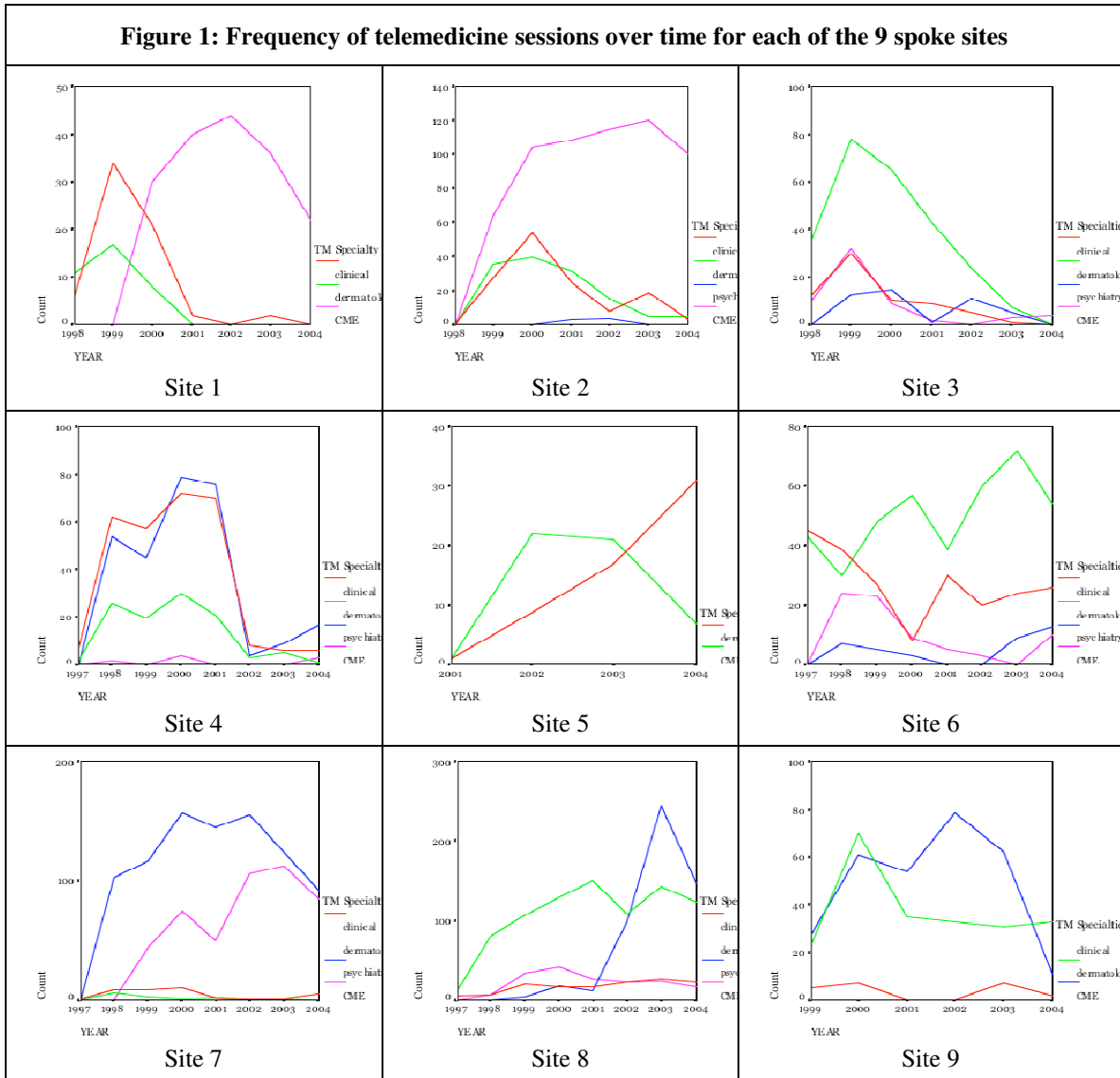
Legend: Red = Clinical; Green = Dermatology; Blue = Psychiatry; Pink = CME

Table 2. Frequency (percentage) of telemedicine sessions by sub-specialties for each of the spoke sites					
Site	Clinical	Dermatology	Psychiatry	CME	Total
1	65 (24%)	36 (13%)	0	*177* (64%)	278 (4%)
2	151 (16%)	120 (13%)	7 (1%)	*647* (70%)	925 (14%)
3	72 (17%)	*249* (58%)	45 (11%)	62 (14%)	428 (6%)
4	*297* (43%)	94 (14%)	*284* (41%)	10 (2%)	685 (10%)
5	0	*58* (53%)	0	*51* (47%)	109 (2%)
6	228 (31%)	*391* (53%)	37(5%)	86 (11%)	742 (11%)
7	44 (3%)	7 (0%)	*895* (62%)	506 (35%)	1452 (21%)
8	136 (8%)	*856* (50%)	525 (31%)	181 (11%)	1698 (25%)
9	21 (4%)	226 (41%)	0	*305* (55%)	552 (8%)

Note. Italics represent the dominant sub-specialties for each site.

The changing nature of the telemedicine network

In 2000, many new sites joined the network. Some of these newly-joined members are large hospitals and private medical centers throughout the state so they are able to provide TM consultations and CME to other member sites.

> *Big hospitals are now part of the STP. They are encouraged to offer services to other sites; that means they are, like SHSC, providers and vendors. An example is [a hospital] that took over from SHSC almost all the services to the prisons.* [Assoc. Dir, STP]

A large number of the new sites that joined the STP belong to pre-existing networks or have stable collaborations with other hospitals or institutions. We call these configurations of organizations sub-networks. A typical situation is that if a member of an existing sub-network joins the STP, all the other sub-network members are invited to do the same, to take advantage of the existing technological infrastructure.

With the increased number of sites joining the network and demanding service, the external recognition gained through several national awards, and the complex array of new services, the STP had to change its focus of attention to one of achieving successful economic and financial outcomes. So, in 2001, the STP introduced a membership fee and a "pay-per-view" strategy. As of 2004, membership fees to join the STP accounted for 30% of its revenues, while the remaining 70% of its revenues came from grant funding.

This change of identity, focused on increasing revenues, is leading to new business strategies. For example, now the STP personnel have to begin thinking about ways of marketing the program in order to promote telemedicine services, as well as improve its image to others.

> *STP hasn't done much public relations and marketing. This is a problem. Everyone at STP, starting with myself, is overwhelmed with things to do and cannot think about new responsibilities. Moreover nobody has a clear idea on how to do marketing. It is kind of a new thing for us. They told me I should be the one in charge of it, but until I receive detailed requests, I cannot move any step further. For example, there are 360 physicians at SHSC and many of them do not even know about the existence of STP.* [Assoc. Dir, STP]

This new economic identity of the STP also creates more competition between the different hospitals in the network. The big hospitals, in particular, compete for being the primary providers of the rural or smaller sites. For example, when a rural spoke site asks for a telemedicine consultation to SHSC, it is up to the STP staff to find a doctor who can conduct the consultation. This can create problems when not enough medical staff are available. For example,

> *Sometimes [the medical director at SHSC] does not know the right person for a specific consultation… She is a kind person and doesn't want to impose on other physicians to do this or that. But when a service is requested by one of our sites, we have to provide it! So, ok, I say. If SHSC cannot do it, I will go and ask [another hospital] to provide it… When I say this, a physician immediately shows up at SHSC who can do it!* [Assoc. Dir, STP]

Thus, it is unlikely that SHSC will forward consultations to other hubs, regardless of their busy schedule. To do so, may create incentives for the spoke sites to look elsewhere for service.

The presence of physicians and the integration of telemedicine with the regular workflow

The remote sites of the STP network are, for the most part, small rural hospitals. These rural hospitals are typically characterized by high turnover of personnel and medical professionals. Attrition leads to fluctuation in telemedicine case volume (Krupinsky et al., 2001). For example, at remote Indian Health Centers, doctors often rotate every 3 to 5 years, medical residents spend only a short time as interns, and other medical professionals, such as nurses and technicians, typically move when they are offered a better paying job. With high turnover, the STP staff must not only retrain new staff on the use of the telemedicine equipment, but remind new medical directors of the benefits of telemedicine. During one teleconference with a remote site, the issue of scheduling a retraining session came up.

STP*: You need to pick a date which as many people as possible are present, so that we can spread the knowledge to as many doctors as possible and reduce any "technophobia."*

Medical director [of remote site]: *The problem we have here is that only 50% of our staff is present on site, and physicians and assistants do not have the same rotation… I don't really think we will be able to pick up a date when everyone is present.*

The data in Table 3 show that four (44%) of the 9 sites did not have physicians located full-time at the hospital. They typically worked part-time in the hospital and part-time in their private practices. Of the 4 sites without the full-time presence of physicians on site (Sites 1 – 4), two sites (Sites 1 and 2) sustained use of telemedicine with the SHSC hub by participating in CME, whereas two sites (Sites 3 and 4) dropped their use of telemedicine with the SHSC hub (see the graphs in Figure 1 above). Clearly, having physicians at the remote site increases opportunities to use telemedicine. As one technology coordinator put it,

> *Physicians here do not stay full time in the hospital because they also have their own private practice. They often cannot take time off to present cases through telemedicine… The problem is that because we are a small hospital, when they are here, physicians are very busy and do not have much time to use the telemedicine equipment. Using telemedicine with SHSC means preparing a lot of documents and allocating time they do not have.* [Site 4 technology coordinator]

Site	Physicians on site full-time?	Membership in another network?	Currently use TM in sub-networks?
**Table 3. Physician status, and membership and telemedicine use in sub-networks for each of the 9 STP spoke sites**			
1	No	Yes	Yes
2	No	Yes	Yes
3	No	No	No
4	No	No	No
5	Yes	Yes	Yes
6	Yes	Yes	Yes
7	Yes	Yes	No
8	Yes	Yes	Yes
9	Yes	Yes	Yes
% Yes	56%	78%	67%

Integration of telemedicine in the regular work practice is considered an important premise for telemedicine adoption from physicians. Our interviews add that sites that have integrated physicians' regular office hours with telemedicine consultations have been able to continue to use telemedicine quickly and easily. As the medical director at Site 6 said,

> *Physicians use telemedicine when the service is quick and can be inserted easily within their regular schedule. What we do to make the scheduling process easy is to suggest some alternative dates for the consultation. For example, to schedule a consultation I give the referent doctor 2 or 3 date options within his blocked time. At the same time I coordinate with the site coordinator at SHSC, to find the availability at their end.* [Site 6 medical director]

Learning opportunities for medical professionals and the emergence of critical individuals

The organization and execution of medical consultations through the telemedicine network is expected to contribute to the diffusion of clinical and technical knowledge at the member sites. When medical professionals at the remote sites interact with specialists at the hub, they may become more knowledgeable about special conditions and pathologies. Moreover, they become acquainted with telemedicine technologies and may be more willing to learn how to use new equipment than if worked in isolation. For example, the medical director at Site 6 explained that nurses and technical assistants are constantly trained in the use of imaging technologies.

> *We take care of training nurses in new technologies, for example in taking pictures with the digital cameras. Recently, [we received funding] to allow us to purchase a special camera for doing eye clinics. The technical assistants have been trained to use the new equipment.* [Site 6 medical director]

The site coordinator at Site 9, a nurse, recognized the learning opportunities given to her by telemedicine and expressed her desire to understand more about clinical issues and to learn new technologies.

> *Since I have started working with telemedicine, I feel like having more responsibilities. I am in charge of all the processes of the telemedicine consultations: from planning to taking photographs. For me, telemedicine is an opportunity to learn about technology. Assisting in dermatology cases made me knowledgeable on how to take pictures and send them. I even learned here how to use a computer! Moreover, I am sort of curious about how to interpret the images. When the consultation is over, I often go back and read how the doctors interpreted the images to learn from that.* [Site 9 site coordinator]

When new knowledge is acquired at the spoke sites, it reduces their need to collaborate with the hubs. For example, as Site 4 gained competencies with the telemedicine equipment and with clinical knowledge in dermatology consultations,

> *…they did not need to use the services of a bigger hospital like SHSC. At [Site 4], for example, they were doing a lot of dermatology consultations in the beginning. Then some doctors gained the knowledge and were able to do most of dermatological analyses without us.* [STP director]

Telemedicine consultations involve a variety of different kinds of medical professionals. For example, there are medical specialists such as dermatologists or pathologists, there are Ph.D.'s that conduct behavioral health consultations, certified nurses that present cases during video consultations, and technicians that operate the equipment. During every remote medical consultation, there is a medical professional (typically the site coordinator or the rural practitioner) who acts as the referent at the spoke. The referent is in charge of the practical operation of the equipment, the collaboration with the hub, and the documentation that is exchanged with the hub for reimbursement. For the 4,884 medical consultations made with SHSC, the referents were physicians (MDs and DOs) in 64% of the cases, nurses in 18% of the cases, and Ph.Ds in 18% of cases. Referents with Masters in Social Work did 1% of the behavioral health consultations.

Given the large percentage of medical professionals, how many different kinds of telemedicine professionals are located at the 9 remote sites? What is their distribution of contribution? Do they all contribute equally, or do some contribute more than others? The data on Table 4 sheds some light on the consultations performed by telemedicine professionals. First, the number of different telemedicine professionals varies widely, ranging from a low of 14 (Site 1) to a high of 113 (Site 8) different people who have been involved in telemedicine consultations as referents. More significantly, only a few of the telemedicine professionals do most of consultations (at least 5% of the cases). For example, there is one Ph.D. referent at Site 7 (representing 4% of all consultants) who conducted 95% of the psychiatric cases. Similarly, one referent at Site 1 (representing 7% of all consultants at the site) conducted 78% of the cases. Overall, 4 different telemedicine professionals conducted 66% of the cases. These data strongly suggest that telemedicine use at the remote sites rely on a small number of medical professionals to carry out the consultations with the hub at SHSC. The interview data suggest that the same trend may be true also for the consultations that are carried out with sites of the network different from SHSC.

Site	No. of different TM professionals at site	No. (%) of TM professionals who interpret 5% or more of the cases	Cum. percent of TM profs who interpret 5% or more of the cases
1	14	1 (7%)	78%
2	21	4 (19%)	86%
3	36	8 (22%)	65%
4	27	1 (4%)	62%
5	18	8 (44%)	76%
6	40	6 (15%)	57%
7	24	1 (4%)	95%
8	113	6 (5%)	42%
9	45	5 (11%)	45%
Mean	49.57	4.05 (10%)	66%
St. Dev.	37.20	2.43 (8%)	21%

Table 4. Data on telemedicine (TM) professionals for each of the 9 STP spoke sites

If the medical professionals who contribute most of the cases leave, the site will find it difficult to replace the productive referent. For example, the site coordinator at Site 4 was the referent for 62% of all the medical cases with SHSC. When this person moved to another hospital in 2002, Site 4 suddenly lost its technical competence, and the telemedicine activity with the main hub was significantly reduced.

Similarly, the main referent at Site 7 contributed 95% of the consultations (see Table 4). In 2004, he moved to Alaska for half of the year and his telemedicine activity dropped.

> *[This person] was the most active psychiatrist at [Site 7]. He was practically the only referent we had there. But now he is spending half a year there and half of the year in Alaska and this reduces the activity of the site. A new paediatrician has recently moved to [Site 7], but it is very hard to start telemedicine with him.* [STP director]

Thus, when there are a small number of knowledgeable referents at the remote site, telemedicine activity is in jeopardy when these professionals with high caseloads leave.

Collaboration with sites of sub-networks

Of the 9 sites we investigated, seven (78%) belonged to pre-existing networks of hospitals and clinics (see Table 3). In a network of hospitals such as the IHS (the Indian Health Service) organizations conduct face-to-face or telephone collaborations for clinical advice and/or research and typically cross-refer patients. Thus, as a member of the STP, many sites are able to sustain their use of telemedicine without interacting with the STP main hubs, but through these alternative pre-existing sub-networks.

Site 9 is an example of how their use of telemedicine changed over time. In the beginning, Site 9 only connected to the hub at SHSC, but now it offers services to 3 other sites in tele-surgery. These three sites were chosen because they are part of the same sub-network. Physicians, nurses, and technicials already know each other because have been working and collaborating in different projects together. Thus, being part of another network gives Site 9 an opportunity to sustain their use of telemedicine.

Reduced awareness with STP

In general, the interviewees at the remote sites felt that STP staff lost interest in them over time because they were not seen as profitable. Moreover, our informants perceived that the STP staff didn't know the specific clinical, organizational and technical needs of small, remote, no-profit organizations. For example, the technical coordinator at Site 4 thought that the policy imposed by STP to have a physician as a tele-presenter or referent (instead of a nurse or a technician) for certain types of consultations was too strict and limited the use of telemedicine.

> *Here at [Site 4], telemedicine was easy at the beginning. We used all kinds of services from SHSC. But then STP got big and became stricter in its rules… and this made the situation different. From 20-30 referrals a month, we went down to zero… [Our site] is a non-profit organization with a great deal of political turmoil. STP probably lost interest in us over time.* [Site 4 technical coordinator]

Added to this is the fact that the growth of STP has created a news vacuum for the remote sites. The reduced flow of information from the STP to the remote sites (and vice versa) reinforces the negative perception about the STP staff and the SHSC hub and challenges the continuous use of telemedicine.

> *A big problem will be the change of the carriers of T1 lines. They [STP] will move from AT&T to MCI and the equipment is not compatible with ours. We will need to adapt to this technological change. I found out about this by chance. Probably STP will help us in finding financial support… But so far we have not heard anything.* [Site 8 technical coordinator]

This negative perception tended to increase, when possible, the existing collaboration with members of the sub-networks. For example, Site 9 in 2002, decided to ask for tele-dermatology consultation to site 4, instead of using SHSC, because on one hand they already collaborated with the physicians at site 4 and, on the other hand "they did not feel the treat of a big University institution [SHSC], where doctors have a different mentality and approach" [Site 4 technical coordinator].

Discussion

In this paper, we investigated the organizational and professional dynamics of remote collaboration in telemedicine networks. In particular, we wanted to know how individuals and organizations successfully conduct medical work at a distance and the factors that sustain telemedicine use over time. Using Strauss and Corbin's guidelines (1998), we examined the themes that emerged from the field and developed a grounded model to explain why some organizations were successful over time, and some were not (see Figure 2).

Figure 2. A grounded model of continuous distant collaboration
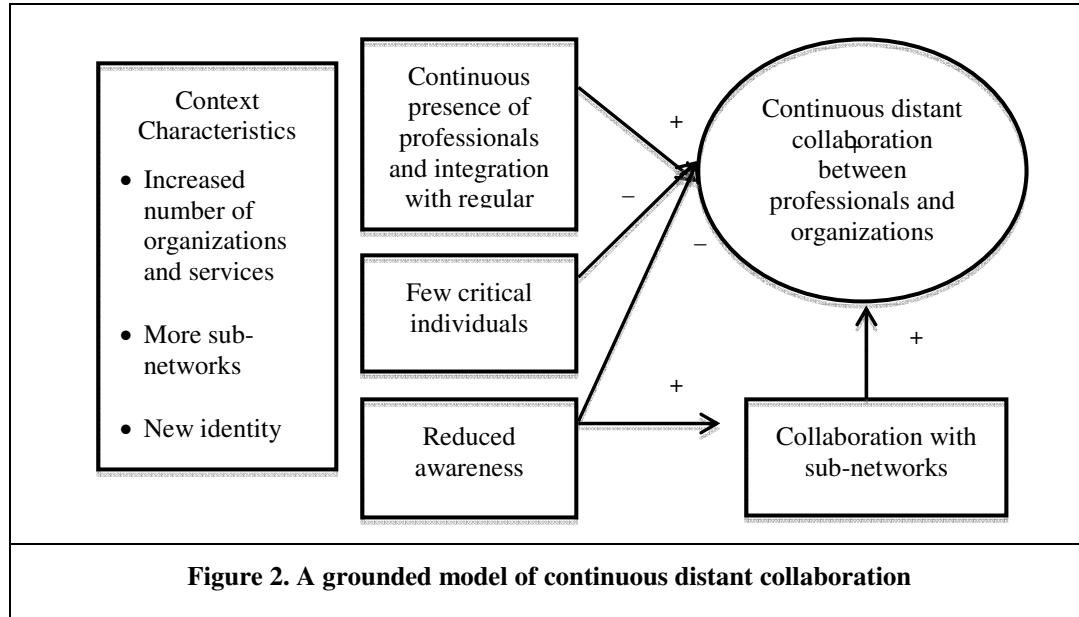
Beginning with the context characteristics, we found that in the 8 years we investigated, the Southwest Telemedicine network notably increased the kinds of services it offered, as well as the sheer number of hubs and spokes. The configuration of the network was affected by the establishment of new relationships between the nodes and by the growth of the network through the inclusion of new sub-networks. Finally, the network changed its goals over time, and shifted its organizational identity to focusing on economic and financial outcomes.

As shown in Figure 2, we identified three causal conditions and one intervening condition to explain the continuous use of technology for distant collaboration at the remote organizations. The three causal conditions we identified are (1) the full-time presence of professionals at the organizations and the integration of distant collaboration practices with professionals' regular workflow, (2) the emergence of critical individuals, those who have become proficient with the use of technology and distant collaboration procedures, and (3) the amount of awareness the people in charge of managing the network have about what is taking place at the remote organizations. Our grounded model suggests that if awareness is reduced, then some organizations will take advantage of the sub-networks that are closer to them, changing at the same time the structure of the network. The intervening condition (4) is the emergence of distant collaboration in sub-networks.

(1) The continuous presence of professionals at the remote sites and the integration of distant collaboration into the workflow. We found that some hospitals discontinued their use of telemedicine when they did not have full-time physicians on site or provided opportunities for physicians to work part-time at the hospital and part-time in their private practice. Previous studies suggested that when physicians perceived difficulties in the integration of telemedicine with their work practice, they tended not to adopt telemedicine technologies (Menachemi et al., 2004; Gagnon et al., 2006). We think that the part time presence of physicians on site can be overcome through adequate support of other personnel (e.g., through the proper training of on site non-physicians telemedicine presenters).

Remote sites that schedule telemedicine activities with regular consultations have a higher probability of sustaining the use of telemedicine over time. This finding is not surprising, as many researchers have shown that the initial adoption of telemedicine is facilitated by organizational integration (Hu et al., 2002). Telemedicine, though, is also

seen as a disruptive technology (Bower and Christensen, 1995; Christensen, 1999), or an innovation that is going to change the way healthcare is delivered and the way professionals work (Ellis, 2000). We suggest that the integration with the regular workflow is, in practice, a co-evolution of regular medical encounters and distance consultations. Medical professionals, in fact, gain knowledge during telemedicine encounters and transfer what they know and the way they work into their regular practice.

(2) Critical individuals.Telemedicine creates a unique opportunity for medical professionals to gain new knowledge at remote locations. This happens particularly for the tele-presenters (or referents). However, in the sites that were less successful, very few medical professionals were involved with telemedicine and their move to another organization made the site unable to sustain telemedicine operations. The situation is made worse by the high frequency of turnovers in U.S. rural hospitals (Gregg and Moscovice, 2003). What emerges is the necessity to periodically communicate the importance of telemedicine and train a large number of medical professionals at every site. Other authors have already suggested the importance of initial training and communication of telemedicine objectives (Aas, 2000; Al-Qirim, 2006; 2007). We suggest that the diffusion of knowledge be supported not only through formal training, but also through the promotion of spontaneous knowledge and information transfer between medical professionals. We emphasize the importance of spontaneous everyday transfers of knowledge (Tagliaventi and Mattarelli, 2006) because periodic telemedicine re-training sessions to professionals were not enough to warrant telemedicine success.

(3) Reduced awareness between organizations. Our grounded model suggests that reduced awareness of STP staff (and the main hub) about what health care professionals really do at the remote sites makes the planning of supporting activities for the sites complicated. Research has shown that awareness reduces the amount of effort needed to coordinate tasks and resources. Awareness provides a context in which to anticipate the understanding and actions of others (Dourish and Bellotti, 1992; Weisband, 2002). The use of online communities through the Internet, may create more transparent access to knowledge from other parts of the telemedicine network where medical professionals can share experiences and relay their specific competencies (Preece, 2000). Creating more awareness at the remotes sites can be promoted through theseonline communities, as well as other media like newsletters, electronic announcements, email, and shared calendars. These could all be used to inform members about others' initiatives.

(4) Collaboration within sub-networks. Our datasuggest that the negative impact of reduced awareness on telemedicine sustainability is moderated by collaboration with other sites. The remote sites that continue using telemedicine over time do not exchange services exclusively with the main hub. Over time, they start new telemedicine collaborations with sites of sub-networks with which they have developed a shared context of working together. A shared context exists when distant professionals have access to the same information and share the same tools, work processes, and work cultures (Hinds and Mortensen, 2005). In distributed collaboration it is more difficult to create a shared context, and this, in turn, makes it more difficult to identify and solve coordination problems (Kraut et al., 2002). We have shown that STP staff does not share the same information with the remote sites nor do they share the same work culture. These two aspects have become salient when the network grew and developed an economic identity that some sites perceived as far different from theirs. This may explain why some sites preferred to establish tele-consultations with other organizations of their sub network.

Implications and concluding remarks

This multi-method explorative case study of the Southwest Telemedicine Program (STP) provided a better understanding of the co-evolutionary dynamics of organizations and professionals that collaborate at a distance. We found that integration with the regular workflow, stable availability of professionals at remote locations, and the promotion of spontaneous knowledge diffusion are associated with the sustainability of distant collaboration over time. Moreover, the lack of awareness by people in charge of coordinating the activities of the network limits their ability to support the work that professionals perform at remote locations and challenges the sustainability of the network.However, the effect of awareness can be reduced when remote professionals belong to the same sub-network; it allows them to participate in technology-mediated interactions with organizations and individuals with which a shared context has already been created.

In distributed work settings, it is difficult to keep informed about the work others are doing (e.g., Gambetta, 1988). This lack of information about others' activities has led researchers and designers of computer-supported systems to create so-called awareness mechanisms in distributed work groups (Dourish and Bellotti, 1992; Dourishet al., 1992;

Fussell et al., 1998; Steinfield et al., 1999). In our study, we found that the members of the STP staff were not frequently aware of the activities taking place at the remote sites. This is somewhat surprising given that the STP staff is responsible for coordinating and controlling telemedicine activities at all sites. Unfortunately, this problem with reduced awareness left members of the remote sites with little understanding of their role in the overall functioning and evolution of the network. Our work suggests that more work is needed to better understand the effects of reduced awareness between organizations on effective distant collaboration over time.

Consistent with studies that see technology and organizational structure as profoundly intertwined (e.g., Barley, 1986, 1996; Orlikowski, 2000;), we also found that distant collaborations over time can change the nature of the work of professionals. From a knowledge diffusion perspective, distant collaboration can empower the centrality of remote workers, thereby enhancing their organizational roles and competencies. Knowing how these new forms of work in distributed settings affect professional workers and their relationships to others is an important area for future research (Weisband, 2008).

This case study has also shown some patterns of knowledge and information diffusion between different professionals in different organizations. This knowledge diffusion not only has changed the work of professionalsbut has contributed to modifying the overall structure of the network. In fact, while in the first years of functioning, the network had a highly centralized hub-and-spoke structure. Over time new hubs emerged and some links between nodes disappeared. This new configuration is in part induced by the knowledge acquired by some critical individuals. Future research should conduct a more systematic investigation the dynamic effect of knowledge and information diffusion (Monge and Contractor, 2003) on distant collaboration in a network of professional organizations.

Our work has practical implications for organizations that promote telemedicine programs and strive to sustain them. First, telemedicine networks should promote not only formal training on telemedicine technology, but also informal knowledge sharing practices. The diffusion of knowledge should be favored at the remote sites, as well as the entire network in the hopes of preventing problems related to professional turnover. One idea in response to these issues is the development of an STP online community, where medical professionals can share experiences and relay their specific competencies, so that remote sites can have a more transparent access to knowledge from other parts of the telemedicine network.

In addition to understanding telemedicine networks, this research has practical implications for other types of professional networks. Scientific collaborations in online communities, or cyberinfrastructures, are often challenged less by the technology than by the ability to sustain their work at distance over time (Birnholtz and Finholt, 2008; Butler et al., 2008; Bowker et al., 2009). We also know that spontaneous, informal communication among professionals increases their knowledge about what others do, thereby increasing awareness (Kiesler and Cummings, 2002). This research suggests that technology provides only part of the answer. Software tools and technical infrastructure make telemedicine and other professional networks possible, but these networks also require people who must attend to them as well as manage emerging social and organizational dynamics.That is, managers and administrators who run telemedicine and other networks should actively promote and maintain basic communication and coordination activities to sustaining these networks over time.

There are, of course, limitations to our study. First, it is a single case, so we do not attempt to make a statistical generalization of our results. More work is needed to understand if the categories and relations that we observed can be applied to other telemedicine programs or to other organizations. Second, within our case study on STP, we interviewed a limited number of sites, and this could introduce bias in our analyses. In fact, we selected the remote sites and hubs with the highest telemedicine activity between 1997 and 2004 and we analyzed the quantitative data on consultations with the main hub, but we don't know if other organizations are currently emerging as relevant actors and are introducing new variability to the network. Our next step in this research will be to use current data and then survey as many nodes of the network as possible. The survey will address the three theoretical issues that emerged from the grounded model: the change in the work and relations of medical professionals, the knowledge diffusion supported by technology, and the relevance of awareness of other organizations' activities and needs.

Finally, in our grounded model we suggested that the sub-networks have positive effects on the sustainability of distant collaboration. That is, remote sites can sustain telemedicine practices without constant oversight by the SHSC hub and STP staff. Yet, research on social networks in healthcare found that *network centrality* had a positive long term impact on the success of those networks (Provan and Milward, 1995). Adding to this is a concern that the growth of sub-networks challenges one of the original goals of telemedicine programs: access to medical specialties

that overcome all the traditional organizational and geographical barriers. We invite researchers to understand how the dynamics that telemedicine and other forms of professional networked collaborations unfold over time.

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