Telemedicine for low-resource settings: Exploring the generative mechanisms

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ABSTRACT

Information Communication and Technology for Health (ICT4H) initiatives, such as telemedicine, can potentially bridge the gap between the health care services available in rural and urban areas. However most of such initiatives have not been able to sustain or obtain optimal results. Comprehending knowledge about what drives success in telemedicine initiatives would be highly valuable for practitioners, policymakers and academicians. In this study, through a qualitative analysis of doctor-patient interactions over a telemedicine initiative in India, we attempt to identify the mechanisms that can enable successful telemedicine interventions. Based on the perspective of critical realism, we explore the phenomenon through the lens of 'generative mechanisms'. Specifically, we identify three different mechanisms that underlie successful telemedicine, namely, (1) Mechanism of rich connectivity, which refers to the expanding scope of information flow between the nodes to include multiple aspects- clinical, managerial and technological; and both online and offline communication; (2) Mechanism of tutoring, which involves learning and skill development of the peripheral doctor; and (3) Mechanism of moulding, which concerns the moulding of naïve patients to expert patients, both in technology use and self management of disease. In addition, the paper demonstrates the efficacy of critical realism as a philosophical perspective for providing substantive insights in the field of ICT4H initiatives.

Key Words: Telemedicine, Doctor-patient interaction, Critical realism, Generative mechanisms, Low-resource context

INTRODUCTION

Seventy-five per cent of health care facilities (infrastructure and manpower) in India are concentrated in urban areas, which accounts for only 27 % of the population. The lack of manpower is mainly at the specialists' level with about half of the posts for surgeons, gynecologists, pediatricians and physicians lying vacant in rural areas (Bhandari and Dutta, 2007). Information Communication and Technology for Health (ICT4H) interventions, such as telemedicine, acting as a conduit of information, offer promise to bridge the knowledge gap between the "haves" and the "have-nots", between the urban and rural areas (Miscione, 2007). Telemedicine has been defined as a distant delivery of health related services

through transfer of audio, video and graphical information via telecommunication networks, including consultative and diagnostic services along with enablement of planning, coordination, collaboration and education (Singh et al, 2009). However, despite the promise, adoption of ICT4H initiatives such as telemedicine, has been slow, uneven and limited in scope (Chandwani and Dwivedi 2015; Sims 2016), especially in low-resource settings such as India (Miscione 2007). In this paper, we conceptualize a low-resource setting as one that is characterized by infrastructural constraints, both, in terms of access to healthcare services and the technical infrastructure (Miscione 2007).

To achieve the potential of telemedicine in a low-resource setting, there is a need for researchers to develop a comprehensive and deep understanding of how the telemedicine process works in such contexts- including an understanding of processes, contingencies, structures and causal mechanisms. This deep knowledge would be highly valuable for managers and professionals involved in design and implementation of telemedicine. Our research focuses on the mechanisms that contingently underlie successful telemedicine in low-resource settings such as India. Specifically, by examining the doctor-patient interactions over a successful[1] telemedicine initiative in India, we attempt to understand "What are the mechanisms underlying successful telemedicine design and implementation, especially in low-resource settings."

One of the important reasons for slow and uneven adoption of telemedicine, is the lack of fit between the technology design and the human dimensions of the technology usage (Avison and Young, 2007; Miscione, 2007). The literature on impact of telemedicine has largely focused on the technological aspects of telemedicine (Mair and Whitten, 2000; Nelson, Miller and Larson, 2010). As highlighted by Whitten, Sypher, and Patterson (2000), '*we know a good deal about bandwidths and resolutions, but little about the human dimensions that make practice possible*' (p. 112). Telemedicine can result in marked changes in technical and interpersonal context within which communication takes place (Miller, 2011: 55). Indeed, successful diffusion of telemedicine programs is dependent upon the capacity of the actors to communicate effectively in this new medium (Miller, 2011); accordingly, we examine both social and technological dimensions- interactions amongst various actors and the interactions of actors with technology. As the purpose of the research is to explicate underlying mechanisms for successful telemedicine, we propose critical realism (CR) as a lens for the study, given its emphasis on generative mechanisms (Archer et al. 1998, Bhaskar 2013, 1998; Sayer 1992).

Generative mechanisms are defined as "*causal structures that generate observable events*" (Henfridsson & Bygstad, 2013). The idea of generative mechanisms draws from Bhaskar's philosophy of critical realism where these are understood as originative arrangements that make possible the visible situations that emerge (Bhaskar, 1998). Aligning with the theoretical lens and the philosophical underpinning of critical realism, we take an interpretive approach and adopt qualitative methods for the study. Qualitative methods are opportune in making sense or meaning of the observable events to delineate underlying generative mechanisms (McGrath, 2013).

Our research contributes to the literature in multiple ways. First, we identify three generative mechanisms that determine successful telemedicine interventions and and how these mechanisms contingently lead to the outcomes specifically in the low-resource settings. The focus on generative mechanisms driven by critical realism advances current knowledge about why some telemedicine interventions evolve successfully while others do not sustain (Sims 2016). Further, the paper demonstrates the efficacy of critical realism as an important

[1] By successful we mean that the telemedicine intervention sustained over a period of time; increasing number of patients used the system; the system was regularly used and both doctors and patients found the sessions useful.

perspective for making substantive contributions to the ICT4H literature.

The rest of the paper is structured as follows. In the following section we dwell on the theoretical framework of critical realism and generative mechanisms. Then we explicate the research context and the methodology. Next we present the findings of the study. In the discussion section we analyze the findings and tie them to the theory. We further outline the contributions to theory and practice. We conclude by highlighting the key insights from the study and outlining the directions for future research.

THEORETICAL FRAMEWORK- CRITICAL REALISM AND GENERATIVE MECHANISMS

Much of the extant IS literature is either situated in an (a) interpretivist paradigm, focusing on the rich understanding of meaning-making of the socio-technical milieu by the actors or in (b) positivist paradigm, focusing on the directly observable phenomena in the empirical domain. The CR perspective on the other hand positions itself as an alternative paradigm (Wynn and Williams 2012), leveraging elements from both perspectives. CR combines a realist ontology with an interpretive epistemology (Henfridsson and Bygstad 2013: 10) emphasizing that though our worldview is socially constructed, reality exists, often independent of the actors (Mingers 2004).

The CR paradigm explicitly focuses on establishing causality, by exploring how and why complex observable events occur in a specific context, instead of merely describing the phenomena, testing theories or proposing models for prediction (Wynn and Williams 2012: 804). Given the ontological and epistemological bases of CR, "*the [research] question must be of the form 'What caused the events associated with the phenomenon to occur?"* (Easton 2010: 123). In other words, a causal research question entails a focus on mechanisms in a specific context (Wynn and Williams 2012). CR-based research attempts to dig deeper into the observable events to effectively identify and explicate the underlying mechanisms that link the "*chains of indeterminate events and complex interactions*" (Grover et al. 2008: 45). These linkages can be explicated in the form of generative mechanisms.

Generative mechanisms are underlying causal structures that result in observable events in the empirical domain (Bhaskar 2013, 1998). Generative mechanisms refer to "*one of the processes in a concrete system that makes it what it is - for example, metabolism in cells, inter-neuronal connections in brains, work in factories and offices, research in laboratories, and litigation in courts of law*" (Bunge 2004: 182). As compared to Hume's conceptualization of causality, critical realists posit that the underlying structures have causal powers; though such causality is contingent and contextual as the observable outcome of a mechanism depends upon existence of other mechanisms (Elder-Vass 2010; Sayer 1992). Mechanisms, inherent to physical or social structures, are causal powers that can enable or limit the expression of a phenomenon in the empirical realm (Fleetwood 2004; Sayer 1992; Smith 2006).

As the purpose of this research is to understand the mechanisms determining successful telemedicine interventions in a low-resource setting, we adopt a CR perspective in this study. CR is opportune in understanding linkages between design and implementation of specific contextual technological interventions and their respective outcomes (Straub and Ang 2008). In other words, the CR perspective allows for exploring explanations that account for both the observable empirical events (such as successful telemedicine interventions in a specific context of a low-resource setting) and the embedded contingent causality.

Telemedicine involves doctors providing healthcare advice to the patients over virtual media. The interventions are highly contextual as "different technologies can shape and be shaped by action in specific contexts" (McGrath 2013). For example, the socio-cultural, economic

and technological aspects in low-resource settings such as India would be drastically different from that of high-resource contexts in the developed world. Therefore, researchers have argued that rather than searching for universal social laws and meta-theories which attempt to explicate a broad range of social phenomenon across contexts, scholarship should focus on mid-range contextual theories. Based on the CR perspective, the lens of generative mechanisms allows for building mid range theories to explicate socio-technical phenomena (such as telemedicine) through context-specific explanations.

Generative mechanisms and telemedicine

Generative mechanisms occupy the middle ground, linking the social laws and observations (Peter Hedstrom & Swedberg, 1996). Volkoff & Strong (2013: 821) posit that Generative mechanisms potentially provide explanations for the observable events, proposing that "*predictive theories based on statistical correlations can only tell us what may happen, and even then depend on debatable assumptions of system closure, variable independence, and normal distribution*." They suggest that retroduction allows researchers to explore the mechanisms that operate under the surface and ascertain causal explanations for the phenomenon (Volkoff & Strong 2013).

Astbury & Leeuw (2010) position mechanisms between social laws and description. Similarly, Henfridsson and Bygstad (2013) posit that generative mechanisms delineate underlying causes that connects social laws to observable outcomes. Bhaskar (1998: 38) posits that "*Generative Mechanisms must be analysed as the ways of acting of things; and their operations must be understood in terms of the exercise of tendencies and causal powers"*. In other words, the researchers need to develop an in depth understanding of the observable phenomenon and based on these events/ observations, determine the underlying generative mechanisms.

Henfridsson & Bygstad (2013) explicate generative mechanisms as composites, and highlight that there are three phases:

1. The first phase involves the conversion of macro level event into micro level. The macro level events are passed on to the individuals through situational mechanisms, which can be both enabling or restricting. In other words, the mechanisms could either enable the individual actor to perform an action or it could be constraining.

2. The situational mechanism is followed by the action formation mechanism. This occurs at the micro level where the individuals exhibit certain behavior and generate a specific action driven by individual's beliefs and attitudes.

3. The third phase is the transformational mechanism, where the individual actor's behavior at the micro level leads to an observable event at the macro level.

Thus the observable outcomes are determined by the individual behavior as the actor interacts with the environmental factors which could include both social and technical factors. As the technological aspects are deeply embedded in the social contexts, these mechanisms should be understood at the contextual level. Henfridsson & Bygstad (2013) further that there are multiple mechanisms which might be operating simultaneously, and that these mechanisms interact amongst themselves. The above arguments imply that the observable outcome can be different in diverse contexts.

Successful telemedicine event entails effective doctor-patient interaction over virtual media, which can be regarded as an observable macro level behavioral outcome (a desirable one). This macro level outcome, however, depends upon several underlying generative mechanisms, which may be unobservable, existing at the micro level. Our research specifically attempts to identify and explicate the underlying mechanisms that enable the

empirical manifestation, that is, successful telemedicine in low-resource settings such as India.

In the following section we explicate the research method for this study.

RESEARCH METHOD

As we have assumed a CR paradigm to investigate the phenomenon of interest, we have adopted a methodology consistent with the CR perspective. We examine both the actors' interpretations and the structures and mechanisms that interact to produce the outcomes in question. The steps for CR- based research entail describing the context, identifying mechanisms, and explicating the interactions between mechanisms and context (Ackroyd 2010).

While Bhaskar did not propose any particular research methodology, other CR scholars advocate adopting a qualitative approach to explore the structures, actors and contextual aspects to explain how they interact to produce the outcome (Ackroyd 2010; Easton 2010). Other scholars have also argued that in order to develop an in-depth understanding of the effects of technology, such as telemedicine, and to comprehend how the doctors and patients interact over telemedicine, qualitative analysis of actual behaviors of the actors should be undertaken (Miller, 2011). Qualitative methods are more opportune in exploring the socio-cultural aspects of technology implementation such as interpersonal communication and how actors interact with technology, which in turn, would enable researchers to identify and explicate the mechanisms underlying successful telemedicine interventions (Hajli et al 2015; Walsham, Robey and Sahay, 2007).

In this study, we follow the methodological principles for conducting research based on the CR paradigm, as proposed by Wynn and Williams (2012). The steps that Wynn and Willams (2012) describe are: 1) explication of events, 2) explication of structure and context, 3) retroduction, 4) empirical corroboration, and 5) triangulation. The following steps are obtained from their approach, and the principles they are based on are mentioned in brackets:

1. Describing the phenomenon: A thick, detailed description of the phenomenon including actors, actions and outcomes (based on the principle of explication of events).
2. Multiple data sources: Obtaining variety of data from multiple sources and engaging multiple investigators (based on the principle of triangulation).
3. Identifying and detailing the structures and the context: Description of the structural aspects, relevant components, and the contextual nuances characterizing the specific phenomenon; and identifying relationships between the components (based on the principle of explicating the structure and context).
4. Linking the structure to events (empirical realm): Identifying and explicating the proposed mechanisms based on logical and analytical explanations (based on the principle of retroduction).
5. Validating the proposed mechanisms: Assessing the explanatory power of the proposed mechanisms based on the linkages between case data and theoretical explanations (based on the principle of empirical corroboration).

In the following subsection, we begin with a detailed description of the research context addressing the principle of 'describing the phenomenon'. In further subsections we explicate data collection and analysis processes.

Research context

In this research, we examine a specific type of telemedicine program- real time tele-consultation over video conferencing at SGPGIMS (Sanjay Gandhi Post Graduate Institute for Medical Sciences).

SGPGIMS, a tertiary care teaching hospital located in Lucknow in the central part of India, is a premier public health institute for super-specialty healthcare and cutting edge medical research. The institute is a pioneer in the field of telemedicine initiatives in India. The institute has been recognized as the National Resource Centre for telemedicine in India and provides consultancy on telemedicine to the central and state Governments in India as well as abroad. SGPGIMS houses all the super-specialty departments to cater to the most complicated cases. The super-specialties are structured as centres of excellence. Department of surgical endocrinology in SGPGIMS, which deals with complicated cases such as thyroid cancers, caters to several patients from far off places across India, but it was observed that many patients came from the state of Orissa (a state about 1500 kilometers away from Lucknow), where advanced facilities for complicated super-specialty procedures such as thyroid surgery were not available. Therefore, the team of super-specialists in the department envisaged a telemedicine infrastructure where video conferencing facilities would be established with three medical colleges in the state of Orissa. The facility was particularly designed for tele-follow-up, that is, after the primary treatment in form of surgery and/or radio-therapy at SGPGIMS, patients could be regularly followed up on virtual media. Post surgery and/or radiotherapy, the thyroid cancer patients need to be on continuous follow-up for screening for recurrence of malignancy, monitoring for parameters such as calcium and thyroid level and titration of drug doses accordingly. The central and the state governments funded the project. The telemedicine system at SGPGIMS, established in 2003, has been successfully providing tele-consultations to thyroid cancer patients from Orissa for more than a decade now, with a growing number of highly satisfied patients.

Most of the patients coming from Orissa belonged to the low socio-economic strata, largely from the scheduled tribes. The travel to Lucknow for follow-up entailed travelling for more than 24 hours and hence, substantial travel costs, along with the loss of potential wages. It was conceived that tele-follow up would enable the patients to access the required advice without incurring those costs. The patients could travel to tele-centre located in one of the medical colleges in their home state (remote end) and the super-specialist surgeon and/or radiotherapist in the tertiary hospital (SGPGIMS) advised them over video conferencing. Notably, the patient needed to report to the primary physician or surgeon in the remote centre with the required documents and reports on the date as advised by the specialists in the tertiary hospital. The doctors at the peripheral site were available to take the history and do the basic examination, such as performing clinical examination or measuring the blood pressure. Peripheral centre was equipped to carry out necessary basic blood investigations, such as TSH (Thyroid Stimulating Hormone) and thyroglobin levels, if suggested by the specialist. After the tele-consultation process was over, the super-specialists typed the prescription on the system. A print out of the same was handed over to the patients by the primary physician/ surgeon who also explained the protocol and advised regarding next follow-up. Figure 1 presents the model of telemedicine at SGPGIMS.

Insert figure 1 about here

Data Sources

In this subsection, we describe the data sources and the analysis process.

The primary data consisted of video recordings of teleconsultations, in-depth interviews and field notes based on observations by two authors. Researchers have emphasized that "*of all observing and recording techniques, video recording has been recommended as the best method for researching doctor-patient communication because it captures all modalities of interaction between participants in a consultation*" (Coleman, 2000: 422). Accordingly, the primary data consisted of video recordings of the doctor-patient interactions. We recorded sixty-two tele-consultations. Further, in-depth interviews were conducted with the key stakeholders to understand their perspectives about telemedicine in general and the specific technological intervention in particular. The key stakeholders were identified by the two researchers on the basis of their observations about the process of tele-consultations. We conducted interviews with the following stakeholders- (1) super-specialists from SGPGIMS, notably, the team of super-specialists not only provided the consultations but also were instrumental in designing the system; (2) doctors at the peripheral node in medical colleges of Orissa who provided the clinical inputs; (3) patients and their relatives who came for teleconsultations and who were the primary beneficiaries of the system; and (4) coordinators at both ends who not only ensured that the technical and medical records aspects were taken care of, but also ensured that the session ran smoothly. Table 1 provides the overview of number of interviews.

Insert table 1 about here

We also included secondary data sources, such as the data provided in the organization's website, published papers, newspaper articles and reports to corroborate the findings and interpretation. Notably, we used multiple data sources, both primary and secondary, and, two researchers were involved in the analysis process, thus addressing the second principle, 'multiple data sources' as described by Wynn and Williams (2012).

Data analysis

Given the focus of our research on the underlying generative mechanisms for telemedicine by examining the processual aspects, we adopted an interpretive theory building approach to analyze the qualitative data (Pettigrew, 1990; c.f. Ravasi and Phillips, 2011). The data analysis in qualitative research involves moving from raw empirical data to develop conceptual understanding of the phenomenon, from data to theory. The analysis process involves '*meaning condensation'*, that is, data reduction while enhancing the meaning (Lee et al., 1999: 89). Broadly the steps involved in data analysis of multimedia data are similar to those in the analysis of textual data.

While analyzing the data our focus was to align with the three principles of CR-based research, namely, identifying and detailing the structures and the context, linking the structure to events and, validating the proposed mechanisms (Wynn and Williams 2012). We adopted the common methods in interpretive theory building as prescribed by researchers (Glaser and Strauss, 1967; Miles and Huberman, 1994; Pettigrew, 1990). The video data was reorganized with each session of consultation process labelled as one unit. The video recordings of the tele-consultation process and the interview transcripts, were then analyzed by two independent researchers (Two authors). One of the authors who analyzed the data has experience in social science research and another is a medical practitioner. The domain specializations of the researchers involved in data analysis ensured that the data is explored through diverse perspectives-one having a detailed insider's knowledge of the habitus and the other adopting a broader sociological perspective (c.f. Pearce et al., 2009).

The initial step in qualitative analysis is coding. Coding entailed extracting relevant categories, themes and concepts from the raw empirical data. The first level coding was an 'open coding' in order to uncover common themes (Glaser and Strauss, 1967; Locke, 2001). Gradually, through an iterative process of data analysis, we arrived at conceptual codes and themes. The coding process was manual and was not based on a pre-determined theoretical framework. Rather, as in interpretive research and in conversational analysis, the framework emerged from the data itself. Interpretive research is especially opportune in discovering unique aspects of contextual factors that influence the phenomenon in question (Walsham, 2006).

As explained above the data was analyzed by two independent researchers (two authors). After the initial open coding, the two researchers had repeated detailed discussion to arrive at the themes conveying the 'meaning'. The final themes identified by the two researchers showed considerable congruence and minor discrepancies were resolved through mutual discussions. For example, when some of the first order categories were overlapping or contradictory, which is common in a meaning condensation process, the researchers re-examined the segments and interactions and discussed till a mutual consensus was reached. This exercise of achieving consistency amongst the codes, is in accordance with prior researchers (for example, Strong et al 2014; Seidel et al 2013) The consistency, thus achieved, enhanced the robustness of the process of meaning condensation.

FINDINGS

In this section, we describe the findings of the study. These findings enabled us to identify and detail in the structures and to understand their relevance, given the contextual nuances. Thus the findings and their interpretations enabled linking the structure to events. We explicate the findings under four dominant themes identified in the analysis: Coordination work, expert patient, formation of informal social support groups, and enhancement of skills of the physicians in peripheral nodes.

Coordination work

Our observations and the video recordings of the tele-consultations highlighted the importance of extensive efforts put in by the coordinators. The coordination efforts entailed that coordinators at both ends, central and peripheral nodes, worked extensively on pre-consultation preparations and post-consultation conversations. The coordinators checked the system connectivity and functioning of the equipment a day prior to the scheduled consultation date and informed the doctors about the same. They assembled at the tele-consultation rooms at both ends around an hour before the the stipulated time for doctors and patients. There they followed a protocol and rechecked various aspects of telemedicine process (Picture 1): checking the technical aspects- equipment and connectivity; ensuring that data and records of the enlisted patients were available on both ends; ensuring that the relevant actors, doctors at both ends and patients, had been informed and their confirmation was taken.

Insert Picture 1 about here

The technical checking involved all the functions, clarity of the audio and video data, prescription process and camera settings. The files of the enlisted patients were arranged in the order in which the patients were scheduled. The coordinators at the central node enquired with the peripheral coordinators whether all the patients were informed and how many of them had confirmed that they will be attending the tele-consultation. The peripheral coordinators shared the information regarding their telephonic conversations with the

patients, identifying if any patient had expressed inability to be present on the specified day. Their files were removed from the list and kept separately for informing the doctors. The final list of the confirmed attendees was matched at both ends.

The coordinators' conversations were friendly and after going through the tasks as per the protocol, they indulged in an informal conversation. Interviews with doctors and patients affirmed the critical role of coordinators.

Dr. M (The Head of Department, Surgical Endocrinology, SGPGIMS) explicated,

> *"These (coordinators) are the backbone of the telemedicine system. I mean that they run the show. I have my patients, my OPD timings, and my scheduled surgeries. I don't get time to think about technical aspects, whether the connection is there, camera is functioning etc. They ensure all of that. I just walk in the consultation room, the patient is ready, the files are up to date and the residents brief me about the case. It is same like seeing the patients in my chamber, well almost… (Smiles)"*

The tele-consultation process involves time commitments of the highly overworked and time constrained doctors. Patients also bear the financial and time costs related to travel to the medical colleges. Therefore, extensive coordination is essential at both ends to ensure the success of tele-consultation process. The coordination work, as described above, concerns both technical aspects and ensuring the actors' involvement. Mr. Y (The lead coordinator, telemedicine at SGPGIMS) highlighted,

> *"We need to address multiple issues to make the tele-consultation process a success. These patients travel from far off rural areas to the respective medical colleges to attend the tele-consultation. We can't afford any technical glitches. We double-check the connectivity aspects a day before and a few hours before the actual consultation time. I am in constant touch with the coordinators at the other end."*

Ms. G, one of the coordinators at SGPGIMS added,

> *"We make sure that all the preparations for the tele-consultation are done well in advance. It requires a lot of planning from both sides, here as well as the medical colleges. We discuss with the super-specialists here and prepare a list of patients according to the follow up dates given to them. Thereafter, we share the list with our coordinator colleagues there in Orissa."*

The coordination involved substantial offline work, especially at the peripheral nodes in Orissa. As evident in the video recordings and emphasized in the interview with coordinators and patients, one of the major responsibilities of the coordinators was to ensure that patients were fully informed and involved. They informed the patients about the dates well in advance, confirmed that they would be coming on the stipulated day and time, ensure that they get the prescribed tests done before they come for tele-consultation, and that they bring all the required records with them. This was essential as many patients had to undertake significant travel to reach medical colleges, and hence entailed proper planning. Mr. D, the lead coordinator at one of the medical colleges explained,

> *"Once we have the confirmation that the teleconsultation is going to happen on such and such date and time, we have to make a lot of arrangements. We ask for the list of patients and once we receive the list, we contact each and every patient and confirm the appointment. We also ask them if they have undergone the tests that were prescribed to them in the previous visit or at SGPGIMS."*

Thus the coordination work, which included offline and online tasks and involved technical and people aspects, played a key role in success of telemedicine.

Expert Patients

One of the important aspects related to the coordinators' repeated offline communication with the patients was moulding a naive patient to an expert one. The patients on regular follow-up were also comfortable with the use of technology, for example, while interacting with the super-specialists they would face the camera instead of the screen. Awareness and expertise of patients related not only to the technology use and adaptation but also to the knowledge, skills and attitude regarding self-management of disease. We found that the patients were confident in their interactions with the super-specialists, and indeed the repeated follow-up patients were fluent with the medical jargons. They communicated effectively with the super-specialists as they related their reports, described their symptoms and explicated the existing treatment protocol. Indeed, many patients maintained their own diaries with the relevant reports and usually read through their records when asked specific questions (Picture 2)

Insert picture 2 about here

We wanted to clarify from the doctors whether the tele-follow-up patients were more involved than the patients coming directly to the doctors and if so why. We posed this question to both super-specialists at SGPGIMS and the doctors at the medical colleges. The doctors reiterated that tele-follow up patients were indeed more aware and informed; were more proactive and effective in communicating with the doctors and in self-management of the disease. The doctors explained that the processes were in place to engage these patients right from the treatment at SGPGIMS. Before being discharged after surgery and/or radiotherapy, these patients were made to witness a live tele-consultation process and were encouraged to interact with tele-follow-up patients and the local doctor on the system to understand how the system works and to clarify any doubts. The support and encouragement from a fellow community member suffering from the same disease was important for comforting the patient.

The chronicity of the disease (thyroid cancer) and repeated interactions with the coordinators enabled the patients to 'learn' most of the aspects related to follow-up processes such as what are the key symptoms that the doctors would ask for, what are the key investigations that super-specialists prescribe and how frequently, the normal range, and treatment protocols. Mr. A, one of the coordinators at a peripheral node remarked,

> *"I feel that these patients are more proactive and also more precise. Maybe because whenever we call them to confirm that they are coming for tele-consultation we ask them again and again, have you done these tests, have you all the reports, please remember what medications you are taking and if you don't remember the names please bring the medicines along with the files. I think over time they come to know what information is required. We have no such procedure in a typical face to face follow up. While the patient is being sent home, we tell them to get the tests done and bring all the reports. There is no prompting that happens before the scheduled date."*

Dr. M corroborated

"When patients with similar background…as in same socio-economic class and education levels…come to us in the clinic directly, they usually give us the file and then wait to be examined and advised. They bring the file that is given to them by the institute."

The processes involved in the design of telemedicine at SGPGIMS, thus, led to conversion of a naïve patient to an expert patient over repeated follow-ups.

Formation of informal social support groups

The telecentres at the peripheral nodes were established in the Medical colleges in Orissa. The patients needed to travel to the local medical colleges from their respective villages to attend the tele-consultation process which were scheduled on fixed days of the month. At the peripheral nodes, the local physicians and coordinators were present on those specific days and facilitated the tele-consultation process as described above. As the patients suffering from thyroid cancer from various parts of Orissa assembled at the telecentre, they had an opportunity to interact with other patients belonging to the similar geographical locations and suffering from similar ailments. They could share the issues, challenges and anxieties with each other as they waited for their consultation, thus leading to the formation of informal social groups. As one of the patients narrated,

"At first I thought I am alone, I had never heard of anyone known who had thyroid cancer. Once I came here I saw many patients who are suffering…we met Mrs Meena here…she belongs to a place near our village…now we come together for the follow up sessions…Sometimes when any one of us is unable to come for some reasons, we carry the other person's report and Dr Saheb advises accordingly."

Another patient explained,

"When we come here, we see patients who have similar disease…and we belong to the same culture and are from nearby areas…we share our concerns and now we are emotionally bonded to some of them…we even meet outside of this set up in several social gatherings."

These informal social support groups emerged because of the design and implementation of the telemedicine process which facilitated the interaction between the patients with similar backgrounds and with common clinical and non-clinical concerns. The informal social network, in turn, enabled the patients to seek social and emotional support as well as to learn regarding disease management and also about technology from each other.

Enhancement of skills of the physicians in peripheral nodes

The primary physicians at the peripheral nodes dealt with the patients directly during the tele-consultation process. They also interacted with the super-specialists at SGPGIMS during the process. They performed clinical examination whenever required, handed over the print out of the prescription, explained the drugs protocols and informed about the next visits. The primary physicians emphasized that their interactions with the super-specialists from SGPGIMS and dealing with the patients had resulted in enhancement of their knowledge and skills regarding management of thyroid cancer patients. They reiterated that this training and learning dimension of telemedicine process was one of the key reasons for their engagement in the telemedicine initiative. As Dr A explained,

"As we were involved in the telemedicine program, we were first called to Lucknow for a training in surgical endocrinology. Dr M himself gave this training over a period of two weeks. We don't get this type of extensive super-specialty exposure in our post graduation. It was a hands-on

training program. Now I feel very confident in dealing with these cases. The regular follow-up of patients in tele-centre and the continuous interaction with Dr M every week enables me to learn continuously."

Yet another primary physician from a medical college in Orissa, Dr C explicated,

"I feel very confident in dealing with thyroid cancer patients now. The team at Lucknow is always there to help. We can call them anytime and they advise accordingly. Many times these patients come on non scheduled days for follow up…Now I can advise them on my own and if there is any doubt I can easily ask the super-specialist in Lucknow."

The upskilling of the doctors at the medical colleges in Orissa can be regarded as a critical aspect of access to healthcare services for the patients from Orissa, as it provided them *local* access to the skilled professionals.

As one of the patient's relative remarked,

"We come here regularly for follow up…every six months or so…now we know Dr S here and many of his team members. We come here if we need any medical advice…the staff here is very supportive...and they speak our language"

The importance of enhancement of local facilities is especially relevant for Indian context which is geographically vast and culturally diverse, and the local public health institutions are not well equipped and developed.

In the next section we tie the above findings to the theory and explicate the generative mechanisms that enabled successful telemedicine.

DISCUSSION

In this section we link the structure to events by identifying and explicating the generative mechanisms and validate the proposed mechanisms on the basis of theoretical and logical arguments. These mechanisms enabled the telemedicine initiative to overcome the major challenges occurring in a low-resource setting. The healthcare system in India, as described above, is highly skewed towards urban areas and the remote rural areas lack access to healthcare, especially specialists' services. While, conceptually, telemedicine systems can enable the delivery of specialists' advise, the context, characterized by infrastructural constraints, poor connectivity and lack of reliable power supply pose significant challenges for design and implementation of such systems. Further, the quality of the healthcare services offered by the providers in the rural areas has been questionable (Das et al 2012). The technology design and implementation needs to be sensitive to the contextual nuances, for example, a telemedicine system which provides home based tele-consultation to elderly patients by connecting the medical practitioners to the respective home (Botsis et al 2008) or a *smart home* to improve healthcare access and comfort (Ehrenhard, Kijl and Nieuwenhuis 2014) might be feasible solutions for a context where the patient is comfortable in using the technology and connecting to the healthcare provider and the context is an individualistic society where health is a 'personal matter'. However, identical systems may not be appropriate for a collectivist society such as India, where social support is an important dimension of care (Chandwani and De 2015) and the perceptions about health and disease are shaped by multiple co-existing systems of medicine such as Ayurveda and biomedical system (Sujatha 2007).

In this section, we analyze the findings to arrive at generative mechanisms that enabled the telemedicine system at SGPGIMS to address the contextual challenges. The three mechanisms specifically address the major concerns of three important stakeholders,

namely the super-specialists (who have to cater to a very high patient load), local doctors (who seek enhancement of their skills and knowledge) and patients (who seek social support, need to learn about self management and, become comfortable with the use of technology).

Mechanism of rich connectivity

Initially, our understanding of tele-consultation process was that of an interaction between a doctor and a patient, where medical advice is provided to the patient over a virtual media. In other words, the flow of information in telemedicine occurred uni-dimensionally between the doctor and the patient, who are the provider and seeker of healthcare services respectively, and that content of the information flow is largely clinical, consisting of medical knowledge. However, we observed that the telemedicine process entailed coordination and collaboration between two nodes- central and peripheral, rather than between doctor and patient. Each node, in turn, consists of several related stakeholders who also play an equally critical role, if not more, in enabling the information flow. In the paragraphs below we describe the importance of role of coordinators and the multidimensionality of information flow in ensuring the success of telemedicine.

The poor infrastructure support, including unreliable power and connectivity, especially in remote rural and peripheral locations entail that the site for establishing the telecentres in the periphery should be deliberated carefully. The peripheral nodes in the telemedicine system at SGPGIMS were established at local medical colleges. The physical infrastructure and skilled manpower available in the local medical colleges could ensure smooth functioning of the peripheral node. However, this required that patients need to undertake some travel to these locations for attending tele-consultation. Further, the tele-consultations were scheduled specifically on particular days every month. This ensured that there were sufficient patients for tele-consultation on a given day so as to fully utilize and justify the time spent by doctors on both sides. The location at medical colleges and scheduling on specific days entailed other challenges, especially regarding coordination.

The coordination between the nodes involved both online and offline domains. Indeed, the coordinators on both sides exchanged information regarding several aspects of tele-consultation process such as availability of doctors, number of patients, availability of updated records and so on. These information exchanges, that occurred prior to the tele-consultation in an offline mode, were extremely crucial for a successful and smooth tele-consultation. The content of the offline interaction, that entailed planning and preparation was largely non-clinical. These interactions ensured that the clinical aspects were taken care of such as preparing the list of patients who were scheduled for the day; confirming the availability of super-specialists at the central node and primary physicians at the peripheral nodes; informing the patients about the appointment well in advance; and checking and ensuring that they brought the necessary reports on the consultation day. The prior coordination work with the patients and the doctors assumes importance, especially in a low-resource setting such as India, as many patients had to travel significant distances to reach the peripheral nodes (local medical colleges).

Another crucial aspect that determines the success of tele-consultation process is technological reliability. This is especially relevant in the Indian context characterized by questionable reliability of connectivity. It was the coordinators' assigned task to check and ensure that connectivity was well established between the nodes and the equipment at both central and peripheral nodes were functioning properly. The telemedicine system involved three levels of connectivity so that in case of failure of leased line, other mechanisms could be used to connect the two nodes. The coordinators were required to check the instruments repeatedly, a day before the scheduled tele-consultations and again a few hours before the scheduled time.

The low doctor-patient ratio in low-resource contexts like India is another dimension that needs to be addressed in the design and implementation of telemedicine. The doctors in India, especially the super-specialists, are considerably overloaded with very high patient turnover. Therefore, the telemedicine system required specific emphasis on making the tele-consultation process as easy, effective and efficient as possible for the already time-constrained doctors, even if the measures make it slightly inconvenient for the other stakeholders involved. Coordinators' work ensured that the tele-consultation process did not pose additional cognitive, temporal or emotional strain for the doctors by aligning the telemedicine system with the existing routines of the doctors. This was achieved by locating the telecentre in spatial set-ups that aligned with the established routines of the doctors, planning the tele-consultation days and time to align with the schedule of the concerned doctors, and focusing on restricting the provision of medical advice for specific diseases (thyroid cancer). The above aspects, in turn, limited the change of routines required by the doctors, and ensured that extra bandwidth required for doctors' heuristics and judgment was minimized. The doctors at both ends recognized the criticality of the coordinators' involvement for enabling and facilitating exchange of medical information between the super-specialists at the central node and the patients/ primary physicians at the peripheral.

The coordinators' work was critical not only for the technical infrastructure, but also for bringing together the key actors required for tele-consultation and ensuring that the information required was available at both ends. The coordination work involved bilateral and extensive flow of information, spanning across multiple dimensions namely clinical, managerial and technical. Significant amount of coordination work occurred offline before and after the online work. The facilitative role of offline coordination work is especially important in low-resource settings and dispersed geographies.

The above aspects provide useful insights regarding mechanisms underlying successful telemedicine for low-resource settings. We posit that the success of tele-medicine entailed mechanism of rich connectivity. Here we specify that rich connectivity refers not only to the technological aspects but also to the process design and implementation. The rich connectivity involved both- (1) design aspects such as selection of site for the nodes, physical and spatial arrangements, choice of technology for connectivity and (2) implementation aspects such as enabling flow of bilateral managerial and technical information along with clinical information and ensuring offline coordination work pre and post tele-consultation.

The macro level, observable, online communication between the doctor and the patient, where the doctor advises a patient, is just one dimension of 'telemedicine', albeit a central one. The other dimensions of communication- managerial and technological, that occurred between the coordinators and between the coordinators and patients were equally critical, if not more, for the success of the actual tele-consultation. These aspects constitute the underlying micro mechanisms that enabled the manifestation of the macro. It was the offline and online coordination that ensured that the key actors ensembled. The effective telemedicine, in turn, resulted in a cordial relationship between coordinators and patients which further facilitated the offline communication. The use of connectivity to perform micro work for the actual macro work, forms the basis of mechanism of rich connectivity represented in figure 2. In the figures representing the mechanisms, the part above the dashed line represents the macro aspects and that below the dashed line represents the micro underlying aspects.

Insert figure 2 about here

Mechanism of tutoring

We identified that the local doctors (primary physician/ surgeon at the local medical colleges) were extremely critical for the success of telemedicine. The local doctors were involved in the conceptualization and design of the initiative from the beginning itself. Their active participation was ensured by their involvement in program formulation and technological design and implementation processes. Further, the doctors from local medical colleges in Orissa who were to be a part of the initiative were trained at SGPGIMS in both medical aspects- knowledge and skills in delivering thyroid cancer care and technological aspects- using the system. The training program formed the basis of a continual engagement of the local doctors with the super-specialists and the coordinators in SGPGIMS. The involvement of local doctors has been emphasized in the healthcare sector, especially in culturally diverse settings such as India, as they are well aware of the socio-cultural and economic nuances of the context which in turn enables them to connect well with the community. The local doctor acts like a family physician, speaking in the familiar vernacular language and hence is perceived to be more accessible.

However, we further the argument of familiarity by highlighting another aspect of accessibility- enhancement of local healthcare facilities and competence of local physicians/ surgeons. The primary local doctors recognized and emphasized the importance of the enhancement of their knowledge and skills with regard to the management of thyroid cancer patients as a result of their involvement in the telemedicine program. This finding is in alignment with prior research which states that telemedicine can be used for enhancing the skills of healthcare professionals in form of continuing medical education programs, and that training and development programs can be conducted remotely (Mishra 2009). Other researchers have also highlighted the importance of telemedicine in enhancing the efficacy of healthcare professionals through extending their social and professional networks (Larsen and Bardram 2008).

The above discussion highlights yet another mechanism that enables successful telemedicine initiative- mechanism of tutoring. The ‘tutoring’ entails not only the training of the healthcare providers in the use of technology but also refers to the micro aspect of knowledge and skill enhancement of the local doctors. Notably, a large part of medical training occurs in an apprenticeship mode and bedside approach, where the doctors discuss the clinical aspects of the case around a patient. The mechanism of tutoring in telemedicine was a simulation of learning through bedside case discussions and hence was well received by the doctors at the peripheral node. The tutoring process and the resulting enhanced involvement of local doctors in the process constituted the micro mechanisms that enabled the macro phenomenon- enhanced effectiveness of tele-consultations. This further increased patients’ confidence in the system itself, thus perpetuating their participation in the telemedicine. The increased participation of patients in telemedicine further enhanced the micro aspect- skill enhancement of the local doctors. Prior research has also demonstrated that the effectiveness of building a community of practice around telemedicine can enhance the medical practice and sustainability of telemedicine interventions (Sims 2016). The mechanism of tutoring is represented in figure 3 below.

Insert figure 3 about here

Mechanism of moulding

Another mechanism that we identified as crucial to the success of telemedicine was ‘mechanism of moulding’. Here we refer to the moulding of the patient from a naïve patient

to an expert patient. The moulding related to three aspects of expertise, namely, self management of the disease; attaining proficiency in dealing with the technology; and building and accessing social support group.

As the system was designed to maximize the utilization of doctors' time, the tele-consultations were scheduled on fixed days every month. This entailed that patients with similar disease (thyroid cancer) belonging to nearby geographical areas assembled at the telecentres located in local medical colleges, which in turn, facilitated interactions amongst the patients and their relatives. The sharing of concerns, anxieties and emotional support led to the formation of informal local support groups. Further, they learnt the clinical aspects of management of thyroid cancer from each other in the waiting time.

The coordinators called patients repeatedly to ask about their reports, symptoms, treatment protocols in order to ensure that the relevant data was available handy during the tele-consultation process. This enabled the patients to learn what were the specific important aspects that were required in follow-up. Moreover, as the patients and their relatives needed to maintain their records and communicate directly with super-specialists over telemedicine, many of them maintained their own records in diaries. The expertize also involved comfort in use and adoption of technology. Facilitated by the coordinators and the support groups, patients on repeated follow up were very comfortable in the use of technology.

The access to the knowledge and social support resulting in the expertise in the three dimensions constituted the micro- mechanism of moulding. This expertise ensured the macro manifestation- smooth and effective tele-consultation process and increased follow-ups. Repeated visits to the telecentre entailed increased interactions with coordinators and doctors, and accessing social support groups. This, in turn, provided opportunities to enhance the expertise, which furthered the patients' participation in telemedicine. Prior research has shown that increased patient knowledge can enhance the quality of doctor-patient interaction over telemedicine considerably (Osei-Frimpong, Wilson and Lemke 2016). In this study, we extend the above argument and posit that for effective tele-consultation the expertise needs to be multidimensional. Figure 4 below represents the mechanism of moulding.

Insert figure 4 about here

Implications for theory

The research contributes to the IS literature in general and, scholarship on ICT4H in particular, in multiple ways. We posit that contextual examination of a social phenomenon can be undertaken through mid-range theories such as the lens of generative mechanisms based on a critical realist perspective, rather than universal social laws. The mid range theories allow the researcher to acknowledge and account for contextual nuances while searching for causal explanations. ICT4H initiatives are highly context specific given the socio-cultural aspects of healthcare as well as ICT. The study demonstrates the importance of adopting a critical realist perspective and the lens of generative mechanism in understanding the underlying causal socio-technical aspects for effective telemedicine.

Further, the macro level social phenomenon is an expression of an interplay between multiple interactive structures. The contextuality relates not only to individual mechanisms but also to the interplay between various mechanisms. In the above study for example the confluence of factors in a low-resource setting entail that the mechanisms should address the issues related to multiple constraints such as poor infrastructure, technological limitations, lack of reliable power, connectivity issues; lack of skilled manpower and low

doctor patient ratios; low patient awareness and education; and inadequate local public health facilities. Further, the Indian context is characterized by geographical dispersion and cultural diversity. These interrelated factors determine the design and implementation of effective telemedicine system for example the choice of medical colleges as the peripheral nodes. The interrelated mechanisms attempt to address these contextual factors to enable effective doctor-patient interaction over virtual media. The very fact that generative mechanisms represent the causal explanations for a context specific phenomenon entails that further researchers should examine which of these mechanism are relevant for their context given the underlying factors. For example, in a high resource setting, the resource constraints, especially technical ones are much less limiting and the location of the peripheral node could be more proximal to the patient. These aspects would entail different mechanisms.

Implications for practice

The research provides direct guiding principles in the form of generative mechanisms for design and implementation of telemedicine in low-resource settings. These insights are particularly useful for IS practitioners and policymakers involved in telemedicine programs as most of these programs are restricted in scope and are unable to sustain or scale-up (Sims 2016). The mechanisms explicate the micro aspects of structures that enable manifestation of the phenomenon (successful tele-consultations). Notably, the mechanisms are represented as reinforcing virtual cycles that have useful insights on scaling-up of telemedicine. Specifically, these mechanisms illuminate how the design and implementation of systems can address the contextual nuances such as constrained technical infrastructure and social support as an important dimension of care. Some of the principles may be applicable to telemedicine in other contexts as well, for example, investing in engaging the local doctors or local healthcare providers. However, the specific aspects of engagement would require further contextual understanding and inquiry.

CONCLUSION

While most of the ICT4H interventions that are implemented fail to sustain, there are certain initiatives that are successful. A comprehensive understanding of the causal structures and mechanisms that underlie successful telemedicine would be highly valuable for academicians as well as practitioners. In this study, adopting a critical realist perspective, we examined a specific telemedicine intervention to identify and explicate generative mechanisms that underlie successful telemedicine in low-resource settings such as India.

The study contributes to the literature in multiple ways. We argued that the critical realist perspective and the lens of generative mechanisms is opportune in highlighting specific aspects of design and implementation of the initiative that underlie successful telemedicine. We identified three mechanisms for enabling successful telemedicine in low-resource contexts, namely, mechanism of rich connectivity, mechanism of tutoring and mechanism of moulding. These mechanisms involve both social and technical dimensions and provide causal explanations for macro level outcome- effective tele-consultation. Notably, the three mechanism address concerns of three different stakeholders respectively- coordinators, local doctors and patients. The three mechanisms address an important set of constraints related to the low-resource settings that can potentially limit the adoption of telemedicine by the specific stakeholders. Table 4 below summarizes how the three mechanisms enable telemedicine in the described context.

Insert table 2 about here

The study highlights several directions for future research. As the generative mechanisms are highly context dependent, further research can study telemedicine in diverse contexts to identify and explicate other mechanisms for successful implementation. Further, in our study, the telemedicine system was designed specifically for follow-up treatment of thyroid cancer. Telemedicine for other conditions such as for acute illness such as stroke, or for lifestyle related diseases such as diabetes, may involve different mechanisms and should be explored in future studies. Furthermore, the mechanisms underlying telemedicine for primary consultation might be different from those for tele-follow-ups. Future researchers need to explore the causal structures and mechanisms for these diverse contexts. Telemedicine can also be designed as an asynchronous communication where a doctor views an image based report and provides his/her opinion such as in tele-radiology and tele-pathology (Mechling 2004). Further research is required to investigate the mechanisms enabling such asynchronous systems as compared to the real time synchronous doctor-patient interactions examined in our study. Insights from such studies would enable design and implementation of context appropriate ICT4H interventions such as telemedicine.

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