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Understanding workflow in telehealth video visits: Observations from the IDEATel project

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ABSTRACT

Home telemedicine is an emerging healthcare paradigm that has the potential to transform the treatment of chronic illness. The purpose of this paper is to: (1) develop a theoretical and methodological framework for studying workflow in telemediated clinician–patient encounters drawing on a distributed cognition approach and (2) employ the framework in an in-depth analysis of workflow in the IDEATel project, a telemedicine program for older adults with diabetes. The methods employed in this research included (a) videotaped observations of 27 nurse–patient encounters and (b) semi-structured interviews with participants. The analyses were used to provide a descriptive analysis of video visits, understand the mediating role of different technologies and to characterize the ways in which artifacts and representations are used to understand the state of the patient. The study revealed barriers to productive use of telehealth technology as well as adaptations that circumvented such limitations. This research has design implications for: (a) improving the coordination of communication and (b) developing tools that better integrate and display information. Although home telemedicine programs will differ in important respects, there are invariant properties across such systems. Explicating these properties can serve as a needs requirement analysis to develop more effective systems and implementation plans.

1. Introduction

1.1. Home telemedicine

Home telemedicine is an emerging technology that has the potential to transcend geographic and social barriers to facilitate the management of chronic illness in an aging population. Almost 21 million people in the United States are living with diabetes [1]. There is a need for interventions that promote patient autonomy and reduce the burden on clinicians. Telemedicine offers the possibility of increasing the frequency of clinician–patient communication and enhancing patient self-management. Telemedicine involves the electronic transfer of medical and health information between multiple participants that are geographically separated [2]. Facets of home telemedicine typically include two-way audio and video communications between patient and clinician and self-monitoring devices such as glucose and blood pressure meters [3]. A central premise underlying telehealth initiatives is that clinically significant changes in a patient's condition occur between regularly scheduled physician visits. These changes can be more closely scrutinized by remote monitoring of physiologic parameters and more frequent communications with health care providers who may suggest periodic adjustments to the therapeutic regimen.

Telehealth has grown considerably in the past decade, with numerous programs in virtually every medical specialty serving both urban and rural communities across the United States [4]. Several studies have demonstrated positive effects of telehealth interventions. For example, telemedicine has been shown to be feasible and acceptable in patients with diabetes [5–7]. However, the evidence is variable in terms of its impact on clinical outcomes such as HbA1c levels [8,9]. In a systematic review, Pare et al. concluded that the telemedicine approach to patient management was promising, but the effects were less conclusive with regards to diabetes as compared to pulmonary and cardiac conditions [10].

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Most home telemedicine studies focus largely on clinical outcomes and patient satisfaction. A few studies have also evaluated the usability of telemedicine systems and characterized both its acceptability and barriers to productive use [6,11,12]. Demiris and colleagues characterized the communication patterns in virtual telemediated visits and found the content to be comparable to that covered by visiting home care nurses [13]. The authors concluded that the approach constituted an effective complement to homecare in the treatment of chronically ill patients.

Despite the growth in telehealth research, very little has been published about the component activities, processes, and skills required of both clinicians and patients in a telemedicine context. Documenting workflow activities *in situ* is an important prerequisite to more effective design and better data presentation. The purpose of this paper is: (1) to develop a theoretical and methodological framework for studying workflow in telemediated clinician–patient encounters drawing on a distributed cognition approach and (2) to employ the framework in an in-depth analysis of workflow in the IDEATel project, a large-scale telemedicine program for older adults with diabetes.

1.2. Theoretical and methodological framework

A workflow describes a set of ordered tasks performed by various agents to accomplish a particular goal within an organization. Systems that are inconsistent with workflow can actually impede health IT systems adoption [14] and can even have a deleterious effect on workflow, resulting in clinical errors and adverse patient outcomes [15]. Research on workflow clearly demonstrates the ways in which technology transforms the process. Workflow in a telemedicine context is characterized by three aspects. First, it is inherently a technology-mediated intervention. Information and communication systems are not appended to an existing process as they are in other domains, but are integral to the process from inception. Second, the central event is the telemediated encounter with the patient. Third, home telemedicine is still a somewhat novel paradigm and there is less of a prescribed workflow, likely leading to variation in practices.

The research in this paper draws upon theory and methods from the distributed cognition approach. The distributed approach to cognition represents a shift in the study of cognition from being the sole property of the individual to being "stretched" across groups, artifacts and cultures [16]. Cognition is viewed as a process of coordinating distributed internal (i.e., knowledge) and external representations (e.g., visual displays, paper notes).

Distributed cognition is a framework that is gaining currency in cognitive studies in informatics. Horsky and colleagues used a distributed representation approach to characterize task complexity in an order entry system [17]. A recent paper by Hazlehurst et al. employed a distributed cognition framework to understand communication during cardiac surgery [18]. An important construct in the framework is the propagation of *representational states*, which is "a particular configuration of an information bearing structure, such as a monitor display, a verbal utterance, or a printed label that plays some functional role in a process within the system" (p. 540). These states are propagated by actors (e.g., clinicians, patients) across a range of media to coordinate actions and accomplish tasks. There is a need to scrutinize the way workers communicate, coordinate their behaviors (e.g., following patient status updates on whiteboards) with one another, and jointly perform problem-solving tasks [19]. Representations are embodied in cognitive artifacts such as visual displays and are intended to exemplify a relationship or concept. Effective representations summarize or abstract a wealth of discrete elements such as findings in patient data over time and effectively relieve the individual from the work of data synthesis [20].

Perry articulates a general research strategy whereby the unit of analysis for distributed cognition is the functional system which is constituted by a collection of individuals and artifacts and their relations to each other [19]. This necessitates (1) a description of the background to the activity, the goals of the system and the resources available; (2) the inputs and outputs (e.g., in updating a patient record); (3) the representations that are available; and (4) the transformational activities that take place in accomplishing the system goal (propagation of representational states). These analytic activities crystallize the goals of a distributed cognition analysis and inform the current research.

The study presented in this paper included the analysis of semi-structured interviews with key informants and observations of video visits involving nurse case managers and patients. One of the methodological objectives was to understand the propagation of representational states across agents and media. We introduce the concept of *state of the patient* as a kind of representational state that reflects the knowledge about the patient embodied in different individuals and inscribed in different media (e.g., electronic health records, blood pressure monitors) at a given point in time. The interviews provided us with a set of background descriptions regarding communication patterns, modalities of communication (e.g., face to face), preparatory activities prior to a visit and decision processes subsequent to the visit (whether to change patient's medications). These correspond to the first goal in Perry's [19] strategies for a distributed analysis of a functional system (description of background, goals and resources). Analysis of the video visits enable us to (1) characterize both the content and process of the visits, (2) explain variation in visits, (3) explore the role of different technologies and related artifacts as they are used to update the state of the patient (transformational activities) and document barriers that impacted the process. It affords us the possibility of gaining insight into a workflow process that has not been well documented and to explore the implications for design.

1.3. IDEATel telemedicine project: context for this study

The Informatics for Diabetes Education and Telemedicine (IDEATel) project was a demonstration project with the goal of evaluating the technical feasibility, acceptability, clinical efficacy and cost effectiveness of telemedicine for management of diabetes in older adults. The target population of this randomized controlled clinical trial was Medicare beneficiaries living in medically underserved areas including individuals in rural regions of Upstate New York and in New York City. A more complete description of the study can be found in several reports [21–23]. The primary goals in the IDEATel intervention were to provide (1) more intensive self-management and education of patients; (2) more frequent and easily accessed blood pressure and blood glucose measurements; and (3) more frequent intervention [24]. The intervention yielded significant improvements in HbA1c, blood pressure (both systolic and diastolic) and in lipids at the 1-year follow-up clinic visit relative to a control group [22].

Patients in the intervention group received a home telemedicine unit (HTU) (American Telecare Inc., Eden Prairie, MN), which is a specially modified computer that connects to the Internet over regular telephone lines [23]. Videoconferencing over telephone lines was the only alternative at the time (circa 2000) given the high cost and limited availability of higher speed alternatives. The HTU was designed to support a range of functions including self-monitoring and electronic upload of fingerstick glucose and blood pressure. It also supported synchronous videoconferencing for monthly video visits with nurse case managers.

Although the system was designed for older adults, a usability study and a training study documented that some participants experienced significant problems interacting with the system

[12,25]. In general, the patients tended to be of lower literacy levels and computer novices. The project therefore redesigned the system and switched from a conventional mouse-and-windows graphical interface (generation 1) to a touch-screen system (generation 2). The generation 2 system also offered other advantages such as automated uploads of blood pressure and glucose. Usability testing indicated that the new design was easier to learn and to use [25].

2. Research methods

The workflow study described in this paper was conducted at Columbia University. The IDEATel study was approved by IRBs at all participating institutions and informed consent was obtained from all participants. The research involved (a) videotaped ethnographic observations of patient encounters and (b) semi-structured interviews with participants.

2.1. Observations

The data were collected in three time periods over the course of 14 months beginning in November, 2005 and ending in January, 2007. We observed three different nurse case managers (NCMs) involved in the New York City IDEATel cohort over that period of time. Observations occurred in one of two specially equipped rooms at Columbia University/New York Presbyterian Hospital. One or two of the investigators (D.K., J.P. or M.R.) observed the activities of the NCM before, during, and after the patient encounter, and took notes. All activities were captured, including interaction with the computer, use of communication devices, and use of artifacts and resources such as paper charts and educational materials. The NCM's interaction with the patient, who was situated in his or her home, was also videotaped. Unfortunately, due to technical reasons having to do with the workstation set-up, it was not possible to capture the patient's voice without significantly altering the nurses' workflow.

An NCM would have as many as seven or eight video visits each day and the investigators would typically observe 3 consecutive visits. In total, we observed about 30 h of activities related to the NCM visits with patients. This translated into 36 visits, out of which 27 resulted in completed visits. The other nine could not be completed for various reasons including technical difficulties and the patient not feeling well enough to continue. Of these 27 visits included in the analysis, 16 were conducted in Spanish. Two of the observers (M.R. and J.P.) are fluent Spanish speakers. During the data collection period, the project was in the process of transitioning from the generation 1 technology to the generation 2 technology. The transition was fraught with technical difficulties that affected all facets of the operation including the NCM–patient video visits. Although the majority of video calls were completed successfully, about half of these calls were characterized by some level of technical difficulty and troubleshooting was incorporated into the nurse's routine. In addition, a technician was hired to support the NCM video visits in patient's homes. Rather than discount troubleshooting as superfluous to the goals of telemedicine, we embraced it and it became a core part of the analysis.

2.2. Video analysis

The goals of the video analysis were to characterize the process of workflow in the NCM visit and in the time preceding and following the visit. In particular, we were endeavoring to (1) provide a detailed descriptive analysis of the video visit workflow, (2) develop a categorical scheme for visits, (3) understand the mediating role of different technologies including the ways in which they facilitate or impede interaction, and (4) characterize the ways in which artifacts and representations are used to understand and update the *state of the patient*. Following Kaufman et al, the video recording was analyzed at several levels of granularity [12]. All videos were time stamped and segmented into episodes. An episode, such as a discussion of medication, reflects the natural boundaries of the visit which are signaled by a shift in topic.

2.3. Semi-structured interviews

We conducted a set of semi-structured interviews with the principal personnel including two of the nurses, an administrative project coordinator, a field support technician, and the supervising diabetologist/endocrinologist. Although the questions differed for each participant, they converged on common themes including communication patterns related to workflow, use of computer systems and other artifacts, established protocols, problems, troubleshooting, and priorities. The interviews were audiotaped and transcribed verbatim. Key informant interviews allowed us to investigate the workflow process that preceded and followed the video taping. It enabled us to assign context and meaning to events, not recoverable from the video record.

2.4. Data analysis

Following Malhotra, we reconstructed the temporal and spatial dimensions of the workflow process through iterative analysis of interview transcripts and observations [26]. To capture different facets of the video visit process, we present several distinct analyses. The *flow of communication analysis* is used to represent the coordination of information across agents over time and the modalities used to exchange information. The interviews and observations were used to construct the workflow process which includes the sequence of events that constitute the video visit. We also analyzed the actions and events that preceded and postdated the visit. The analysis was jointly performed by two of the investigators (D.K. and J.P.).

Documenting the *systems resources* (e.g., applications and artifacts) that are used in the context of the visits represents an extension to the workflow analysis. This analysis was based on both the interviews and the observations. A *time-on-task analysis* was performed based on an analysis of the videos. This analysis reflects the sequence of activities and percentage of time devoted to each task. The inputs to each activity include all software, artifacts and communications (e.g., patients and technician). The time on task measures the percent time devoted to discussing and documenting different facets of the patient's health. It is also used to record the percent of time used for troubleshooting the system.

Certain visits and episodes were selected for closer scrutiny. They are presented as case studies in the results section and are used to illustrate different kinds of visits. These were transcribed verbatim and translated into English, when necessary. Following a cognitive task-analytic approach, we performed a goal-action coding [12]. Two of the investigators have extensive experience using this coding method and parts of the analysis were performed jointly by both of them. The analysis assumes a cyclical pattern of interaction in which a user has a goal leading to action followed by a system response. The coding provides a basis for characterizing progress as well as for diagnosing user problems. It also enabled us to understand the ways in which different systems or applications mediate changes in performance. This analysis allows us to recover routine dimensions of performance and the ways in which nurses improvise to accommodate any unusual situational demands.

The basic coding scheme was as follows: **Goal:** The primary objective of a task, reserved for high-level objectives such as "diagnosing a patient," or "retrieving patient's medical chart." **Sub-goal:**

In any minimally complex task, goals need to be decomposed into sub-goals (e.g. "open browser," "go to website"). **Action:** Actions refer to any behavioral or cognitive steps, which are typically in the form of an inference. **System Response:** After each interaction with the system, the response generated by the system (e.g. providing an alert, transitioning to a new display, or updating information in a field).

3. Results

The first section of the results section explores the different dimensions of workflow that constitute the nurse case manager–patient video visit. The second section presents an in-depth descriptive analysis of three video visits that reflect distinctly different workflow processes.

3.1. Dimensions of workflow

This subsection is divided into characterization of the information systems and artifacts available to the participants. The second subsection provides an examination of communication in workflow as broken down by the three phases of the visit cycle. The third subsection consists of a content/topic analysis and a time-on-task analysis across all visits.

3.1.1. Analyzing the system resources

In this section, we describe the nature of the tasks performed during the video visit and the system resources used. The process was characterized by the use of a wide range of resources that serve different functions as shown in Table 1. There were two primary clinical software applications: (1) WebCIS, a general-purpose electronic medical record system [27] that also has a project-specific diabetes module and (2) a project-specific patient management database that enabled the nurses to record patient-specific information related to the program goals (e.g., monitoring behavior goals).

The NCMs also employed a troubleshooting system that enabled them to report technical problems. Paper patient charts were available for review. They contained information that was either not available or not easily accessible through the clinical applications. A yellow notepad was used to record information about each of the visits. The document camera was a valued education tool, though we only observed one of the nurses using it during the course of a video visit. Fig. 1 illustrates the NCM interacting with the patient. On the left display, she is viewing the patient as well as blood pressure and blood glucose values in the generation 2 video software system. The case management software is visible on her right monitor. A larger image of a similar screen is illustrated in the adjacent column of Fig. 1. The nurse is holding the patient chart in her hand and the yellow pad is also visible on the desk.

3.1.2. Flow of communication

In this section, we characterize the workflow process with particular emphasis on the modalities of communication. It is useful to partition the workflow process into three sections: *the pre-visit*, *the visit*, and *the post-visit*. The nurse had monthly video visits with a patient or more often if the patient's health required it. For example, those with higher HbA1c levels were likely to have more frequent video visits. Fig. 2 represents the communication process and each of the people who were involved in the video visit process. A central goal of this process is to update the *state of the patient*. For most encounters, the NCM could draw upon her own history of interacting with the patient. The patient care provider (PCP), the patient's primary physician, had access to privileged information that might not be accessible in the charts. Of course, the patient also had information about his or her own state of health.

The information was transmitted through eight communication modalities represented by icons in Fig. 2. Three of them are synchronous and the remaining five are asynchronous. The selection of modalities is contingent on the nature of the information to be conveyed, the relative distance between the participants and the periodicity in which they communicate. The medium of communication provides different resources for establishing common ground or mutual understanding [28,29].

3.1.2.1. Pre-visit. The visit was preceded by a set of preparatory activities and conversations. The administrative assistant (AA) contacted all patients the day before they were scheduled for a visit to confirm their availability. If they were inaccessible, she continued attempts via phone, mail, and other sources. This process continued until a visit was arranged or determined that the patient was unavailable due to hospitalization, relocation, drop-out, or death. A technician was needed on some of the visits, and this scheduling was coordinated by the AA through email and phone contact. The NCM received the schedule the day before and reviewed the patient's chart prior to the visit. She recorded patients' names and whether they used "Gen 1" or "Gen 2" units on her yellow pad. She also noted issues of interest from their charts such as lab work, blood pressure values and behavioral objectives from the last visit. This information was used to structure the video visit. Prior to the visit, the NCM coordinated with both the patient and the techni-

Table 1
System resources and artifacts used during video visit.

Name	Function
Computer-based	
WebCIS application	Hospital-wide electronic medical record system. Contains patient's history of diabetes, past results, labs, follow-up diabetes notes written by nurse after each visit
IDEATel NCM application	Database application developed for the project, used to collect information about frequency and quality of video visits, and patients' adherence to behavioral goals set by nurses
Video software generation 1	Vendor application that facilitated video communication between nurse computer and patient computer, and allowed the nurse to download patient BP and BG values
Video software generation 2	Same functions as Gen 1 though it afforded greater control over downloaded values
Email	One of communication methods for project staff
Troubleshooting ticket system	Nurses (or AA) opened troubleshooting tickets for patients who experienced technical computer problems
Paper-based	
Patient chart	Contains patient information, such as laboratory results, letters to PCPs, previous notes and recommendations
Notepad	Legal pad used to make notes about each patient's prior to and during the visit, especially to note BP and BG results
Scheduling binder	Used to enter information about next visit (date and time)
Other tools	
Telephone	Facilitated communication with patient and technician
Document camera	Projection of explanatory and educational materials for the patients during video visit

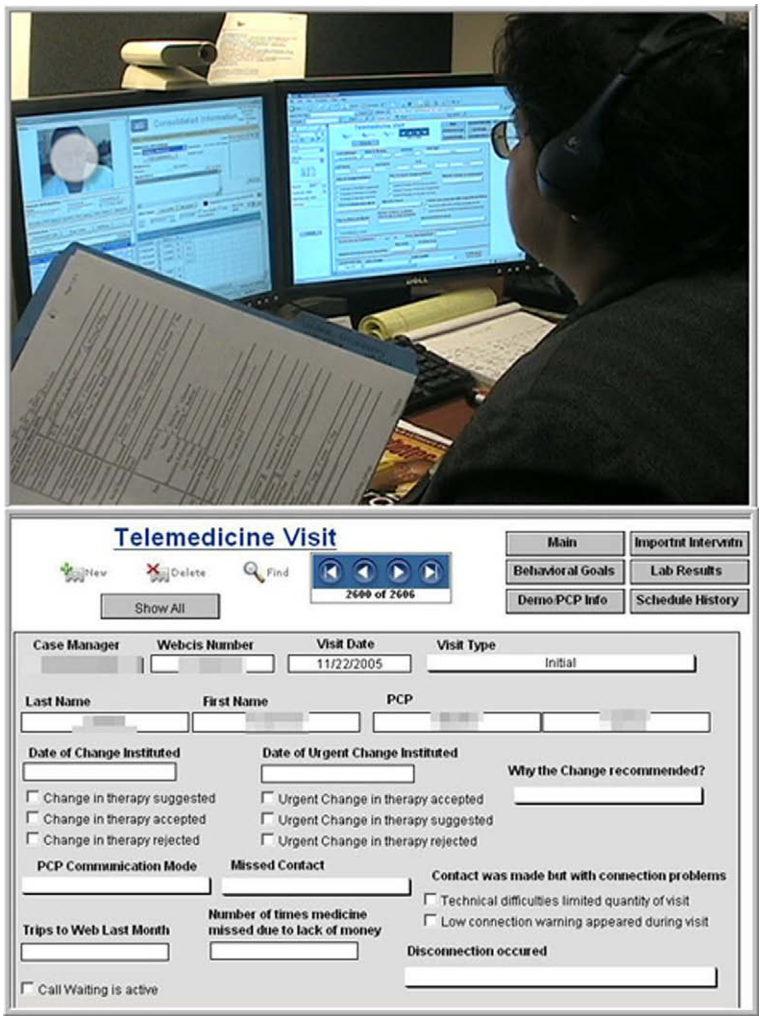


Fig. 1. Video visit has been initiated. Patient video is on the upper left-hand corner of the left-hand display. Case management software is open on the right-hand display and in the second frame.

cian by phone. She did basic troubleshooting with the patients if there was a problem with the unit and the patient was judged to be capable of undertaking this process.

3.1.2.2. Video visit. The center of our analysis is the NCM visit which is described in detail in subsequent sections. The core activities in the visit were carried out by the nurse. The majority of the IDEATel patients in New York City were Spanish-speaking. Two of the nurses were bilingual and the other one spoke only English. Technical problems were very common. Some of the problems could readily be resolved (e.g., restarting the patient's computer or trying to re-connect to get a better connection). At other times, the nurse would conduct the visit over the telephone or reschedule the video visit for another time. The two preconditions to a successful visit were (1) establishing a connection and (2) uploading (self-test) blood glucose and blood pressure results (if they had not been previously uploaded). In the generation 2 units, the blood pressure and blood glucose values were automatically uploaded nightly (assuming the units were in working order). The uploaded values were used to shape the direction of the call. For example, a pattern of high blood glucose values would lead the NCM to pursue questions to determine the potential cause (e.g., change in diet) and to target patient education. Once values were reviewed, the call was driven by several factors including whether goals had been met (e.g., for maintaining a certain blood pressure). We observed that a routine visit was often guided by the structure of the WebCIS interface and to some extent, the structured interface of the nurse case management software. The NCM's questions would closely follow the order of data fields in the clinical information system.

When he was present, the technician played an instrumental role in the success of video visit. He also mediated the communication, assisting the patient in addressing the information needed by the nurse. This was an unanticipated benefit that became an integral part of the visit with certain patients. The technician reported that he did as many as seven visits each day and was present at about 40% of all visits.

3.1.2.3. Post-visit. The post-visit was characterized by (a) a decision phase in which a determination was made whether to change the patient's regimen—a decision that was jointly made by the NCM and the endocrinologist and (b) a documentation and communication phase in which the state of the patient had been updated to reflect pertinent changes. Once a week, the NCM met face-to-face with the project endocrinologist/diabetologist to review the dossiers of all of the patients she interacted with in the prior week. This was preceded by a daily exchange of emails and included a review of handwritten and follow-up visit notes printed out from WebCIS (web-based clinical information system which serves as the hospital's electronic health record system). This note provided a succinct summary of the state of the patient and indicated whether there had been a positive change in health status (e.g., goals have been met), a negative change, or no change (Fig. 3). The fact that it was

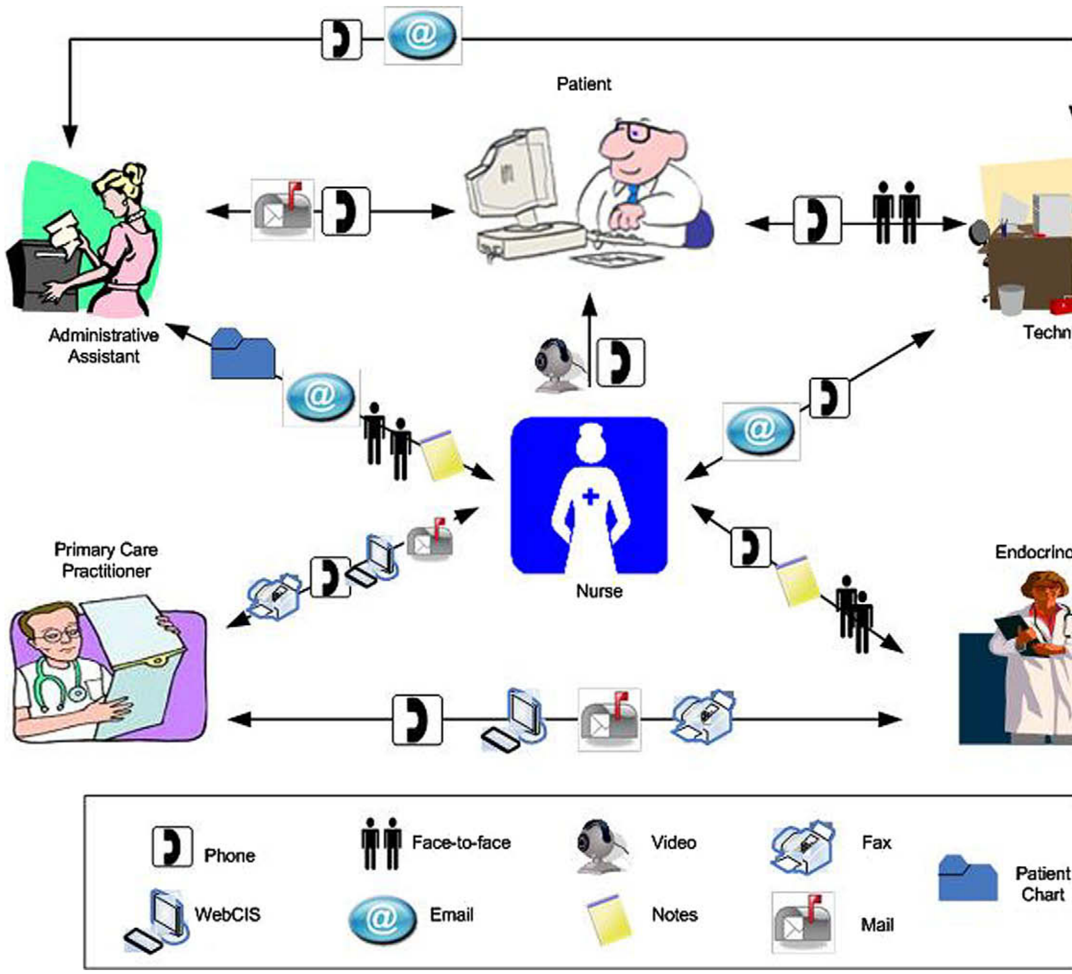
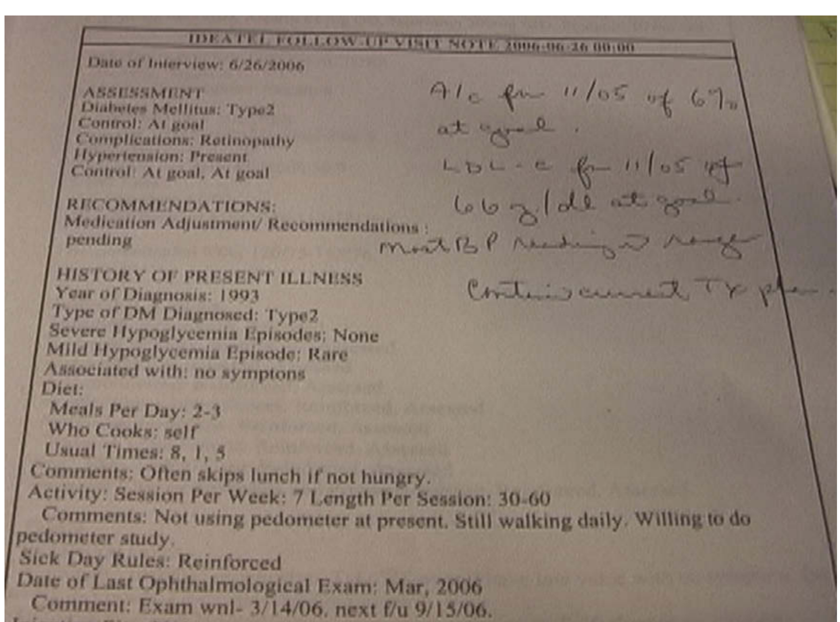


Fig. 2. Flow of communication between participants. Each of the modalities was used to convey different kinds of information. There are eight modalities, including three synchronous ones (i.e. face-to-face, telephone and video) and six asynchronous ones.



IDEATEL FOLLOW-UP VISIT NOTE 2006-06-26 00:00

Date of Interview: 6/26/2006

ASSESSMENT
Diabetes Mellitus: Type2
Control: At goal
Complications: Retinopathy
Hypertension: Present
Control: At goal, At goal

RECOMMENDATIONS:
Medication Adjustment/ Recommendations :
pending

HISTORY OF PRESENT ILLNESS
Year of Diagnosis: 1993
Type of DM Diagnosed: Type2
Severe Hypoglycemia Episodes: None
Mild Hypoglycemia Episode: Rare
Associated with: no symptons
Diet:
Meals Per Day: 2-3
Who Cooks: self
Usual Times: 8, 1, 5
Comments: Often skips lunch if not hungry.
Activity: Session Per Week: 7 Length Per Session: 30-60
Comments: Not using pedometer at present. Still walking daily. Willing to do pedometer study.
Sick Day Rules: Reinforced
Date of Last Ophthalmological Exam: Mar, 2006
Comment: Exam wnl- 3/14/06. next f/u 9/15/06.
Injection Site: N/A

Fig. 3. WebCIS follow-up note with NCM's handwritten recommendations that are reviewed by the endocrinologist during their face-to-face meeting.

handwritten indicated that information had a certain provisional status subject to discussion with the endocrinologist.

The decisions about whether to change regimens focused largely on "BP, lipids, and sugar" and it involved tracing changes over the patient's recent history. Many of the visits were routine and there was no need to suggest a change to the patient's therapeutic regimen. On the other hand, some patients were on as many as 20 medications and these needed to be closely scrutinized. The endocrinologist recounted that one patient was actually "taking 3 pills that are the same thing with different names, and they are tripling their blood pressure medication, with no better response". Once the recommendations were made and the record was finalized for the last visit, the NCM or the AA communicated with the PCP through one of the modalities discussed in the last section. According to the endocrinologist, the PCPs were very receptive to the suggested changes, although they may have been aware of mitigating factors unknown to the IDEATel clinical team. For example, a patient may have resisted changing medications in the past. Patients were often particularly reluctant to begin using insulin injections because the needle can represent a significant barrier.

3.1.3. Time on task

We observed 27 complete video visits across the three nurse case managers. The mean visit time (not including pre or post-visit) was 17:50 min (SD = 7:30 min; range: 9:20 to 41:50 min). The longest visit was an initial visit in which a very thorough and detailed medical history was gathered, and the nurse did as much documentation in real time as was possible. This visit was an outlier; more than 11 min longer than the second longest visit. The average differences between any of the nurses or between Spanish and English visits were negligible. Thirteen of the 27 visits were characterized by technical disruptions ranging from 15 s to 14 min. These visits averaged 20:26 min, almost 2 min longer than the overall mean. Some of the disruptions reflected difficulties connecting, slow connection speed, poor sound quality and patient errors. Eight visits exceeded 20 min, 8 ranged from 15 to 20 min, 7 from 10 to 15 min and 4 lasted less than 10 min.

During the visit, the tasks were structured according to the medical topics routinely covered in a clinical visit with a patient with diabetes. During the pre-visit, the NCM reviewed the patient's last visit, any available laboratory values including self-test blood glucose and blood pressure prior to the visit. WebCIS was the primary application used during the course of the video visit. The paper chart was consulted and the NCM used the yellow pad to keep track of blood glucose and blood pressure values. When possible, she would input additional noted information into the patient's record. The sequence of structured fields in the "follow-up visit" note in WebCIS often guided the order of tasks that were performed during the visit. The course of the conversation was partly determined by protocol, partly by notes from the last follow-up visit and data that were available from the medical record and other documents.

Any emergent issue such as that reported by the patient or any changes in the patient's blood glucose, blood pressure or laboratory values structured the course of the visit including its sequence, content and duration. Approximately 25% of the visit was devoted explicitly to discussion of blood glucose and blood pressure, and would also be routinely raised in the context of other tasks such as exercise and weight. Accessing and managing these values required coordination between the video software application used to upload the values, WebCIS and the patient chart and values that were noted by the NCM from a prior visit. During two visits considerable time was devoted to troubleshooting the technology; this was the only scenario in which these values were not a focal point of the discussion.

Discussions of medications were central to almost all visits except when there was no need to consider changes in the regimen. In addition, there were circumstances in which the NCM recognized that the patient alone could not read the medication label and did not pursue the matter. On subsequent occasions, a technician was sent. Exercise, weight, and diet were subjects of review as well as educational initiatives. In WebCIS, medications were a free-text field, and the NCM had to erase old values and enter new ones. Consequently, patients' medications were tracked using free-text fields rather than structured medication entry fields. Depending on the tempo and intensity of the conversation (e.g., a serious matter arises), NCMs made the changes either in real time or after the completion of the visit.

Patients were given pedometers and were provided with an online web-based portal to record their values. However, they often read them to the NCM who would record them. This would serve as a focal point for discussing exercise. The patient's weight became more central in visits in which it was an issue or when it was discussed in the context of another condition such as shortness of breath. These discussions constituted almost 40% of visit time.

Table 2 presents a time-on-task analysis based on a micro-coded analysis of the transcripts. Towards this end, we used the video of the subject. This is a fine-grained analysis in which we coded every single action. An action is any computer-based activity such a mouse click or switching of screens or any entry into the system. Use of any artifact also constitutes an action. The first visit as presented in Table 2 is a routine one. The analysis begins with the pre-visit preparatory activities which engage the use of three applications and the paper chart. The activities including reviewing the patient's recent medical history and readying the system to connect to the patient. These activities lasted less than 6 min and totaled 66 actions. The visit time totaled 18:15 min, out of which most of the time was devoted to blood pressure/blood glucose and medications. The patient suffered from multiple health problems including elevated blood pressure, glaucoma, and depression. In addition, the patient had switched primary practitioners. This resulted in changes to his medications and caused some confusion during the session. The patient used the pedometer to measure his walking and reported the total number of steps. The NCM subsequently calculated the daily average and recorded the value in WebCIS.

The NCM would multi-task and record other entries when the tempo permitted. The NCM also engaged in preparatory activities to collect information in anticipation of the next topic transition. The post-visit involved completing the visit documentation. The forms were designed in such a way as to facilitate rapid data entry. For example, the learning objectives are in the form of checklists (WebCIS) and the behavioral goals (NCM application) involve selecting from short pulldown menus.

3.2. Video visit case studies

On the basis of the workflow, we can characterize three kinds of video visits: (1) an *initial visit* involving a new patient (long interviews that involved a very thorough review); (2) *routine visit*, as described above (Table 2), which involved an interaction with a patient who is relatively stable. The structure of this visit often adheres closely to the American Diabetes Guidelines and corresponds to the sequence of fields on the display; (3) a *complex visit*, characterized by an emergent or ongoing medical or behavioral problem (e.g., patient fails to meet predetermined behavioral goals). Analysis of an initial and a complex visit are presented below.

As discussed, the initial visit necessitated a rather comprehensive review and lasted a little over 41 min. It serves to orient the patient to the nature of the interaction, gather data to construct the state of the patient, and educate the patient on basic issues in diabetes management.

Table 2
Micro-coded analysis of time on task for a routine visit.

Episode	Time	Sources of input	Number of actions	Comments
Pre-visit	5:51	• NCM • WebCIS • Video • Paper Chart	66	Reviews laboratory values Reviews notes from last visit
Visit time	18:26			
Opening	00:42	• Patient	0	Discussed emergency visit to hospital for chest pain (no admission, but changes in medication). No actions noted during this discussion
Download and discuss BP & BG	04:28	• Patient • Video	2	Noted that BP was a bit high
Medication	06:46	• Patient • Technician • WebCIS	30	Noted that patient had a new doctor. Several (possible) changes to medications related to BP, BG, depression and glaucoma were noted and documented. Patient has difficulty communicating changes and technician provides assistance reading labels on vials
Lab values	00:37	• Paper chart • Notepad • Patient • WebCIS	19	Patient is talking and nurse takes the opportunity to update the patient record with most recent lab values
Exercise	03:48	• Patient • Notepad • Calculator • WebCIS	22	Obtains values from patient regarding pedometer use. Calculates daily average and inputs them into WebCIS
Lancet disposal	00:21	• Patient	0	Reviews procedure for lancet disposal. Patient indicates compliance
Scheduling appointments	01:44	• Patient • WebCIS	2	Suggests that next visit will be in January, but will be scheduled by assistant
Post-visit	09:28	• WebCIS • NCM • Notepad	229	Complete assessment in WebCIS including learning objectives and activity report (time spent on each facet of care such as BP control). Completes behavioral goals in NCM software

3.2.1. Case 1: Initial visit

GOAL: Initiate Video Visit
2:28 Action: Clicks on ''Make a Call"
ACTION: Shifts screen to second display
3:01 SR: Hour glass appears and faint connection sounds
3:24 – Ok...I hear you now – Oh, ok –
3:29 – I am going to turn on the computer now
3:30 ACTION: NCM1 jots down something (not visible on camera)
3:31 ACTION: Clicks on button & starts video visit (NCM1 jots down something)
3:41 SR: Patient's face is seen on screen
3:42 – Good afternoon Mrs. A – welcome to the IDEATel program! – [laughs}...At last we see each other...
4:21 – Ok, this visit is going to be a little bit longer...
4:41 – How long ago did they tell you that you had diabetes?
This same year? – Ok
4:43 GOAL: Activate Case Management System Telemedicine Visit
ACTION: Activates/maximizes display
SR: Telemedicine Visit appears
4:46 GOAL: Activate WebCIS
ACTION: Activates/maximizes WebCIS Data Entry Forms display
SR: WebCIS Data Entry Forms appears
ACTION: Clicks on IDEATel Initial Visit History of Present Illness in WebCIS.

Comment: The focus shifts to the History of Patient Illness Form in WebCIS

4:59 – When did they tell you (referring to diagnosis of diabetes)? Did you have an analysis done or did you have any symptoms? ...Oh, so when you had your annual check-up they found your sugar high? Oh, ok...
5:17 – Who is your doctor? ...yes, of course...
Patient is seen getting up from her chair (looking for something)
5:45 ACTION: NCM1 jots down information on her pad, then types in information, and seems to wait for patient to get something...
5:47 ACTION: Enter HPI Physician and Year of Diagnosis
6:02 – Oh – Ok – Dr. X. And do you have an appointment with him or have you already seen him? Next month?
6:19 ACTION: NCM records physician name on paper form
6:20 – Ok, if you have it, let me take it down for (research assistant)
6:42 Ok – let's continue. Is there someone in your family who also had diabetes? Who?

NCM1 interspersed her questions with educational information for the patient. She used both WebCIS and her yellow pad to record information obtained from the patient.

15:32 – Because sometimes those long spans of time without eating until the next day could bring your sugar down – Oh, it goes down less than 70? When that happens to you, you already know what symptom you get when your sugar goes down? So, you check your sugar and if it is less than 70 you take half a glass of juice or of milk or in case you have little candy .... and you can eat up to three, or even a spoonful of honey, and then 15 min later you check your sugar again to see if your sugar went up more than 70, and if it is still low – take a little more of juice or milk ...and then eat normally – Ok.

She then continued on with questions about walking, eating schedule, patient's mother dying of diabetes, feet, etc. while filling in the WebCIS form. A variety of topics were discussed, interspersed with some explanations, for example, explanation of blood pressure results:

Ok – the lower number (the little number from below) is a little bit high – supposedly you should have it less than 80 and the higher number is OK. Your goal for the BP should be 130/80 – or less than that, Ok – and if you can take your BP if not every day or at least you should take your BP at least every 2 days – this way the nurse will have the information here because we give your doctor a summary to help him manage your diabetes – you know this is a combination of what you eat, the exercise and activities you do, and the medicine he prescribes you – and if we give the doctor your numbers (the little numbers) he could know better how (more or less know) to manage it with the medicine in accordance with what you eat and what you do – Ok.

This visit highlights the breadth of issues involved in conducting a video visit. The initial visit was used to gather detailed background information on the patient. The visit served multiple purposes including the development of behavioral goals and learning objectives as well as the population of fields so that nurses could refer to it in the future. Up until the completion of the visit, there were many unknowns about the state of the patient. The visit represented a departure point for future goal setting and information-gathering strategies. The NCM could also gauge the communication and computer competencies of the patient and record this information for use in subsequent video visits. For example, they could triage the level of technical assistance required.

3.2.2. Case 3: The document camera as an educational tool

The primary thrust of the third visit was in response to an emergent problem, namely that the patient's HbA1c went up from 6.5 to 7.3% over the course of her participation in the program. This happened despite the fact that the patient routinely monitored her blood glucose. This problem became the focus of the video visit and the nurse case manager (NCM2) explored this problem with the patient and took the opportunity to educate the patient about the relationship between HbA1c and self-test blood glucose measures. The nurse used the document camera twice; once to illustrate the point about HbA1c values and the other time to talk about the diet.

12:12 When you began, you had 6.5 which means it has been going up little by little, but it's been going up. Then you had 7.2; now you have 7.3 that is sending you a message, right, that to be careful with what you are eating – and now that you are not exercising....

12:20 So, another little thing I noted here while looking at your labs, right, is that you drew blood/had blood drawn in the month of October, and it was that your general sugar average – or say your A1c went up a bit.

12:38 Do you remember how much your A1c should be?

12:59 Let me see if you can see them because they are a little small but I am going to try to show them to you ...wait a second...tell me if you see them.

13:00 ACTION: places pamphlet on document camera.

The nurse placed a pamphlet on the document camera and adjusted the camera so that the patient could see the numbers on the camera (see Fig. 4). The pamphlet illustrated the correspondence between self-test blood glucose values and HbA1c.

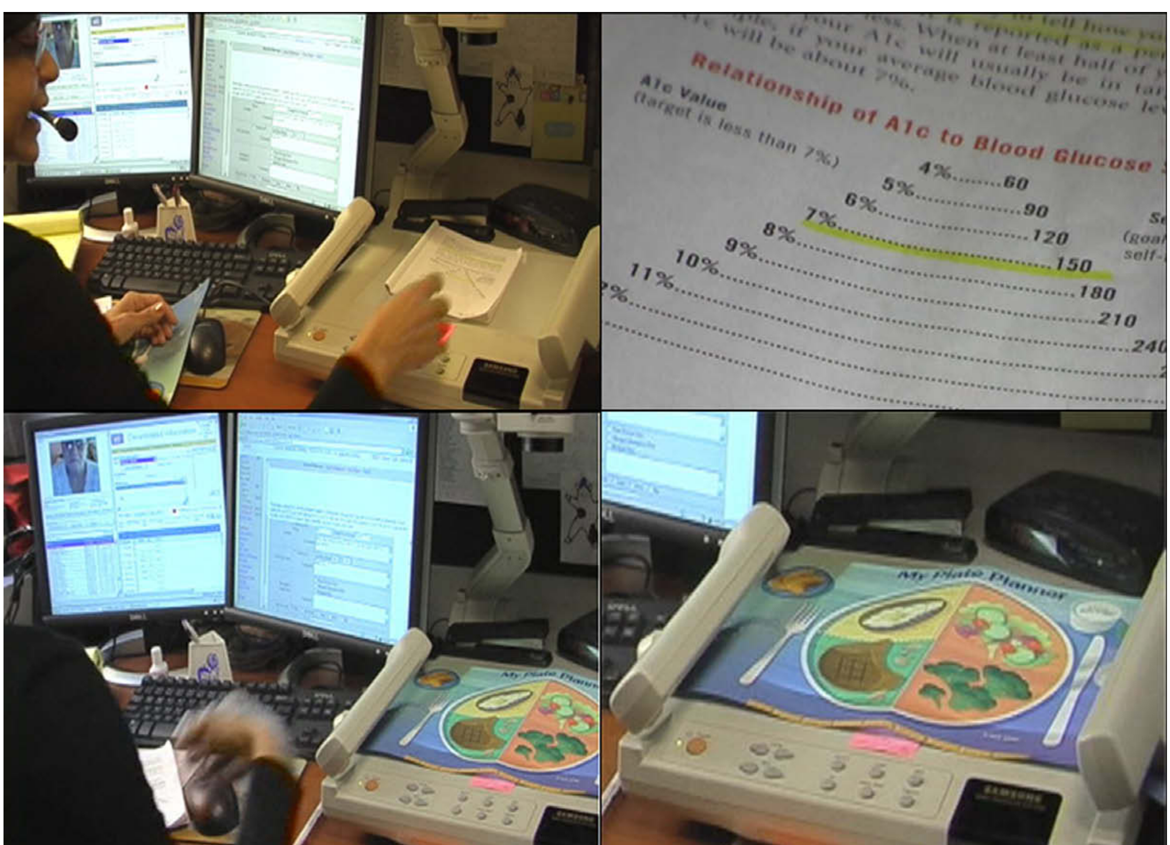


Fig. 4. NCM using the document camera to educate the patient about A1c and meal planning.

13:07 ACTION: NCM2 turns on camera
13:12 I'm going to show them to you through the lens...
13:27 Are you seeing anything in your lens? In your screen?
13:39 ACTION: NCM2 adjusts camera lens for better focus
13:52 So – here it says 7%, right; 7% is the little #
13:53 ACTION: NCM2 adjusts the camera
13:57 ACTION: NCM2 uses pen and points to relationship between A1c and blood glucose self test (7% TO 150)
14:05 ACTION: NCM2 uses pen and traces relationship When you have a #7 of A1c it means that the general average of your blood in three months is at more or less 150 – less than 7% would be better.
14:17 ACTION: NCM2 uses pen and points For example, at 6% in your blood, it means that your general average in your blood would be at 120 – and that should be the percent that you should have – from 7 and below – from 7% and below. You see – ok.

The nurse continued to use the document camera to demonstrate some points about a diet as illustrated in Fig. 4.

15:03 ACTION: places the ''My Plate Planner" educational aid on camera tray
15:05 Are you eating a balanced diet – say –including vegetables, meats, ...
15:17 Ok – here I have another picture here – that I wanted to show you – I don't know if you can see it now – it's a picture of a plate.
15:27 Ok – you see that it has a plate, right, and that plate is divided in four parts – or in three parts.
15:29 ACTION: takes pen and makes circular motion around the perimeter
15:37 In the largest part which is 1/2 of the plate you have vegetables
ACTION: points to the broccoli.
15:41 You have broccoli for example, you have cucumbers, you have lettuce, 2–3 (little) tomatoes, and that is the most you should eat – green vegetables, that are very low in carbohydrates, right.
15:54 ACTION: POINTS TO THE POTATO (CIRCULAR MOTION) So, here you have a baked potato with a little butter or margarine – the margarine has less cholesterol.
16:02 Here you also have other foods that have carbohydrates, as are rice, pasta...this is the quantity you should eat of these foods with carbohydrates, say a fourth part of the plate.
16:09 ACTION: points to potato.

The NCM continued to explain the different groups and proper portions to maintain dietary health. The entire episode lasted about 6 min. The document camera and the visual aids provided points of reference for grounding the conversation and added a new dimension pertaining to patient education.

4. Discussion

4.1. Methodological framework for studying telehealth video visits

The development of robust, sustainable and effective home telemedicine programs remains a significant challenge. This paper provides a detailed glimpse into the workflow surrounding and during the video visit, the principal instrument for clinician–patient interaction in home telemedicine. We articulated a methodological framework and research strategy for studying and evaluating telehealth systems as a distributed functional system [19]. We adhered to a data collection and analysis strategy predicated on reconstructing the workflow process based on an iterative analysis of interviews and observations. In doing so, we documented routine aspects of the workflow process as well as those that were anomalous or problematic. The framework includes strategies for identifying analytic foci for understanding the video visit process. Each of the foci reveal a different dimension of workflow and identify factors that shape the ways in which the systems and resources support work demands in a particular setting [19].

The research employed semi-structured interviews to characterize all facets of the process that are not visible to the observer, in particular, the activities that preceded and post-dated the nurse case manager-patient video visits (which we did not observe). We also conducted video-analytic observations for 27 nurse case manager–patient video visits. Although observations are viewed as a "gold standard" in workflow research, structured interviews were very important in revealing much of the background context as well as recounting the events that happened off camera. The study characterized the flow of communication between the five principal participants and the eight synchronous and asynchronous communication modalities. The interviews and video-based observations were used to chart the sequence of activities and branching decision points.

The video observations were used to analyze the system resources and artifacts and their functions over the course of the visit. There were six computer applications that were employed by the nurses, various paper-based artifacts as well as other communication tools such as the document camera. Each of these resources was used in different ways to retrieve patient information, coordinate communications with patients, update the patient records, plan modifications to the regimen and communicate with other agents in the process.

We used analysis at varying levels of granularity. At the macro-level of analysis, we quantified the time on task across all of the video visits and characterized the ways in which different resources were used for different phases of the encounter. Micro-analyses provided moment-by-moment analysis of all activities over the course of a video visit. We can characterize the distributed cognition process as the propagation of a series of representational states [16] that we referred to as state of the patient. These states reflect what we know about the patient's condition at a given point in time. Each state receives input from the products of the prior state (e.g., past glucose history of patient) and provides outputs to the successor state. Each representational state reflects the cumulative input and collective knowledge of the system including the internal representations of the nurse and patient and the external knowledge embodied in the different systems and artifacts. The transformational activities realized in changing states serve to accomplish the goals of the distributed functional system [19].

All facets of the workflow were mediated by information technologies and other artifacts. On the basis of our observations, the process appeared to be relatively reliable, although relatively work intensive. During the video visits, the nurses needed to coordinate different applications, data sources and other artifacts, often at the same time they were interacting with the patient. To complicate matters, the connection was not always stable and there were problems with audio dropouts. Fewer applications and better system integration would reduce redundant entries, inefficient transitions between applications and lower workload. In addition, if there were more uniformity in the kinds of data representation and modes of interaction, then the process could be streamlined. Reducing the inefficiencies, redundancies and barriers to communication could have the effect of allowing the nurses to spend more time on patient care and increase the frequency of contact.

4.2. Implications for design and implementation

The implications of this work for design can be characterized in terms of improving the coordination of communication and developing tools that better integrate and present or display information in a way that reduces cognitive load. Although home telemedicine programs will differ in important respects including the target population, there are invariant properties across such systems. Explicating these properties can in effect serve as a needs requirement analysis to develop more effective systems and to elaborate better implementation plans. The defining element of a home telemedicine intervention is remote communication (either by video conference or telephone) with the goals of accessing patient information to monitor the state of their health and to equip and educate them so that they can better manage their own condition. The core personnel of a telehealth team typically include, at minimum, a nurse case manager, a person responsible for coordinating and scheduling patients, and a physician responsible for therapeutic decisions, usually a domain expert such as a cardiologist or endocrinologist who addresses more complex clinical issues.

The process can be described as a cycle of reoccurring events. Video visits occur with a certain periodicity (in our case, monthly). There are a set of activities that precede the visit, including coordination, information assembly and preparation. The telehealth visit has a typical content (e.g., review of BP values) and a somewhat stable sequence of information exchange. The post-visit involves a documentation process and an information exchange leading to a decision to continue present management or to change therapeutic regimens. Therapeutic changes infuse the planning process which restarts a couple of days prior to the visit. The pre-visit, visit, and post-visit phases of the process require different resources. This cycle incorporates multiple communication modalities. Each modality affords a different cost/richness tradeoff, with face-to-face being the richest and most costly [28]. Routine communications can employ less costly channels and others necessitate devices that can increase common ground.

The study also documented different kinds of video visits that involve qualitatively different interactions and can be differentially supported by representations and tools. Newer clinical information systems will need to afford greater degrees of customization and support a wide range of display configurations. Seemingly minor factors, like the order of data fields in a form, guide the workflow and need to be customized for different visit types. A wide range of artifacts were used by the NCM in the study. Undoubtedly, some of them will have enduring value and others will likely be replaced by better and more integrated data representation tools.

System integration remains a significant challenge for the current generation of home telemedicine initiatives. The IDEATel project, as do many such interventions, leveraged the use of the legacy clinical information system. In spite of considerable resources devoted to system integration, redundant data entry could not be completely eliminated. The project typifies the conflicts between the capabilities of general-purpose EHRs and of disease-specific chronic disease management systems. Disease-specific systems often lack the broad overview needed for management of the comorbidities. In contrast, general-purpose EHRs need to serve many user groups and frequently cannot accommodate the disease-specific workflows that are needed for optimal management of the target disease. Future EHRs will need to concurrently support general data views and workflows as well as highly disease specific ones.

5. Conclusions

Home telemedicine is a promising approach to healthcare delivery for patients who suffer from a chronic illness. However, these interventions have thus far yielded mixed results. A telemedicine intervention has many "moving parts" that introduce layers of complexity and the potential for workflow disruption. The research was conducted in a messy, real-world environment, fraught with technical and other challenges. Although confronted with immense challenges, the nurses demonstrated remarkable adaptability and resilience.

The study suffers from a number of limitations that impact the generalizability of claims. This is a unique patient population and the technologies employed are somewhat idiosyncratic. We observed only 27 visits, a fraction of the more than 37,500 visits that took place in this intervention. However, it is reasonable to speculate that many of the dimensions, challenges and barriers will be evident in other telehealth interventions. The distributed cognition approach which informs our work is predicated on in-depth studies of a particular setting and the abstraction of patterns of technology-mediated work across settings. The integrative framework employed in this paper may suitably be deployed in other settings.

The lessons learned from this project can be used in future telemedicine projects to more efficiently coordinate communication, improve the accessibility of information, reduce redundancy of data entry, and develop shared representations that can be used to update the state of the patient in a timely fashion. In-depth analysis of the workflow processes can provide insights into the conditions that promote successful health outcomes in a telehealth intervention as well as conditions that are likely to yield suboptimal results.

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