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Tertiary-Level Telehealth: A Media Space Application

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Abstract. A media space provides the communications channels to support the interactions between people at different locations using video and audio links and shared access to data. This paper looks at a telehealth implementation of outpatient consultations for tertiary-level paediatric surgical patients, consultations which exercise a high degree of interpersonal and data-sharing communication between the participants. Framing the telehealth situation as a media space invites the designer of the telehealth system to access a large body of prior work which identifies and discusses many of the issues that will arise in this complex multi-participant telehealth context. This paper presents, as a case study, a two-year project that developed and deployed a whole-of-room telehealth system in partnership with surgeons from The Royal Children's Hospital (RCH), Melbourne, Australia. Based on observations at the hospital and discussions with the surgeons, a descriptive model of the proposed telehealth consultation (and of its deployment in a clinical trial) was developed. This descriptive model became the vehicle for gathering requirements and for design and evaluation of the telehealth system. The evaluation contained four major components: two human factors studies, an observational study of training and process change for the clinicians and a clinical trial of the resulting system. The case study demonstrates the flow of design decisions from concept to deployment. It highlights the gaps that appeared in the descriptive model when the transition was made from the laboratory to deployment in the hospital. The conclusion is that, at this relatively unexplored level of telehealth, there are likely to be gaps in such a descriptive model that are not uncovered by laboratory experiments or by analytic evaluation but emerge only during a clinical trial with actual patients, clinicians and patient data.

Key words: tertiary telehealth, outpatient consultation, media space application, descriptive model, case study

1. Introduction

Telehealth at a tertiary level has much in common with media space applications. People are placed in separate locations connected by video, audio and shared data and they then proceed with the work at hand. Tertiary healthcare is delivered by specialists, or teams of specialists, based in major hospitals, in contrast to primary healthcare delivered by general practitioners within the community and secondary healthcare delivered from regional hospitals. At a tertiary level, a large proportion

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of healthcare is delivered as outpatient consultations, where patients come to the hospital for scheduled appointments with specialists and their support staff. The project at the focus of this paper explored the idea of delivering these outpatient consultations in a telehealth mode. The specialist would be located in a consulting room within the major hospital and the patient, together with an appropriately trained clinician, would be located in a consulting room in a regional healthcare facility. The two rooms, with video and audio links and with shared access to patient-related data, would form the media space. The consultation would involve dialogue and interaction across the media space link as the various participants reviewed the case, examined the patient, discussed the patient's medical records and reached a plan for moving the patient's condition forward.

This paper looks at requirements, design and evaluation of a tertiary telehealth system to support a particular area of use: remote outpatient consultations for paediatric surgical patients. Many issues are highlighted that have been raised in the media space literature and in the broader Computer Supported Cooperative Work (CSCW) literature, and this is done in the context of a real-world healthcare situation. The paper's contribution to the CSCW literature is that it presents, in the form of a case study, the chain of requirements, design and evaluation of a real-world telehealth system from early concept to laboratory trials and a clinical trial. The case study maintains a focus on the eventual users of the system: the surgeons, supporting clinicians, paediatric patients and the patients' families and carers. It does this in the context of tertiary telehealth, an area not commonly addressed in telehealth but one in which multiple participants, strong interpersonal relationships, rich shared data and complex dialogue are often present.

The overarching concept in this paper is that a descriptive model is constructed of the way that the clinical situation would take place in a telehealth mode. This descriptive model is the repository for the requirements, is focused on the intended users of the system and drives the design and evaluation of the resulting telehealth system. The descriptive model is based on observations of the conventional face-to-face clinical situation and on the expectations of the multiple participants, the roles they would play and the resources they would need to meet the clinical situation in a telehealth mode. At the level of complexity of tertiary telehealth, the descriptive model is likely to be incomplete, especially when put to actual clinical use. A major purpose of the evaluation is to discover gaps in the descriptive model and to use these discoveries to critique and modify the descriptive model, the telehealth implementation and future approaches to its evaluation.

1.1. Background

Surgeons from The Royal Children's Hospital (RCH) in Melbourne, Australia, approached the author and his research team at the CSIRO ICT Centre in

Canberra in 2005. The specialist types of paediatric surgery that these surgeons perform often require rehabilitation periods lasting years and with regular outpatient follow-up. Their hospital's catchment covers a large part of south-eastern Australia, so the need for regular travel to Melbourne places a large burden on many families, in terms of time, cost and emotional stress. The surgeons wanted to investigate the possibility of conducting some of these consultations in a telehealth mode, perhaps linking RCH and a regional hospital near to the patient's home. The concept fitted well with team's overall research direction, which was to investigate and develop concept demonstrators for telehealth applications over broadband Internet under funding from the then Australian Department of Communication, IT and the Arts (DoCITA).

The initial project plan was to construct a telehealth system to meet the needs of a specific surgical specialty and to deploy it in a clinical trial between RCH and another hospital. To access more patients for the trial, the plan was modified to locate the trial entirely within RCH and to extend its scope to include three other surgical specialties. The initial intention was to use maxillo-facial surgery as the field for the case study, concentrating on birth defects of the bones and soft tissues of the head (cleft palate, for example) and the initial system design focused on this specialty. Later in the project, the hospital's Director of Surgery decided to include a group of orthopaedic sub-specialties (general orthopaedics, limb reconstruction and hand plastics) to increase the number of patients available for the clinical trial and to broaden the range of patients using the system during the trial.

1.2. Progressive evaluation

Progressive evaluation of the telehealth system was conducted during this project. Two qualitative human factors studies were conducted in the CSIRO ICT Centre laboratories in Canberra and Sydney to explore the usability of the media space implementation. Expert reviews of the system were conducted by a surgical fellow from RCH and by an expert in using telehealth for intensive care. In the week prior to the clinical trial, a series of training sessions at RCH introduced the system to the clinicians and allowed them to give a final critique of its functionality. Finally, a four-week clinical trial was held within RCH.

2. Prior work

2.1. Media space

Mackay cites the first use of the term "media space" by R Stultz and his colleagues at Xerox PARC in 1986 (MacKay 1999) (p57). The original intention of a media space was to support "informal types of communications that occur in hallways and common areas, re-establishing the possibility of informal communication for people located apart from each other" so an important design feature was that “the [video and audio] connections were always there” (ibid. p57). This interest in linking separately located groups of people via video and audio arose from “a concern for both the social and technical practices of collaborative work” (Bly et al. 1993) (p 30). Early media space examples linked people who already knew each other. Their behaviour in media spaces and ways of using them developed over time.

Early media spaces used expensive analogue equipment and were limited to large research and development organisations. They included a 30-node network called “CRUISER” (Fish et al. 1993), the “RAVE” video environment at EuroPARC (Gaver et al. 1992), the “Portholes” system at PARC and EuroPARC (Dourish and Bly 1992) and a system which connected colleagues in two American cities (Bly et al. 1993). Long-term studies looked at office-to-office connections (Adler and Henderson 1994; Dourish et al. 1996). Ackerman and co-authors’ report of an audio-only media space describes a two-month study of its social use (Ackerman et al. 1997).

Researchers used short-term studies to explore the use of video and audio technology in media space settings (Gaver 1992). Gaver and colleagues explored the need for multiple video channels to adequately represent the use of the physical space, the objects in the space and the activities of the participants, developing what they called a Multiple Target Video system in which users could switch their display to select from a number of cameras located in the remote site (Gaver et al. 1993). The tasks used in that paper were extended and augmented in subsequent papers to form a series of Multiple Target Video experiments (Heath et al. 1995; Heath and Luff 1997; Heath et al. 2001; Luff et al. 2003). In this last paper the authors generalised their findings to focus on what they termed “fractured ecologies”, by which they meant the discontinuities of perception that users of a media space experience as they try to interpret positions, actions and objects in the remote regions of that space. They identified the following aspects which need to be supported so that participants can perceive and understand objects and actions in the media space (ibid., p 78–79):

- Determining the location, orientation and frame of reference of other participants in the space
- Determining their standpoint with regard to the other participants
- Discriminating the actions of others when these actions involve shifts in orientation and reference to the space
- Referring to objects and features of the space in a way that coordinates with the real-time actions of others
- Providing a stable constellation of relevant objects, artefacts and scenes within the space

Robertson discussed the issue of shared objects in collaborative processes such as might take place in a media space. She explained that, for an object to be useful in a collaborative process, it needs to be publicly available to the participants (Robertson 2002). In a case study of medical video-conferencing between a major and a regional hospital, a major impediment to success was the lack of public availability of discussions, objects and patient data at the regional hospital (Kane and Luz 2006).

Remote guidance can be an important aspect of collaboration in a media space. Kuzuoka and colleagues used remote control of cameras and laser pointers in a series of remote guidance systems: GestureCam (Kuzuoka et al. 1994), GestureLaser and GestureLaser Car (Yamazaki et al. 1999) and GestureMan (Kuzuoka et al. 2000; Heath et al. 2001). These papers highlight the issues identified by Luff and co-authors (Luff et al. 2003).

Other researchers have used graphics drawing over displayed video of the task space as their method of providing remote guidance (Kraut et al. 2003; Ou et al. 2003; Fussell et al. 2004). They used a range of task performance measures in their evaluations and also extended their evaluations by looking for evidence of common ground in the dialogue between the participants. Kirk and colleagues projected unmediated video views of gestures into the remote workspace to create a mixed reality guidance environment (Kirk et al. 2005a, b; Kirk and Fraser 2006).

Harrison and Dourish distinguish between the "space" (and the spatial metaphors such as desks, offices and hallways that are created by the location of audiovisual equipment) and the "place" created by the cultural understandings about behaviour and action that are associated with the participants' use of that space (Harrison and Dourish 1996; Dourish 2006). This relates to issues of privacy in a media space; for example, whether the same room used as a meeting room or a doctor's consulting room (differing "places") requires different support for privacy features. These include awareness of being on- or off-camera and awareness of people at the remote site who are off-camera (Bellotti and Sellen 1993); regulating social interactions, managing others' access to information about oneself and comporting oneself to match the norms for the particular social situation (Boyle and Greenberg 2005); managing degrees of disclosure (Palen and Dourish 2003); and attending to the social and cultural practices relating to privacy and security for the particular situation (Dourish and Anderson 2006).

2.2. Telehealth applications

The field of telehealth has a long history, including simple voice communication, broadcast and television technologies and digital communication over telephony or packet-switched networks (Bashshur 2002). Videoconferencing technology has been used extensively to support telehealth applications, adapting the model of a business conference to the situation of a doctor and patient and sometimes including presentation of a computer screen as an adjunct to the telehealth event.

Broadband internet connections enable more complex telehealth activities, supporting multiple high-quality video and audio streams and real-time sharing of large data sets. A number of experimental telehealth systems using broadband internet have been demonstrated and trialled, often focusing on more advanced healthcare scenarios where high levels of personal communication are required and the shared data sets are large. Three examples that were used as reference points for the project described in this paper are given below.

- A surgical teaching demonstration conducted by the California Orthopedics Research Network (CORN) linked multiple audiences across California with a lecture room and an operating room (Dev et al. 2004). Lecture material and related live surgery were presented and the members of the audiences discussed the material amongst themselves and with the lecturer and surgeon.
- Delivery of critical care management from a major hospital to the emergency room of a regional hospital ("Virtual Critical Care Unit", ViCCU) (Li et al. 2006; Westbrook et al. 2008; Wilson 2008; Wilson et al. 2010). The specialist at the major hospital led the team at the regional hospital through the procedures for dealing with emergency patients. The working space included the region around the patient's bed, the vital signs monitoring systems and the equipment used to treat the patient. Video cameras provided the specialist with overviews and close-up views of the patient and the medical team; the patient and medical team could see and talk with a head-and-shoulders view of the specialist. This system was installed in Sydney, Australia, and the surrounding region and trialled over a two-year period.
- Remote interpretation of cardiac ultrasound for emergency and intensive-care patients ("ECHONET") (Hansen 2007; Hansen et al. 2008; Wilson et al. 2010). These trolley-based units were deployed at a major and a regional hospital in Tasmania for a three-month trial. Each contained ultrasound equipment and a number of video cameras and displays, enabling a specialist in one hospital to direct and interpret cardiac ultrasound examinations in the other hospital. The working space included the immediate region of the patient's bed and the ultrasound equipment. Three-way dialogue was supported between the specialist, the sonographer and the patient.

3. Descriptive model of a telehealth outpatient consultation

3.1. Observations of face-to-face outpatient consultations

At the beginning of the case study presented in this paper the research team that was developing the telehealth system conducted four sets of observations of face-to-face outpatient consultations, after discussions with the surgeons about what the surgeons aimed to achieve in these consultations. The first two sets involved maxillo-facial and cranio-facial patients, one at RCH and the other on a rare off-site visit by the surgeons to the Royal Hobart Hospital in Tasmania. These involved examination of the patient, with the surgeon standing besides either the seated patient or, in the case of an infant, besides a seated parent holding the child in his or her lap. Because surgery on the skull may have developmental implications for the patient, these examinations included looking at the child's whole demeanour, in many cases by watching the child playing with toys or moving around the consultation room. The children also saw other specialists (dentists, orthodontists, speech therapists and neuropsychologists) during their hospital visit.

The second two sets of observations were conducted at RCH with the orthopaedic sub-specialties that would be included in the clinical trial. The examinations of these patients included passive testing of joints and limbs on an examination bed and active testing of standing, walking, posture and mobility. Discussions with the patient & family often involved current and previous radiology data (such as X-Rays) using the computer on the surgeon's desk.

There were common patterns across the four sets of observations. In each case, the surgeon took charge of the consultation, leading the dialogue with patient and family. The surgeons, patients and families had existing doctor-patient relationships and used these to move smoothly into the consultations. They discussed the patient's progress since the previous consultation and the surgeon examined the patient while the family watched. The surgeon used the results of the examination and that day's radiology data to propose how the patient's care could be managed until the next appointment. It was clear that the patients and families expected to be involved in these discussions, which focused on the surgeon's reasoning behind the management plan. For example, the patient might postpone resuming an active sport until a subsequent X-Ray showed a certain level of healing of a major bone. The consultation concluded when there was agreement to the management plan.

There were some variations across the observed consultations. Some surgeons, especially with older patients, conducted the consultation in a relatively formal manner. Other surgeons, especially with younger patients who needed to be encouraged to talk, move and be examined, used movement, gestures and voice to engage their patients in the consultation. A position plot for one surgeon showed that he visited every part of the large consultation room during the course of the afternoon clinic. There was variation in the way the families engaged with the consultation. Some took a relatively quiet role; others were actively engaged with the situation and spoke firmly and directly about their concerns for the patient.

3.2. Describing a telehealth consultation

The telehealth equivalent of a conventional consultation would place the surgeon in one room (the "surgeon's room") and the patient and family, accompanied by a clinically trained assistant, in another room (the "patient's room"). The dominant feature of the face-to-face consultations was that the surgeon was in charge. In the telehealth equivalent the surgeon would still be in charge and the clinician located with the patient (the "assistant") would assist the surgeon. In constructing a descriptive model of these telehealth consultations, attention was paid to all the parties involved (surgeon, patient and family and assistant) and to their conversational, information, spatial and awareness needs.

The descriptive model contained the following:

3.2.1. *Sequence and flow of events*

- The assistant ushers the patient and family into the patient's room and they sit in their allocated position.
- The surgeon greets the patient and family by name.
- The surgeon asks how the patient has been since the previous consultation and reviews the patient's progress with the patient and family.
- The surgeon directs the assistant to examine the patient and observes the examination through appropriate video and audio links.
- The surgeon displays current radiology data for the patient and discusses this data and the examination results with the patient and family.
- The surgeon proposes a plan of treatment or management until the next consultation and reaches agreement about the plan with the patient and family.
- The surgeon calls for any further questions then closes the consultation.

3.2.2. *Dialogue between the participants*

- The surgeon needs to have naturally flowing dialogue with the patient and family and technical dialogue with the assistant.
- The assistant needs to present an examination of the patient using views of the patient, gestures and spoken dialogue. The assistant also needs to speak directly with the patient and family to manage their presence in the consulting room.
- The patient and family need a naturally flowing dialogue with the surgeon and they need to respond to directions or instructions from the assistant.

3.2.3. *Information needs*

- The surgeon needs to see the patient's medical records, including on-line radiology. The surgeon needs to monitor the details of the patient examination.
- The assistant needs to see any patient data that the surgeon displays during their discussions of the patient's condition.
- The patient and family need to see any patient data that the surgeon presents to them during the consultation. They need to observe the dialogue between the surgeon and assistant about the patient during the examination and during any discussion of the patient's condition.

3.2.4. *Spatial and awareness needs*

- The surgeon needs desk space for medical records and convenient locations for any telehealth displays, cameras and microphones. The surgeon needs to be aware of who is in the patient's room.
- The assistant needs appropriate places and equipment to examine the patient and a place to sit during the discussion phases of the consultation.
- The patient and family need places to sit during the discussions. They need to see what is happening during the examination of the patient and to be aware of who is in the room with the surgeon.

3.2.5. *Support for specific actions*

- The surgeon needs support for pointing, drawing and action gestures when discussing the patient's condition and the radiology data with the patient and family.
- The surgeon needs to guide and direct the assistant to examine the patient. In the scenario envisaged for this concept, it was not expected that the clinical staff at the remote hospital would have the specialist training needed to conduct these examinations on their own.

4. Design of the media space

The media space provides video, audio and data links between the participants in the two rooms of the telehealth system. With multiple participants the design of the media space must take into account the specific needs of each of the participants and provide resources to meet those needs. The surgeon's and patient's rooms and the video, audio and data links between them (the media space) were designed to be located in dedicated rooms within the hospital. This reflected the ultimate design intention of placing the system in rooms within a major and a regional hospital and allowed the designers to give specific locations for the components.

4.1. Physical space

As there was a need for places for the family to sit and a space for the patient to be examined, the patient's room was partitioned into two areas. One area held seats for the patient and family to sit while they talked with the surgeon. The other area, where the assistant would examine the patient, held a chair, examination couch and walking space. The surgeon was not expected to move very much so the communication components in the surgeon's room were placed on a curved desk with the surgeon on the concave side so that he or she needed only to swivel in an office chair to move between components. A matching curved desk was placed in the patient's room with the patients and assistant on the convex side. The curve of the desk emphasised the partition of the space in the patient's room and enabled an across-the-desk metaphor with the imagined location of the surgeon inside the concave side of the desk in the patient's room. This asymmetric design of the rooms' layout was proposed by Matthew Hutchins and is shown in Figures 1 and 2.

4.2. Video and audio links between the rooms

Two video/audio bi-directional links ("close-up video links") were set up between the surgeon's room and the patient's room. One was on the right-hand-side of the surgeon's desk, connected to the side of the desk in front of the patient's and family's sitting area (Figure 1). The other was on the left-hand-side of the surgeon's desk, connected to the side of the desk in front of the examination area (Figure 2). The video camera settings, screen sizes and distances were set so that the remote parties' heads and shoulders were represented at sizes approximately equivalent to people talking to each other across the width of the desk. Small barrel video cameras were mounted so that they hung down from the top of the screen, thus simulating direct eye-to-eye visual contact. These configurations were designed to support a natural flow of dialogue between the rooms. The actual spatial directions of attention supported the metaphor of locating the surgeon inside the curve of the desk in the patient's room. The audio speakers in the patient's room were set at normal speech volume and a party not taking part in the conversation could hear what the other parties were saying.

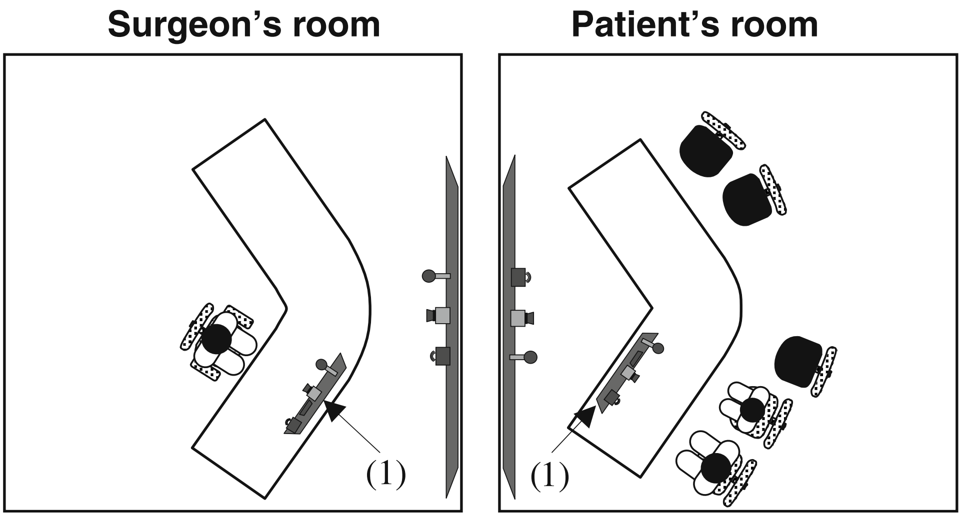

Figure 1. Surgeon talking with patient and parent via combined screen, camera, speaker, microphone, and foldback monitor (1).

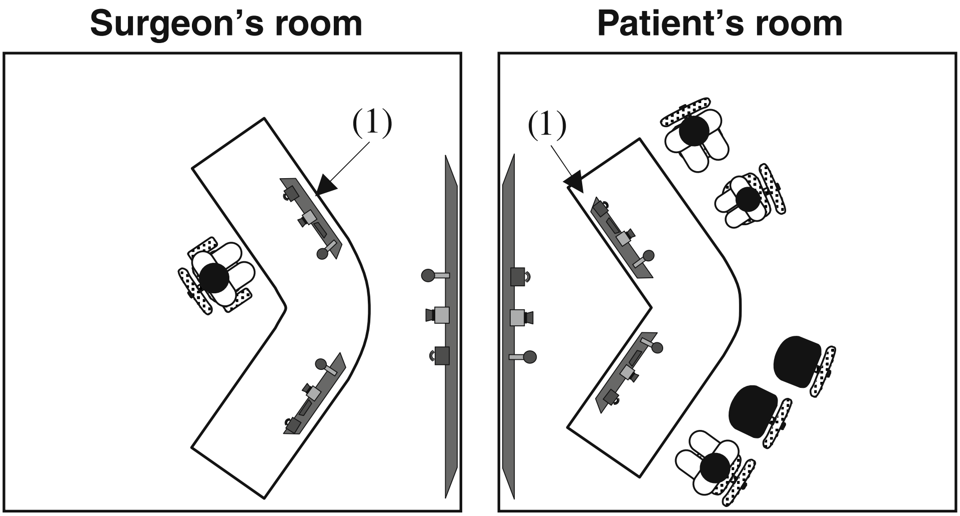

Figure 2. Surgeon directing assistant via combined screen, camera, speaker, microphone, and foldback monitor (1) to examine seated patient.

4.3. Room overview video and audio

A third bi-directional video and audio link ("room overview link") was installed to provide all participants with an overview of the room remote to them. It used a large-format plasma display mounted at the wall in front of the participants, together with a wide-angle video camera, microphone and speaker. The plasma displays and components are shown in Figures 1 and 2 as located on the imaginary wall dividing the two rooms. In each of the actual rooms the setup was oriented so that the overview video camera showed a view of the door leading into the room. The microphone also picked up general sounds in the room, including the sound of the door opening and shutting, giving the occupants both visual and auditory signals when anyone entered or left the room. In keeping with the concept of the video and audio streams of a media space being always available, these three video and audio links remained active during the outpatient consultations. Further, each video camera was fixed in location, viewing direction and zoom factor, so the resulting video streams formed constant reference points for the participants.

4.4. Video cameras for examining the patient

Four video cameras were provided in the examination area of the patient's room to give special-purpose views of the patient.

- A pole-mounted camera with remote Pan-Tilt-Zoom capability provided a view equivalent to that of a surgeon standing beside a seated patient. It could be tilted up to give an overview of the examination couch and zoomed in to view specific targets.

- A hand-held camera provided close-up views of the patient.
- Twin arm-mounted cameras provided hand-positioned views of the patient. They could also be used as a stereo pair to give 3D images or 3D video.
- A tripod-mounted camera 40 cm above the floor showed the standing posture and walking gait of younger orthopaedic patients.

4.5. Data display and remote pointing and drawing

Interactive display of image and video data was provided for the participants by four Wacom tablet displays with electronic pens. One was located where the family sat, one was mounted on an articulated arm for the assistant and the other two were placed on the surgeon's desk in front of the two close-up video links. All four displays were set to show the same data at any one time and the data could be chosen using a touch-screen menu which listed each of the video and image data sets in the system, including screen capture from the hospital's computer display of radiology data. The tablet displays allowed the family to see what the surgeon was seeing during the examination of the patient and they provided the focus for pointing and drawing actions from the surgeon, patient and family during discussions. They provided feedback to the assistant, who could see what the surgeon was seeing and could adjust the position of the cameras or the patient as needed.

A pointing and drawing facility was provided with the electronic pen and tablet displays, using a graphics overlay facility within the tablet displays. Holding the pen just above the tablet surface produced a coloured dot that followed the tip of the pen to create a pointing gesture. Drawing on the surface of the display created a coloured line in the track of the tip of the pen to create a drawing gesture. These pointing and drawing gestures could be performed over any displayed data set and they were visible simultaneously on all four tablet displays. Each tablet was coded for a different colour so that more than one person at a time could point and draw. The drawings were ephemeral, fading after five seconds in the manner described in earlier video guidance studies (Fussell et al. 2004).

4.6. Remote pointing and drawing directly into the examination area

An eye-safe laser attached to the pole-mounted video-camera provided a pointing and drawing capability onto any surface within the field of view of that camera. The surgeon used a pen-based control interface on the tablet display to point or draw over objects in the patient's room by pointing and drawing over the video image of those objects on the tablet display.

The layouts of the surgeon's and patient's rooms are illustrated in the diagrams of Figures 1 and 2 and shown in Figures 3, 4 and 5.

Figure 3. Surgeon's room (Photograph courtesy Royal Children's Hospital).

5. Qualitative human factors studies

Two qualitative human factors studies were carried out during the development of the telehealth system:

- A study of the way that the three video/audio links between the patient's and surgeon's rooms supported communication and awareness across the media space connection.

Figure 4. Patient's room showing both parts of the room.

Figure 5. Patient's room showing details of the examination space.

- A study of the use of the pointing and drawing system and the extent to which it supported collaborative spatial tasks and collaborative decision making.

These studies were designed to deal with the fact that there were no actual patients or clinical staff to use as study participants. Given the laboratory focus of the studies, it would have been inappropriate to have asked patients, already stressed by their health situation, to take part. Similarly, it would have been inappropriate to have taken the scarce time of practising clinicians. The studies were designed in the following manner:

- The study participants were drawn from the adult population in the local communities and explicitly did not have medical or clinical training.
- The study tasks drew on analogues of the tasks contained in the descriptive model of the telehealth consultation and they were performed by participants who were placed in analogous situations to the participants in the descriptive model.
- The study tasks were evaluated in terms of the way that the participants used the system to communicate and collaborate with each other, as expected from the descriptive model of the telehealth consultation.

These studies were similar, for example, to the qualitative study of software being evaluated for the then novel Xerox "Star" workstation (Bewley et al. 1983). Bewley and colleagues were exploring how participants would use an emerging technology application (a drawing package). The telehealth studies presented here were conducted at a level of task abstraction that allowed them to focus on collaborative processes between the participants rather than on specific outcomes from the tasks.

5.1. Video and audio links and room configuration

5.1.1. *Equipment and method*

Two rooms were configured with the curved desks, chairs and three video and audio links of the telehealth system, using the same layout as for the surgeon's and patient's rooms (Figures 1 and 2). This study investigated visual coverage of the two rooms and support for collaborative discussion and decision-making across the media space's boundary about objects and locations in the two rooms. Each run of this study required two participants, one in each room. Six pairs of participants took part.

The two study tasks, "room drawing" and "furniture placement", were based on tasks used in earlier media space studies (Gaver et al. 1993; Heath et al. 1995; Heath et al. 2001). After initial introductions, the participants were asked to draw a sketch map of the other room. The purpose of this task was to see how the participants would use the video links, how they would conduct a dialogue with their partner and what use they would make of their own physical space during that dialogue.

The second task involved a two-seater sofa located in the surgeon's room. The participants were asked to find the best place to re-locate the sofa into the patient's room so that it did not interfere with access to the room and so that observers sitting on it would have a good view of the activities of the study. This task provoked a discussion about spatial locations, relative sizes and location context and invited the participants to use pointing, gesture, focus of attention and conversation grounded in their shared access to the space, to objects and to actions (Clark and Brennan 1991).

During the tasks, the researcher who directed the study created a series of interruptions. These interruptions were intended to trigger changes of direction of attention and create three-way conversations across the media space boundary using the two close-up video systems. All six runs of this study were video- and audio-recorded and the participants each completed an audio-recorded exit questionnaire.

5.1.2. *Summary of results*

Grounded conversations. During the room sketching task, four pairs of participants spoke extensively with each other. They established common frames of reference and grounded their conversation in shared perceptions of the objects in each room. They asked about objects ("You've got some furniture up the back, haven't you?") and offered descriptions of objects in their own room using pointing, touching and size gestures. They used humour to bridge the artificiality of the laboratory setting. One pair tried to establish north/south conventions for directions within each room but abandoned them in favour of pointing, gestures and relative location descriptions ("Behind, on my right hand side ..."). The other two pairs chose to sketch with minimal conversation, relying on what they could see in the video streams and asking only direct questions about objects.

During the furniture placement task, however, all six pairs engaged in active dialogue and communicated using voice, gesture and body movement. Eleven of the twelve participants got up from their chairs and moved about the rooms, reaching and touching objects as part of the conversation, as illustrated by this dialogue example:

W: How big is the sofa?

V: Can you see it?

W: Yeah, I can see it behind you.

V: [Moves to, and lies on, the sofa] Can you see me? [Gestures along her body length to show the size of the sofa]

Each pair was sufficiently engaged in this dialogue that the scripted external interruptions did not disturb its flow.

Close-up video links and direction of attention. Three sets of interruptions were planned, using the close-up video links. Their purpose was to see if the participant in the surgeon's room would respond to the source of the interruption by turning to talk via the close-up video link that was directed to the researcher who created the interruption.

The first interruption followed a set of instructions for both participants. The researcher turned to face the close-up screen and said "Does that make sense?" using her body direction and gaze direction to direct the question to the participant in the surgeon's room. Five of the participants explicitly turned their attention from the room display to the close-up display in response. The sixth had been confused by the earlier instructions and continued gesturing to the room display to clarify the situation.

The second interruption was a question unrelated to the task at hand, directed at the participant in the surgeon's room and using material shown on the close-up display. All six responded by turning to face the close-up display, addressing the question then turning back to continue with no noticeable break in the furniture placement dialogue.

The third interruption was a direct question about the participants' perception of space in the patient's room (for placing the couch). Four participants turned and spoke directly to the close-up video display; the other two spoke and gestured to the room display to illustrate their answers. All participants in the surgeon's room agreed that it was easy to tell when the researcher in the patient's room was talking to them. All six pairs moved their attention between the room overview display and the close-up video links during the sequence of tasks, matching the moment of dialogue with the choice of display.

Pointing, gestures and spatial referencing. All six pairs used pointing, gesturing and spoken spatial references and they interleaved these meaningfully into their dialogue. They referred to objects in their own space:

A: What do you have in front of you on your left hand side; it looks like a glass or something?

L: [Reaches out to touch object] Yes, a glass.

They referred to objects in the remote space:

V: Put the ... move the white thing ... over there [points to the remote space and gestures a sideways movement].

They used gestures to bridge the media space:

A: I guess the task is to move that couch [points to the remote space] into this room [points into the room where he is sitting].

When problems arose with this aspect of communication they could be traced back to a mismatch of frames of reference. An example was the use of the terms "front" and "back" of the room, where the front of the room could be the wall showing the overview display of the remote room or could be where the participants were sitting "in front of" their desks. One room had an additional data projector sitting, unused, on a shelf and references to the wall with the data projector caused a misunderstanding that took several turns of conversation to correct.

All six pairs engaged in vigorous dialogue during the furniture placement task. In the patient's room the dialogue was supplemented by arm gestures, pacing out to measure distances, and touching and moving objects. In the surgeon's room the dialogue was supplemented by pointing and gesturing across the media space boundary and by body movement. At the end of this task all six pairs reached agreement on a suggested location for the furniture item in the patient's room.

5.2. Shared pointing and drawing system

The qualitative human factors study of the shared pointing and drawing system has been described in detail (Stevenson et al. 2008) and a summary of the study is presented here.

5.2.1. *Equipment and method*

This study was conducted using two of the Wacom pen and tablet displays (one in each room) and one of the close-up video links between the two rooms. It used abstractions drawn from the descriptive model of the telehealth outpatient consultations. Small-scale spatial guidance was represented by guidance to draw an amorphous shape on a 10 cm × 15 cm patch of fabric (Figure 6). Location and orientation on a small child was represented by placing the cut-out patch onto a

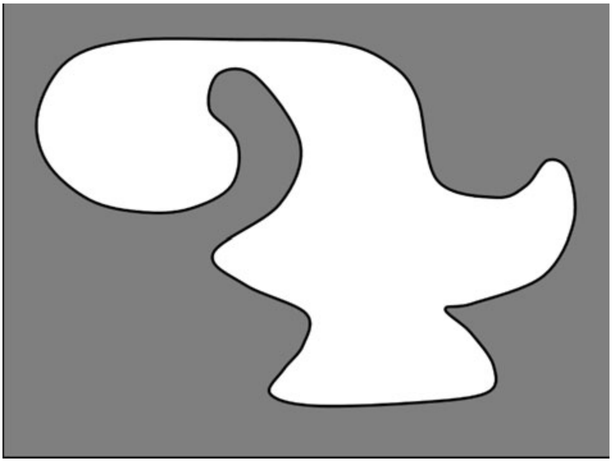

Figure 6. Example shape.

child's dress (draped over a foam core for shape) in a particular location and orientation. The study was performed with a participant in the surgeon's room guiding a participant in the patient's room, using a close-up video system and the tablet-based pointing and drawing tools (pointing over video, drawing over video, pointing into the workspace, drawing on surfaces in the workspace).

The outcomes of the study were observations on how the participants used the pointing and drawing tools to perform the task and how those tools supported the collaboration between the two participants during the task. The task was designed to control for prior experience with situations outside the experimental regime. The small time-scale of the task steps and the amorphous nature of the shapes prevented the participants jumping directly to task conclusion. This is in contrast to human factors studies involving familiar objects, such as Lego construction blocks used in the remote video guidance experiments by Kirk and colleagues (Kirk et al. 2005a, b), where the blocks are describable and many people have had experience playing with them.

Six pairs of participants, recruited from nearby research and university populations, took part in this study. The equipment for the surgeon's room was located in Sydney and that for the patient's room in Canberra. None of the pairs of participants knew each other. To control for variation in managing runs of the study, the instructions, including pictures of the shapes and photographs of their placement locations on the child's dress, were presented to the "surgeon" participant as a series of pages on a computer display.

5.2.2. *Summary of results*

Pointing and drawing choices. The participants used each of the four pointing and drawing options during the study, switching between options as the task progressed in response to their partner's expressed needs. They were aware of the trade-offs between options; for example, the pointing/drawing on video was easier and more precise for the "surgeon" but harder for the "assistant" to follow [compared with the laser into-workspace pointing and drawing] because it required the assistant to look away from the task to see the gestural instructions.

Frames of reference. The participants drew draft versions of the shape and then used these drafts as frames of reference, using phrases like "curve outwards" and "curve inwards" to assist the editing process. Two instructors explicitly asked their actors to rotate the fabric patch "so the horizontal side is the longest". This showed awareness of the actor's orientation and served to align the instructor's view of the fabric with the displayed shape on the instructor's private view of the study instructions.

In placing the patch at its correct location on the dress, the instructors used spoken instructions such as "towards the hem", "it's in the middle, below the pocket" and "a centimetre or two towards the seam". The dress itself provided the frame of reference for the instructions though some male "assistants" had trouble distinguishing the front of the dress (with breast pocket) from the back (with zip).

Collaborative behaviour. All six pairs of participants exhibited collaborative behaviour throughout the study. During the study they spoke to each other often, looking up from the task to make eye contact. The training phase was self-paced by the "surgeons", who read the instructions to their partner as they progressed. They shared the humour of the unusual shapes and verbally celebrated success at the end of drawing the shape. While drawing the shape they exchanged verbal confirmation of the curve's segments. The pairs were observed to negotiate the initial approach to the task and to negotiate repairs to the dialogue when difficulties were encountered.

6. Deployment at the Royal Children's Hospital

6.1. Training the clinicians

An observational study of the training sessions conducted for the clinicians (Stevenson 2008) is summarised here. The surgeons and their assistants attended one-hour training sessions, which were held at RCH during the week prior to the clinical trial. As there had been staff mobility during the lead-up to the trial only one of the twelve clinicians had seen details of the telehealth system prior to the trial. Nonetheless, they very quickly grasped the functionality of the system's components and spent the bulk of the training sessions establishing how they would work together as a surgeon-assistant team and how they could adapt their conventional consultation practice to the telehealth mode. For particular cases of examining the patient they requested last-minute changes to the telehealth system to enable better observations of the posture and walking gait of a group of younger patients.

As they progressed with the trial, the surgeons and their assistants reported extensively on two aspects. Firstly, they noted that it took time to learn to use the system without needing to think explicitly about what they were doing at each step. Secondly, they noted that they learnt to work more smoothly with their assistant as the trial progressed. At the end of the third week of the trial they were still observing progress on these two issues.

6.2. Clinical trial

6.2.1. *Method*

A four-week clinical trial of the telehealth system was conducted at RCH in Melbourne during September 2007. The trial used two meeting rooms within the hospital, one for the surgeon's room and the other for the patient's room. A third room was used to conduct exit interviews with the patients and families. The reception and the waiting area of an adjacent clinical part of the hospital were used to receive patients.

The trial involved three half-day clinics per week with between two and six patients per clinic. The basic pattern was to have one "general orthopaedics" clinic, one "limb reconstruction" clinic and one "maxillo-facial" clinic per week, repeating that pattern with the same pairs of surgeons and assistants over four weeks. The pattern varied slightly to allow for prior commitments of the clinical staff. The limb reconstruction clinic was replaced by a hand plastics clinic in week 3 of the trial and some clinics had more than one assistant. Having the same clinicians repeating their telehealth work week-by-week enabled them to progressively learn to use the telehealth system and to systematically consider their patients in the light of consultations during previous weeks.

Patients were invited to take part in the trial if they had an outpatient consultation scheduled for the period in which the trial was running and if they met certain clinical criteria. Those patients who accepted the invitation conducted their day at the hospital as they normally would have, visiting radiology and other specialists as scheduled, then came for their surgical consultation to the trial rooms rather than the normal consulting rooms.

Forty-four patients and families took part in this trial and 43 completed an exit interview after the consultation. Twelve clinicians took part: five surgeons and seven other staff who took the role of assistant (surgical fellows, registrars, specialist nurse and physiotherapist).

The purpose of this clinical trial was to test whether the implementation of the descriptive model as a telehealth system would be acceptable to each of the different groups of participants (surgeons, assistants, and patients and families). The surgeons and assistants were able to compare their telehealth experiences with the many prior face-to-face consultations that they had conducted and the patients and families were able to compare their particular telehealth experience and expectations with their experience of previous consultations. A face-to-face phase (with surgeon, assistant, and patient and family) was scheduled immediately after the telehealth phase to refresh the participants' memories of prior face-to-face encounters and to ensure the adequacy of healthcare for the patients in this trial.

The protocol for the clinical trial consisted of two parts: recruiting the patients and conducting the outpatient consultations. The patients were recruited if they were post-operative, their recovery was proceeding normally and they had a review appointment scheduled for September 2007. A similar protocol covered a small number of pre-operative patients. The consultation itself followed the following sequence:

- Confirmation of the informed consent process
- A telehealth phase which broadly followed the descriptive model of the consultation under the direction of the surgeon
- A face-to-face phase in which the surgeon walked to the patient's room and met with the patient and family
- An exit interview conducted with the patient and family, using a combination of Likert-Scale items and semi-structured questions

The surgeon and assistant separately completed a two-item questionnaire after each patient and a long interview at the end of each clinic. The consultations were video-recorded, with a camera in each of the two rooms. All interviews were audio-recorded and transcribed. The video recordings and the interview transcripts were coded using a grounded theory approach described by Corbin and Strauss (Corbin and Strauss 2008).

Aspects of this telehealth trial which have been published include a detailed evaluation of the trial (Stevenson et al. 2010) and a case-study in broadband telehealth (Wilson et al. 2010). A detailed account of this work and its context appears in the author's doctoral thesis (Stevenson 2010).

6.2.2. *Summary of results*

Telehealth and face-to-face phases of the consultation. The surgeons focused on the telehealth phase and continued the consultation until they had reached a conclusion. For 41 of the 44 patients, the surgeons said that they would have been happy to let the patient leave after just the telehealth phase of the consultation.

The face-to-face phase of the consultation was an opportunity for the participants to deal with issues that they felt had not been adequately covered during the telehealth phase. During the face-to-face phase the surgeons focused on social closure, handling any further questions from the patients and repeating the advice and instructions they had given in the earlier phase. They sometimes made brief confirmatory examinations of the patient. The patient and family sometimes revisited an issue raised in the telehealth phase and occasionally asked new and relatively sensitive questions.

Of the 44 patients and families, 13 stated in the exit questionnaire that they felt that the face-to-face phase was, for them, an important part of the consultation. Their reasons included an expectation or preference for the actual presence of the surgeon and for physical contact between the surgeon and patient.

Relationship between surgeons and assistants. The surgeons and assistants knew each other well; they worked in the same department of the hospital. The telehealth situation, however, introduced new aspects to their relationship. They were placed in a position of guidance rather than review (the assistants' work reviewed by the surgeons) and in a position where the surgeons needed to rely on the assistants' examination of the patients and their reported observations of the patients (rather than the surgeons having hands-on access to the patients). In spite of their existing relationship and their own clinical skills, they needed to learn how to work with each other in the telehealth environment and how to conduct their clinical practice in that environment. Observations of the consultations and self-reporting by both surgeons and assistant in the exit interviews showed that this learning was still happening three weeks into the four-week trial.

Video/audio links and spatial awareness. Actions and words observed during the telehealth phase showed that the participants were able to use the three video links to meaningfully place the direction of their attention as this example shows:

> [The patient is seated in the examination space, visible to the surgeon through one close-up video system; the parents are seated in the family space, visible through the other close-up video system]
>
> Surgeon: [Facing the family space] The important thing [turns to face examination space] are you listening, <patient-name>? [Looks and gestures to the patient] the important thing, even though I am telling them, [gestures to the patient's parents] is to do the exercises.

A second example shows that a young patient understood the directionality of the surgeon's attention:

> The patient was sitting on the examination bed putting her shoes on and her father moved to sit in the examination chair to assist her. The surgeon had been using the examination close-up video system to observe while the assistant conducted the examination.
>
> Patient to father: He can't see [me] now [showing that she was aware of the surgeon's gaze direction through the examination close-up video system to her and that her father was now blocking this line of sight]

Several patient examinations occupied large parts of the patient's room. From the way the surgeons directed and commented on these examinations, it was clear that they had a good understanding of spatial positioning and spatial relationships within the patient's room.

Use of the tablet displays. The surgeons made extensive use of the tablet displays to observe the examination of the patients, and did so in conjunction with the fixed close-up video link to the examination space of the patient's room. Where special cameras were involved (the overhead camera, the low-level horizontal camera and the hand-held cameras), they placed these views on the tablet display. They also used the tablets to display and annotate X-Ray and CT images in discussions with the patient and family. In one case, where radiology was not available, the surgeon used a live video display of the child's foot and annotated angles and features. The close-up video link had a sufficiently wide-angled lens and enough depth-of-field to cover the chair, the examination couch and the floor-space in between. The surgeons used this view to monitor and give overall directions for the examination.

The assistants used the tablet display to monitor what the surgeon was seeing during the patient examinations. This allowed them to adjust what they were doing to best show it to the surgeon. The family used their tablet display to monitor the examination of their child through the surgeon's eyes. Several commented that this was very useful for them and helped them understand the surgeon's explanations. It also gave them confidence in the surgeon's plan for the immediate future.

Use of remote pointing and drawing. It was only during the installation of the telehealth system at the hospital that the surgeons found that displaying their radiology data from the hospital's computer onto the tablet displays gave an image that was acceptable for these clinics (even though the process involved some loss of resolution due to the image compression involved). The surgeons chose to use this simpler option, rather than coordinate displays on two hospital computers (one in each room), to show the radiology data and they used the pointing and drawing tools to explain and discuss the data with the patients and families. This was the dominant use of the remote pointing and drawing tools.

> Surgeon: I found it very useful to have the tablet so I could draw it. Often I need to resort to pen and paper.

The original intention for these tools was to assist the surgeon in directing a remote assistant to examine the patient. This intention had been formed when the project plan called for a trial to a regional hospital with only generalist-trained assistants. In the actual trial, located at RCH, there were surgical fellows, residents and other trained staff to take the role of assistant. While one surgeon did demonstrate the use of the laser drawing tool for guiding the examination of a few of his patients, the surgeons generally chose to direct the examinations with spoken high-level medical terminology or with spoken references to relative positions on the patient's body. During the exit interviews the surgeons noted that it would have been too laborious to direct a lesser experienced assistant to conduct the examination step by step and the surgeons would not have been able to properly interpret the assistants' observations.

Surgeon: I had an excellent assistant. A less experienced examiner would add time and complexity ... Not everyone could follow those directions so quickly and understand what I was asking for.

The surgeons felt that if they were to embark on a long-term trial of this form of telehealth then they would need to form working relationships with their intended remote assistants and would need to ensure that these assistants were trained to perform the specialised procedures used to examine their patients.

In a number of cases the patient and family engaged in the dialogue by pointing and drawing over the display to ask questions or to confirm their understanding. One young patient highlighted the gap in the bone on his X-Ray and coloured it in to show that he understood that when the bone had grown to fill the gap he would be able to resume playing sport.

Patients' and families' prior experience. The patient and family usually had prior experience of outpatient consultations.

Surgeon: Hello <name>, how has it been since last time?

The style of the response varied with the family. Some responded immediately with detailed descriptions of the patient's progress and issues they wanted to raise. Others engaged in a dialogue, responding to more specific questions from the surgeon.

The families showed an awareness of the radiology data, typically X-rays:

Surgeon: Hip and socket developing hand in hand

Mother: The way it should be

Surgeon: Yes

Mother: Can you do the May [X-ray] and this one side-by-side?

[Surgeon sets up the display as requested]

Mother: So at this stage it's looking pretty good, isn't it?

7. Discussion

7.1. Meetings between researchers and clinicians

The research team developed its understanding of the surgical outpatient consultations from initial meetings with the surgeons and from observations of clinics conducted at RCH. They used this understanding to develop a descriptive model of a telehealth consultation for this outpatient situation and presented the model to the surgeons at a subsequent meeting, working through scenarios based on the proposed room layout (Figures 1 and 2) with justifications from the research team's previous experience in broadband telehealth. Review meetings were also held during the two-year development of the system. However, maintaining continuity with particular surgeons was difficult. Mobility amongst staff in this hospital sector and other commitments of senior staff meant that the research team was often dealing with surgeons and assistants who were new to the project. Each new clinician brought a fresh perspective and the need to regularly update the descriptive model of the proposed telehealth consultations to include these perspectives.

7.2. Human factors studies

The primary purpose of the two human factors studies was to uncover and deal with issues that might affect the performance of the participants in the telehealth system prior to actual deployment of that system. The first study tested media space aspects that had been described in the early media space literature, such as direction of attention, public sharing of actions and artefacts between the rooms and continuity of spatial understanding of the remote room through multiple video streams. The second study tested the ability of the pointing and drawing system to support collaborative spatial activities and decision making on the scale of examining a small child.

These two studies demonstrated an approach to dealing with the inappropriateness of using actual clinical participants in these laboratory experiments—a situation that one would expect to be common in developing telehealth systems for tertiary-level healthcare. Important features were the creation of abstract tasks which captured the essence of the corresponding real-world task, control for prior experience amongst the participants and using the process of completing the tasks rather than the task completion itself as the results of the study. The descriptive model of the intended telehealth activity (in this case the outpatient consultation) was used to design the tasks and to choose the processes of task completion that were to be observed.

The first study showed that the three video/audio links and the spatial layout of the desks that formed the basis for the media space were able to support discussion and awareness of objects and spatial actions within the two rooms. In particular, it showed support for the understanding of the direction of attention of the participants between the two rooms. Confirmation of this gave the research team confidence to use this communication and spatial structure in the design and deployment of the telehealth system in the clinical trial.

The second study showed that the shared pointing and drawing system was able to support collaborative dialogue and decision making on the spatial scale of the tablet displays using video of objects the size of a small child, with pen-based interaction over both image and live video. This again gave confidence that the implementation of this technology (deployment of hardware, design of interaction software) would be unlikely to present major problems when used by the actual consultation participants.

7.3. Training the clinicians

It was planned that training would be provided for the clinicians in the use of the components of the telehealth system but the response of the clinicians showed a much broader view. They immediately recognised that they would need to change their normal consultation practice and they focused their attention on this change. Although they were able to successfully conduct their first telehealth consultations with the system, they were aware of the way they were learning to use the system and learning to manage the changes in their normal practice during the trial.

7.4. Clinical trial

7.4.1. *Video and audio links*

The clinical trial was the first time that the telehealth system had been used with patients and many aspects from the human factors studies carried through to the trial. For each of the 44 patients, the surgeon and the patient and family were able to conduct conversations which were grounded in shared access to patient data, a shared understanding of the examination of the patient and a shared history of earlier consultations and clinical involvement. They used the three media space video links to understand the placement of people and objects in the remote room and to understand the actions taking place there. The surgeons, in particular, demonstrated that they understood the continuity of actions that spanned the patient's room. The surgeons used their video views of the patient's room and the objects that they could see as frames of reference for dialogue between themselves and the patient and assistant. The surgeons and assistants formed a strongly collaborative relationship in examining the patient and discussing the issues and uncertainties that arose during the examination.

7.4.2. *Remote pointing and drawing*

During discussion between the surgeons and the patients and families over X-Rays and other image and video data, both parties used remote pointing and drawing gestures on the tablet displays and local spatial references to support their conversation. In many consultations, the discussions that led to agreement on a plan for the future centred on shared gestural access to the radiology data, in a manner consistent with the outcomes of the second human factors study, where the focus of attention was often on the pointing and gestures in relation to the underlying image and video data.

Although the surgeons were aware of the possibilities of using the remote pointing and drawing tools to direct their assistants, they generally chose to use higher level medical terminology or simple spoken references to relative positions on the patient's body to direct the examination of the patient and to support discussion and investigation of the patient's condition. They did not discuss this choice during the consultations but raised it in their self-reporting at the exit interviews, recognising that this higher level spoken approach was important in conducting the consultation in a timely manner. They also noted the importance of the existing working relationships with their assistants, both for giving them directions and to support an accurate clinical interpretation of the their observations. The surgeons explicitly mentioned the importance of the assistants' specific examination skills and of the working relationships between surgeons and assistants.

7.4.3. *Engagement of patients and families*

The way that the patients and families used the system matched the descriptive model of the telehealth consultation in terms of their experience and expectations. They engaged directly with the surgeon at the start of the consultation, showing an understanding of the patient's progress to date and reporting in detail on the patient's condition since the previous consultation. They paid close attention to the examination of the patient and actively discussed the surgeon's proposed plan for managing the patient over the next time period. In the exit interview they had clear and well-justified points of view on the way that the telehealth consultation had progressed.

7.5. Evolving the descriptive model

The hospital deployment provided evidence that filled four major gaps in the descriptive model of the telehealth consultation in the context of a clinical trial. These gaps were related to aspects that were introduced by the transition from face-to-face to telehealth mode of consultation and by aspects of the structure of the trial. The first was the presence of a learning curve for the clinicians reaching some weeks into the trial. They learnt to use the components of the system smoothly, to work with their assistant in a manner that was not part of their normal staff interactions and to adapt their consultation practice to the telehealth environment. The second concerned the intentions of the surgeons to progress with a full consultation in the telehealth phase, taking the time needed to reach a satisfactory conclusion. The third was the nature of the relationship that would evolve between the surgeons and the assistants. The fourth was the way the participants made use of the face-to-face phase of the consultation, treating it largely as social closure with elements of reassurance and confirmation of advice or conclusions.

8. Conclusion

This case study shows the conception, design, implementation and clinical trial of a tertiary-level telehealth system as an example of a media space application where the key feature is the focus on all the intended users of the system. The requirements for the system were sourced from observations of the corresponding face-to-face clinical activities and were expressed in a descriptive model of the intended telehealth application. In constructing the media space that would contain the telehealth application, this descriptive model was used to resolve the many media space issues that had previously been identified in general form in the literature.

Qualitative human factors studies tested the media space aspects of the developing telehealth system against the descriptive model of the intended telehealth activities. These were conducted at a high level of task abstraction to allow them to be performed by generic adult participants rather than by the actual intended users of the system, because it would have been inappropriate at this level of healthcare to have involved these intended users in laboratory studies. The task abstraction controlled for prior experience amongst the participants. It also allowed the observations taken during the studies to focus on media space support for collaborative processes between the participants rather than on task completion.

The descriptive model of the intended telehealth application was extended to include requirements of the planned clinical trial, which was then designed on the basis of this extended descriptive model. The clinical trial, however, uncovered four major gaps in this extended descriptive model: a learning phase for the clinicians spanning much of the trial; the focus of the surgeons on the telehealth phase of the trial; the new working relationships that emerged between the surgeons and their assistants; and the use that the participants placed on the face-to-face phase of the consultations.

This case study represents almost two years' experience in developing a novel telehealth system for a complex healthcare application. By posing the telehealth system as a media space application, the study could draw on a large body of published experience of the issues involved. Having constructed a descriptive model of the telehealth application focused on the intended users, the study could produce specific solutions to the known general problems of communication between parts of a media space. The media space aspects of the system were tested by qualitative human factors studies at a high level of abstraction, enabling the use of generic participants in the studies and the observation of collaborative process rather than task completion. Finally, the training sessions and clinical trial in the hospital uncovered major gaps in the extended descriptive model of the telehealth application, gaps which were not exposed until the system was used with real patients, real clinicians and real patient data. For this relatively unexplored level of telehealth, this case study indicates that there are likely to be gaps in such a descriptive model that are not uncovered by laboratory experiments or by analytic evaluation but which emerge only during a clinical trial with actual patients, clinicians and patient data.

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