Human-Centred Evaluation of Broadband Telehealth for Tertiary Outpatient Consultations: A Case Study Approach

A thesis submitted for the degree of

Doctor of Philosophy

of

The Australian National University

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Declaration

Except where otherwise indicated this thesis is my own original work.

Duncan Stevenson
2nd February 2010

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Preface

Research context and research colleagues

In parallel to being enrolled as a full-time student, reading for the degree of Doctor of Philosophy, at the Australian National University (ANU), I was employed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in its Information and Communications Technologies (ICT) Centre. I had permission from my CSIRO ICT Centre Director to use the results and intellectual property from my work at CSIRO towards my degree and corresponding approval from the ANU to be enrolled as a full-time doctoral student. The team in which I worked came under the umbrella of a six-year funded project from the then Australian Department of Communications, Information Technology and the Arts as part of its "Building on Information Technology Strengths" Program.

This project, called the Centre for Networking Technologies for the Information Economy (CeNTIE), established a gigabit per second research network across Australia and developed a range of experiments and demonstration applications to showcase the use of broadband Internet under appropriate Quality-of-Service regimes (Wilson and Percival 2002). The project was managed through a series of activities and milestones. The milestones were typically reported as demonstrations of completed work to an appropriate industrial or academic audience. My team focused on developing, deploying and evaluating telehealth applications for a range of telehealth situations.

The emphasis of our work was to engage with application partners for each of our case studies. Our case studies, therefore, had a basis in the real world of application requirements. Our field trials and evaluations were done in real-world contexts, appropriately constrained to meet the realities of our working prototypes. This application emphasis enabled us to concentrate on the technical issues of developing and deploying our work and on the human issues of real-world requirements and access to actual application participants in our trials and evaluations.

Motivation for this work

Although the projects conducted under CeNTIE funding all had strong industrial linkages, the milestone-based management model limited our scope for fully reporting on our work. Two aspects, in particular, were inadequately represented. Firstly, the importance of using a real-world setting to demonstrate the results of any particular project was not adequately explored or discussed. Secondly, the evaluations of the projects tended to be primarily at the technical or implementation level rather than at the level of engagement by people who would use the application in their everyday working environment. The research activity described in this thesis, undertaken during the second 3-year funding phase of CeNTIE, provided an opportunity for me to focus on these two aspects as a core part of my project work with CSIRO.

Note on gender of participants

In this thesis I have used the term "he or she" and equivalents where reference is made to an abstract person. Where reference is made to specific people I have used the appropriate gender of the pronoun. For example, in planning for a surgeon to use our telehealth system I use "he or she". In referring to any of the five male surgeons who took part in our trial I use "he". This emphasises the individual nature of their responses to the trial and its evaluation.

Publications arising from this research work

Material from this research work has been published in three conference papers; all were double-blind reviewed with multiple reviewers:

1. Stevenson, D (2006) Evaluating an In-Vivo Surgical Training Demonstration over Broadband Internet, presented at the Australasian Computer-Human Interaction Conference, OZCHI 2006, in Sydney. This paper presented an evaluation of a preliminary case study which explored the use of an international advanced-broadband link to demonstrate a surgical training master class constructed around live 3D video of the surgery.
2. Stevenson, D, J Li, J, Smith and M Hutchins (2008) A Collaborative Guidance Case Study, presented at the Ninth Australasian User Interface Conference, AUIC 2008, in Wollongong. This paper presented a laboratory study conducted to assess the way in which our implementation of remote guidance technologies supported the collaborative tasks identified as representative of aspects of remote examination of child patients.
3. Stevenson, D (2008) Training and Process Change: A Collaborative Telehealth Case Study, presented at the Australasian Computer-Human Interaction Conference, OZCHI 2008, in Cairns. This paper presented observations from the training sessions conducted for clinical staff prior to the major telehealth study of this thesis.

Two journal papers have been written and submitted:

1. Wilson, Stevenson and Cregan Telehealth trials on advanced broadband networks, to Telemedicine and e-Health and accepted for publication with revisions.
2. Stevenson, Hutchins and Smith Human-Centred Evaluation for Broadband Tertiary Outpatient Telehealth: A Case Study, to The International Journal for Human-Computer Interaction, special issue on evaluation in healthcare.

Acknowledgements

Firstly I acknowledge and thank the members of my supervisory panel, Professor Tom Gedeon, Associate Professor Henry Gardner (both in the School of Computer Science, ANU) and Dr Cécile Paris (CSIRO ICT Centre).

The research work that supports this thesis was done in the context of my employment at the CSIRO ICT Centre and later as a Visiting Scientist, and I thank my CSIRO ICT Centre Director, Dr Alex Zelinsky, for his support. The funding for this work came from the CSIRO ICT Centre and the Australian Government through the Advanced

Networks Program of the then Department of Communications, Information Technology and the Arts.

As is typical in CSIRO, I worked with a team of highly skilled and dedicated scientists. I acknowledge and thank them for their collegiate approach:

In the Canberra laboratory: Chris Gunn, Matthew Hutchins, Jocelyn Smith, Doug Palmer, Matt Adcock, Alexander Krumpholz and Ken Taylor

In the Sydney laboratory: Susan Hansen, Jane Li, Laurie Wilson, Tony Adriaansen, Alex Krumm-Heller, Keith Bengston, Bob Shields, Dean Economou, Leila Alem and Rosemary Hollowell.

Under the combination of CeNTIE and ICT Centre funding we had an unparalleled opportunity, not normally available to doctoral students and academics, to develop advanced ICT research prototypes and to deploy them in realistic application settings. In Section 1.5 I specifically acknowledge where the work of my colleagues overlaps with the work presented herein.

The case studies presented in this thesis were conducted with many external participants. The preliminary case study was conducted in collaboration with the Stanford University Medical Media and Information Technologies (SUMMIT) group (Dr Parvati Dev, Prof. LeRoy Heinrichs, Robert Cheng, Margaret Krebs, Dr Pat Youngblood), with Stanford University Hospital (Dr Camran Nezhat and colleagues) and with Nepean Hospital (Dr Pat Cregan and colleagues). Funding for the SUMMIT group in the USA was partly supported by the National Library of Medicine, contract number N01-LM-3-3512.

The three laboratory case studies were conducted with volunteer participants from our work, university and local communities. I thank them for their willingness to be involved. I also thank the secretary of the CSIRO Human Research Ethics Committee (HREC), Caroline Bull, for her assistance in preparing our HREC applications.

Many people at the Royal Children's Hospital, Melbourne, contributed to the success of the telehealth pilot trial that we conducted there: John Meara, Leo Donnan and Andrew Greensmith championed the project, Annette Da Costa helped us prepare the Ethics Committee application and Michelle Vu project managed the hospital's role in the trial. The surgeons who took part were Andrew Greensmith, Abhay Khot, Chris Harris, Chris Coombs and Michael Johnson. Hospital staff members who took the roles of clinic assistant and who managed recruitment of patients for the trial were Kylie Pollard, Cheryl Dingey, Meredith Cadwallader, Derek Neoh, Derek Carr, Lachlan Currie, Aaron Cook and Rodrigo Teixeira.

I acknowledge and thank the patients and their families who took part in the trial and who were willing to share their experiences with the research team.

At home, my wife Caroline and my three children have provided warmth, support and encouragement during my enrolment as a student at the ANU.

Abstract

Outpatient consultations form a large part of the healthcare of patients at tertiary hospitals, both as a precursor to in-patient treatment and for the management of on-going health conditions or long-term rehabilitation and monitoring after treatment. These outpatient consultations are generally conducted at the hospitals, most often located in large cities. Patients who live outside these cities face extensive travel to attend these consultations, placing a burden on themselves and on their families or carers. An ability of a tertiary hospital to deliver outpatient consultations in a telehealth mode to regional or remote locations closer to the patients' homes would potentially relieve much of this burden of travel.

Tertiary healthcare is highly complex. It can involve multiple clinicians, can require long time periods for its completion and often includes the patients and their families in the management of the healthcare situation. Outpatient consultations typically involve high levels of interpersonal discussion supported by access to data about the patient. Telehealth methods of delivering these outpatient consultations will be very demanding on the network connection between hospital and remote telehealth nodes. The next generation of Internet or intranet, often referred to as "broadband", will have the capacity to deliver multiple high-quality, low-latency video streams and to provide shared access to large data sets. The prospective match of the capabilities of broadband networks and the needs of tertiary-level telehealth opens the possibility of effective, tertiary-level outpatient consultations in a telehealth mode of delivery.

In this thesis I use a case-study-based approach to evaluate the development and pilot trial of a broadband telehealth system in a tertiary paediatric context. I use the data from these case studies to explore the way that a human-centred approach can be used to evaluate outpatient telehealth trials at a tertiary level of healthcare. My results show that human-centred evaluation for this level of telehealth must take a broad approach; that the telehealth activities must take place in a realistic setting; that qualitative and quantitative responses from participants must be complemented by observational data; that data must be gathered from all the participants; and that their competence to give meaningful responses must be recognised and their multiple, and possibly differing, points of view must be taken into account. Finally, my results show that the researchers must take into account the wider clinical and hospital contexts and in particular the participants' view of these contexts, when interpreting evaluation data.

My overall prediction is that telehealth applications for tertiary-level outpatient consultations will have important, transient phases in their development, and that a human-centred evaluation approach is the appropriate way to evaluate telehealth applications during these phases. These transient phases are not reported in conventional telehealth literature but my analysis of my case studies suggests that they are central to this class of tertiary level telehealth delivery.

1 Introduction

1.1 Overview

The research presented in this thesis provides an experience-based critique of how human-centred evaluation approaches can be effectively used to evaluate broadband telehealth applications for tertiary outpatient consultations. A human-centred evaluation approach focuses on the participants (clinicians and patients) as they use the application for its intended purpose. It captures the participants' responses to the use of the application. It captures their judgements about the way the application supported them in what they did and their judgements about the outcomes. It respects the participants' experience and points of view and it allows for multiple differing points of view and differing judgements. It interprets the participants' responses in terms of the way they see the overall context of the application. A human-centred evaluation lends itself to elements of discovery as well as measurements of comparison or success and is suited to activities in their early stages of development, especially where the activities centre on personal actions rather than mechanical processes. In contrast, other forms of evaluation, such as process-centred or outcome-centred evaluation, are generally more suited to mature systems where the behaviour is well-understood and the evaluation aim is one of formal comparisons or measurements of success.

I used a case-study approach to my research, in which I followed the development and pilot trial of a prototype telehealth system. This system was designed to support post-operative outpatient consultations at the Department of Surgery, Royal Children's Hospital in Melbourne, Australia. The case studies were focused on the evaluation of different stages of the telehealth system. The evaluations were conducted in a human-centred manner, and I used their results to reflect on the human-centred evaluation processes themselves.

1.2 Motivation

There is a clear need to make tertiary healthcare more available to people who live in regional, rural and remote areas of countries such as Australia. The motivation for the specific telehealth system came from a group of surgeons at the Royal Children's Hospital, Melbourne, who approached the CSIRO with the concept that it could be possible to deliver some of their outpatient consultations using an appropriately-designed telehealth system. The hospital in which the surgeons worked was part of the public health system and its management recognised that it had a responsibility to care for not just the paediatric patients but also for their whole family. This approach reflected both the responsibilities associated with public funding and good clinical practice, because families play a central role in managing the long-term care and rehabilitation of children.

Tertiary outpatient consultations have a high level of interaction amongst the participants, including:

- Dialogue: between the clinicians and patients, and amongst the clinicians
- Gestures: demonstrating movements and actions, demonstrating the use of objects, annotating visual presentations of data such as X-rays
- Examination: of the patient, including visual examination and having the patient demonstrate static poses and dynamic movements

- Discussion of patient data: physical data (photographs and charts) and digital data (radiology and stored results of other clinical tests)

Implementing a telehealth system to support this level of clinical and personal interaction requires access to a high-performance network. Broadband networks, whether providing public Internet access or access via an organisation's private intranet, will be able to meet this level of demand. Many research broadband networks are providing gigabit-per-second bandwidth, enough for many simultaneous high-quality video channels and at latencies low enough to support natural dialogue. In some countries, broadband networks already reach a high percentage of the population. This conjunction of telehealth applications which demand high network performance and the progressive roll-out of broadband networks with the quality-of-service characteristics to support that demand has the potential to satisfy a demand for the delivery of tertiary outpatient services well beyond the bounds of the hospital's host city.

As telehealth moves into more complex areas of healthcare, such as those delivered at a tertiary level, the level of human involvement in the overall activity increases. Our telehealth case studies showed that the interactions between the participants in our telehealth outpatient consultations formed an important part of the overall clinical outcomes. This level of interaction was apparent at the beginning of this project, when the research team observed conventional face-to-face outpatient consultations conducted at the hospital. It subsequently became clear that evaluating these human interactions and responses would be an important part of evaluating the telehealth experience as a whole. The research direction, of determining how a human-centred evaluation approach could be used to evaluate this class of telehealth, emerged from these early field studies.

There are three main levels of healthcare: primary healthcare is delivered locally to patients by general practitioners and allied healthcare workers. Secondary healthcare is delivered at regional hospitals. Tertiary healthcare is delivered by specialists working in tertiary hospitals, which are often centres of excellence in a particular class of healthcare such as paediatrics. In Australia these tertiary hospitals are usually located in the major cities. The health situations of their patients are typically complex, with long treatment times. A need to travel regularly to their particular hospital places burdens on both the patients and their families or carers.

1.3 Case-study-based approach

The research for this thesis follows the development, deployment and evaluation of a prototype telehealth system, spread over a two-year period. My aim was to investigate how a human-centred evaluation approach could be applied to this overall activity and I took a case-study-based approach, following a methodology described in Chapter 3.

These case studies were:

- **A preliminary surgical training study** using high-quality video streams, live surgery and an appropriate surgical audience
- **Laboratory testing** of the major subsystems of the telehealth system. Three laboratory experiments were conducted:
    - Testing the usability and coverage of the fixed video and audio links between the two telehealth nodes
    - Testing user-interface options for the remote guidance technology
    - Testing the collaborative support aspects of the remote guidance technology
- **Training** the surgeons and clinical support staff to use the system
- **Exit-interview and questionnaire-based evaluation** of the pilot trial
- **Observation-based evaluation** of the pilot trial using video and audio recordings of each consultation.

Figure 1.1, on page 4, shows the relationships between these case studies and the laboratory and hospital contexts.

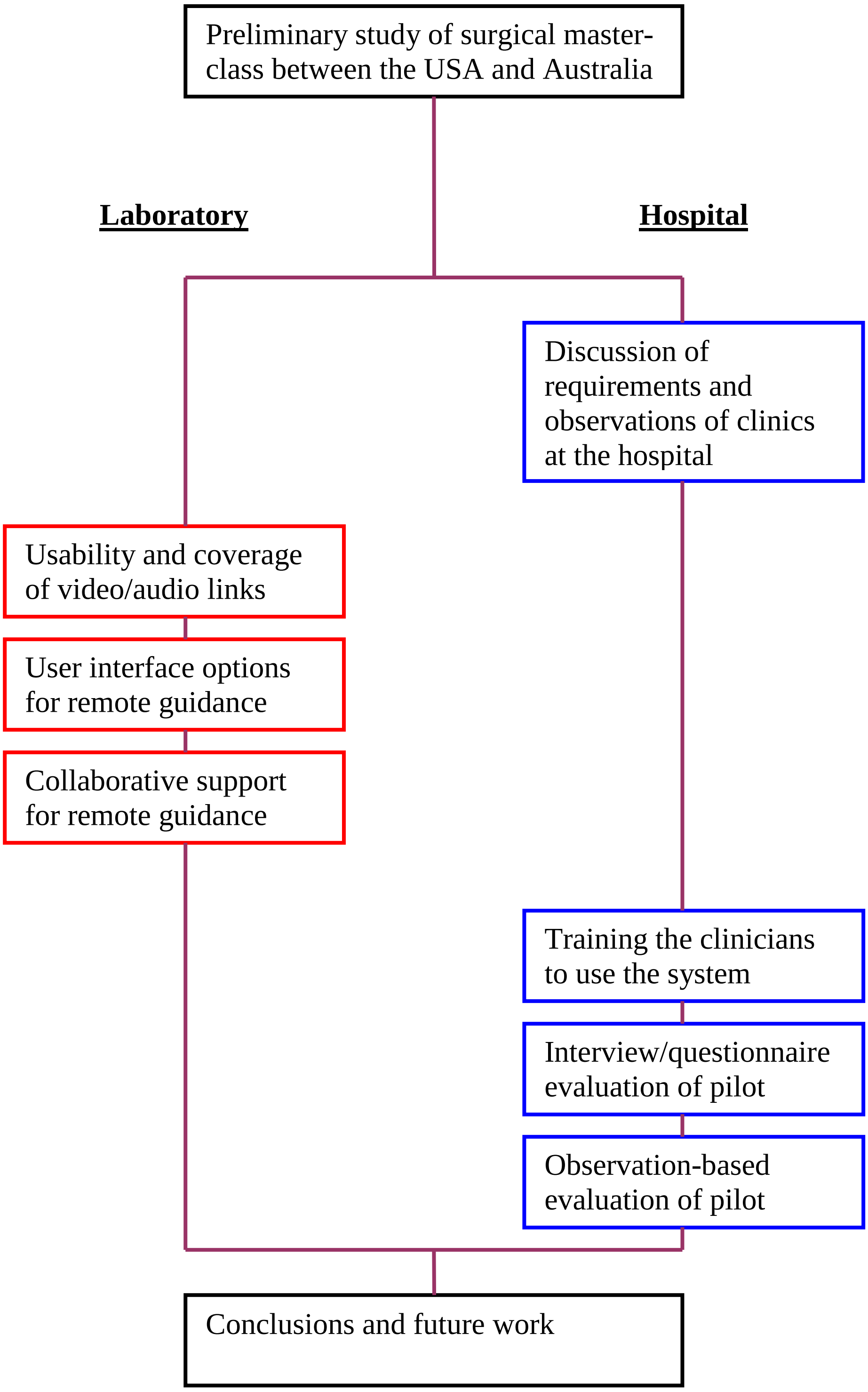

Figure 1.1: Schematic diagram showing the relationships between the case studies and the laboratory and hospital contexts

This thesis draws on seven case studies (four field studies and three laboratory studies) each described in detail in separate chapters as shown in Table 1.1.

	Description of event	Purpose
1. **March '06** ***Chapter 4***	**Remote surgical training demonstration linking an Operating Room in Stanford University (USA) and an audience in Sydney (Australia)**	**Explore a multi-participant scenario combining multiple teaching modalities, with live surgical video data and a clinically trained audience**
2. **Feb. '07** ***Chapter 6***	**Laboratory study between two rooms at the CSIRO ICT Centre's site in Canberra**	**Explore support for communication and awareness from the fixed video/audio links between surgeon's and patient's rooms**
3. **March '07** ***Chapter 7***	**Laboratory study between two rooms at the CSIRO ICT Centre's Canberra site**	**Usability evaluation of remote guidance interfaces**
4. **April '07** ***Chapter 8***	**Laboratory study between two rooms located at the CSIRO ICT Centre's Canberra and Sydney sites.**	**Establish whether the remote guidance interface supports the style of collaborative behaviour required in our major hospital study**
5. **Aug '07** ***Chapter 10***	**Training sessions for hospital staff using the telehealth system installed at Royal Children's Hospital, Melbourne**	**Conduct an observational study of the way the hospital staff responded to the training sessions**
6 **Sept '07** ***Chapter 11***	**Four-week pilot trial of the telehealth system at the Royal Children's Hospital**	**Evaluate the responses of the participants using questionnaire and exit interview data**
7 **Sept '07** ***Chapter 12***	**Four-week pilot trial of the telehealth system at the Royal Children's Hospital**	**Evaluate the responses of the participants using video and audio recordings of the outpatient consultations**

Table 1.1: Events and purpose for the seven case studies presented in this thesis

Each study was conducted by my former CSIRO colleagues and me, with differing levels of involvement in designing and conducting the studies. In six of the studies I took primary responsibility for the evaluations; in the seventh study I shared this task with another colleague. The first study was a preliminary exploration of a multi-participant scenario which used a purpose-built multi-stream video link between the operating room in the USA and the audience in Australia. The other six studies used an evolving whole-of-room telecollaborative system intended to support remote outpatient consultations between a tertiary hospital and a regional medical centre.

Descriptions of the case studies

Study 1 was a preliminary study to observe the use of a high-quality low-latency video conferencing approach to presenting a surgical master-class from the Operating Room to a remote audience. The actual surgery was presented using a twin-camera laparoscope ("key-hole" surgery) to give a live 3D video view of the surgical site to both the surgeon (wearing a virtual reality headset) and to the remote audience (wearing polarised glasses). The evaluation addressed both the use of this novel method of remotely presenting live surgery and also the overall structure of the event and the interactions between the surgeon and audience.

Study 2 was a laboratory study to explore the way the fixed video and audio links supported communication and spatial awareness between the surgeon's room and the patient's room. The researchers adapted experimental tasks used by Gaver and colleagues (Gaver, Sellen et al. 1993) to include whole-of-room activities and used adult non-clinically-trained personnel as the study subjects.

Study 3 was a usability evaluation, conducted in the laboratory, of three user interface designs for the remote guidance technology that was included in the telehealth system. This remote guidance technology was intended to aid the surgeon in guiding the assistant, who was located remotely with the patient. It supported pointing and drawing over live video from the patient's room and pointing and drawing directly into the part of the patient's room where the assistant examined the patient. This study used a special-purpose set of tasks which were intended to mimic the actions and guidance during an actual outpatient clinic.

Study 4 was an evaluation, conducted in the laboratory, of the way that the remote guidance system would support collaboration between the surgeon and the remotely located assistant. This study used the same set of tasks but placed a different emphasis on the conduct of the tasks and on the task outcomes.

Study 5 consisted of six one-hour training sessions conducted for clinical staff of the Royal Children's Hospital in the week prior to the telehealth pilot study. Its purpose was to observe how the clinical staff went about learning to use the telehealth system.

Study 6 was an evaluation of the pilot trial of the telehealth system, conducted at the Royal Children's Hospital, Melbourne. This study drew on the exit interviews and exit questionnaires which all participants in the study were asked to complete.

Study 7 was a complementary observational evaluation of the pilot trial, using video and audio recordings of each of the consultations.

1.4 Structure of this thesis

Chapter 1 presents an overview of my research and the approach I have taken to conduct it. It also contains a summary of the case studies presented in this thesis and an outline of my main results.

Chapter 2 is my literature survey. It presents work done in the emerging field of broadband telehealth together with work in the more mature fields of computer science and conventional telehealth.

Chapter 3 describes the research methodologies used in this work.

Chapter 4 presents the preliminary case study in the field of remote surgical training.

Chapter 5 describes the laboratory study approach used to resolve design questions and to explore the match between implementation and requirements at the component level.

Chapters 6 to 8 present the three laboratory studies conducted during the construction of our telehealth system.

Chapter 9 describes the resulting telehealth system which was used in the hospital pilot trial.

Chapter 10 presents the training of the clinical staff in the use of the system.

Chapters 11 and 12 present the results of the pilot trial.

Chapter 13 contains reflections on the way the case studies as a whole relate to the research results.

Chapter 14 presents conclusions and outlines areas for further work.

1.5 Acknowledgement of colleagues' work

Remote surgical training study

The 3D video software was developed by Chris Gunn, based on the open source Digital Video Transport System (DVTS) software (DVTS_Consortium 2004). The evaluation questionnaire was developed by me in collaboration with colleagues at the Stanford University Medical Media and Information Technologies (SUMMIT) laboratory. The actual demonstration was conducted with help from my networking technology colleagues at the CSIRO and from members of the SUMMIT team. Two CSIRO colleagues, Matthew Hutchins and Jocelyn Smith, operated the video cameras in Sydney. I analysed the video and questionnaire data, conducted follow-up telephone interviews and wrote the conference paper on which the report of this study is based (Stevenson 2006).

Video and audio communication study

I designed this study, conducted it with Jocelyn Smith and analysed the data with assistance from Jocelyn Smith.

User interface and collaborative remote guidance laboratory studies

Jocelyn Smith designed these two studies, in collaboration with Matthew Hutchins and me. Jocelyn and I conducted the studies with assistance from Jane Li in Sydney and Ken Taylor in Canberra. Jocelyn took the primary role in analysing the user interface study and I took the primary role in analysing the remote guidance study, each with assistance from the other. I took the primary role in writing a conference paper on the collaborative remote guidance study (Stevenson, Li et al. 2008).

Telehealth system training study

Matthew Hutchins and I conducted the training sessions for this study. I performed the analysis of the video data and wrote the conference paper on which the report of this study is based (Stevenson 2008).

Telehealth pilot trial

The pilot trial of our telehealth system at the Royal Children's Hospital was conducted by Matthew Hutchins, Susan Hansen, Jane Li and me, with advice from Jocelyn Smith. Jocelyn Smith and I developed the exit interview questionnaires as part of our application for approval to the hospital's Human Research Ethics Committee. Matthew Hutchins converted the many hours of video recordings of the consultations to digital form and produced an initial description of them. I analysed the exit interview data (completed questionnaires and interview transcripts) and I summarised and analysed the video recordings.

1.6 Summary of results

This section summarises the results of my critique of how human-centred evaluation approaches can be used for broadband telehealth applications for tertiary outpatient consultations. The components of these results are numbered and referred to as supporting evidence emerges from the case studies.

R1 *Development of broadband telehealth systems for tertiary outpatient care must account for the high level of human interaction involved. Scenario testing of these interactions will require reference to the actual clinical context of the intended application even though access to clinicians, patients and patient data may be very restricted during the development phase.*

R2 *Deployment of broadband telehealth systems for tertiary outpatient care contains pronounced transient phases which have not been noted previously in the literature.*

R3 *Effective evaluation of these telehealth systems in their early phases is complex and requires:*

- *R3.1* *A human-centred evaluation approach conducted in realistic settings*
- *R3.2* *Both quantitative and qualitative responses from the participants, complemented by observational data*
- *R3.3* *Data from all participants, with recognition of the competence of those participants to provide such data*
- *R3.4* *Recognition of multiple, and possibly differing, points of view amongst the participants*
- *R3.5* *Recognition of the wider clinical and hospital contexts in designing and evaluating the trials*
- *R3.6* *Recognition of the participants' views of these contexts in interpreting their evaluation responses*

R4 *In longer-term trials of more mature broadband telehealth systems for tertiary outpatient consultations, a hybrid evaluation approach is appropriate, with a human-centred approach employed during the transient phases and a more mechanical performance or outcome-based approach for steady-state operation of the telehealth system.*

2 Literature

2.1 Summary

Broadband telehealth for tertiary healthcare is an emerging field, still largely in the research domain, and prior work tends to form a series of individual case studies rather than a mature whole. The field covers a range of healthcare activities, including:

- Teaching advanced surgical concepts (for example, instruction from an operating room to a remotely located audience of surgeons)
- Demonstrations of advanced clinical procedures, such as those that occur at international conferences or meetings, where the person giving the demonstration may be presenting from their home hospital using their own patients.
- Mentoring of clinicians by specialists where the clinicians are dealing with patients and the specialists provide guidance or advice over a telehealth connection.
- Delivery of specialist expertise, where the specialist directs the clinical activities which take place at a remote location.

These activities often have several people at each telehealth system node and are characterised by high levels of interpersonal communication and by shared access to data about the patient. The telehealth systems supporting these activities make use of the high bandwidth and low latencies of the broadband network connections.

In this literature review, I describe prior work that has informed the design, construction and pilot evaluation of the telehealth system of this thesis.

This literature review addresses literature from the four relevant areas (Broadband Telehealth, Conventional Telehealth, Human-Computer Interaction and Evaluation, and Computer-Supported Cooperative Work) in separate subsections, shown in Figure 2.1.

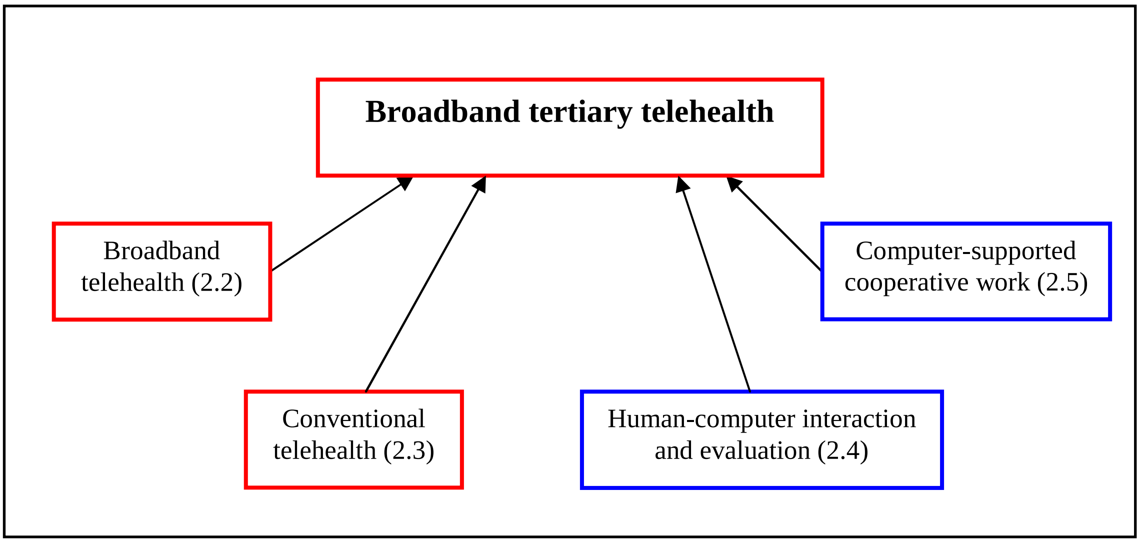

Figure 2.1: Broadband tertiary telehealth and related fields of research

2.2 Broadband telehealth

Work to date in broadband telehealth has generally involved tertiary-level healthcare, either in specialist training for clinicians or in making the services of specialist clinicians available to locations remote from their hospital. Primary and secondary health care have not featured in broadband telehealth, possibly because the venues from which they are delivered do not have access to broadband networks. At the time of writing this thesis, broadband networks are typically research networks sponsored by government or academic consortia and they connect to major hospitals through academic or government collaborations. Examples of these networks include:

- Internet2 in the United States (www.internet2.edu)
- The Global Ring Network for Advanced Applications Development (GLORIAD) linking developed countries in the northern hemisphere (www.gloriad.org) and the Trans-Eurasia Information Network.
- CeNTIE in Australia, funded by the Australian Government (www.csiro.au/science/CeNTIE.html)
- Networks in Japan include Japan Gigabit Network and the Science Information Network 3. Other networks in the Asian region include the Korea Advanced Research Network, the China Education and Research Network and the China Science and Technology Network, the Hong Kong Academic and Research Network and the Singapore Advanced Research and Education Network (Shimizu, Nakashima et al. 2009).

I note here that I am using the term "broadband network" to refer to packet-switched networks which use the Internet Protocol Suite, rather than to dedicated digital or analogue telephone lines.

Open-source software such as DVTS (DVTS_Consortium 2004) together with commodity digital video cameras has enabled affordable, low-latency, high-quality digital video links between nodes on broadband networks such as the above.

Live surgery presentations

Early presentations of live laparoscopic surgery together with two-way videoconferencing were given in the United States during 1998 and 1999 using Internet2 (Damore, Johnson et al. 1999). Examples of demonstrations with international reach include a conference presentation of stereoscopic high-definition video of live surgery (Gwangju_Institute_of_Science_and_Technology 2005), a teaching presentation of eye surgery between Singapore and Japan (Singapore_National_Eye_Centre 2006), live video of cancer surgery presented from Korea to the Stanford University School of Education (Dr Paul Kim 2006, personal communication), live surgical video between Australia and Singapore (Carati, Shimizu et al. 2006) and a series of live surgical presentations between Japan and Korea (Shimizu, Nakashima et al. 2006).

More recently, research and educational networks within and between countries in the Asia-Pacific region have been used extensively for presentation of surgical training (Shimizu, Nakashima et al. 2007; Huang and Shimizu 2008; Shimizu, Nakashima et al. 2009). These authors emphasise the importance of video and audio quality in these surgical training environments, stating "high quality moving images are mandatory for surgical training and consultation" (Shimizu, Nakashima et al. 2006) and emphasising the importance of “smoothness of the motion picture, sharpness of images and clarity of sound” (Huang and Shimizu 2008). In their review paper on telehealth presentation of surgery in the Asia-Pacific region, Shimizu and colleagues identified 100 case studies involving thirteen countries between February 2003 and June 2007 (Shimizu, Nakashima et al. 2009). Their discussion focused largely on the technical issues of image and video quality and of broadband connectivity.

Focused clinical teaching over broadband

Dev and colleagues used the California Orthopedics Research Network (www.internet2.edu/health/archive.html) to conduct a state-wide surgical teaching case study using live video of hand surgery (Dev, Srivastava et al. 2004). The presentation was a choreographed surgical lesson, interleaving live surgery with explanations supported by high-quality 3D anatomical images. The audience interacted by asking questions and making comments during the event. The authors had designed the presentation around their vision of integrated remote surgical instruction and evaluated the presentation in terms of the opportunities for surgical learning that it created and the organisational effort involved in staging it.

Dev and colleagues developed a broadband application for collaborative study of stereo dissection images of human cadavers (Dev, Srivastava et al. 2006). This application used a peer-to-peer model, where any of the collaborating users could take the lead in exploring the clinical data by controlling the shared 3D pointer. It used high-resolution stereo paired images and the interactions created transmission bursts of typically 70 megabits per second, putting it beyond the capabilities of standard Internet. The evaluation instruments included “questionnaires, network traffic measurement tools and a 5-point perceptual scale to assess user response”.

A concept Virtual Reality demonstrator using a shared haptic virtual environment, coupled with a high-quality video and audio link between the participants, was presented to a conference audience in Australia, with the other node in the USA. It was evaluated in terms of technical achievements and in terms of the responses from a clinically informed audience (Gunn, Stevenson et al. 2004; Gunn, Hutchins et al. 2005). A surgical training application, based on this concept demonstrator, was presented as a pilot trial (March 2005, Royal Prince Alfred Hospital, Sydney) and as a validation trial (November 2005, Royal Australasian College of Surgeons skills training venue, Melbourne) (Hutchins, Stevenson et al. 2005; O'Leary, Hutchins et al. 2008).

Clinical applications over broadband

The “eICU” was designed to provide staff working in a hospital intensive care unit (ICU) with remote access to intensive care specialists to support them in making decisions about their patients (Celi, Hassan et al. 2001), cited in (Wilson 2008). It has been evaluated for both clinical outcomes (hospital mortality and length of stay) and economic outcomes (Leong, Sirio et al. 2005), showing a significant reduction in mortality rate and reduced hospital costs. The authors conducted their study in a large tertiary teaching hospital over the period 1999 to 2001, with a total of 2140 patients receiving ICU care, 1396 before and 744 after the installation of the eICU system (ibid.).

The Arizona telemedicine network (www.telemedicine.arizona.edu) spans the state of Arizona, with major nodes in several cities. The major nodes are connected by T3 links (45 megabits per second) with other nodes using T1 links (1.5 megabits per second) and connections over standard Internet and wireless links. The network provides a wide range of clinical services, including regular telemedicine consultations in 17 different specialties. This is an example of the majority of clinical telemedicine application environments, which use a mixture of telecommunications infrastructure and industry-standard videoconferencing equipment, and where the user interfaces are not often tailored for their specific application (Wilson 2008).

In his survey of technologies for complex and critical-care telemedicine, Wilson noted that, while a number of telemedicine projects have addressed critical care, “most have used general-purpose telemedicine systems and have actually been able to support only limited aspects of the complex process of critical care support” (ibid.). Wilson summarises the requirements for telemedicine systems for critical care environments:

- A level of personal interaction which supports the unique team dynamics of critical care, and
- Access to data and information which is both timely and complete, in order to support decision making (ibid.)

Wilson described a critical care system that was designed specifically to address these two requirements, using purpose-designed hardware, software and user interfaces. The Virtual Critical Care Unit (ViCCU) linked the emergency room of a small hospital (Blue Mountains Hospital) to the west of Sydney with a large referral hospital (Nepean Hospital) in Sydney using a dedicated broadband connection (ibid.). This system used multiple near-broadcast-quality video streams together with digital transmission of the patients’ vital signs to allow an emergency care specialist at Nepean to manage the early care of the patients as soon as they arrived at the Blue Mountains Hospital. This involved directing the nursing staff and the relatively inexperienced doctors (often locums at weekends) to manage the patients during the “golden hour” of treatment immediately after a critical event such as a heart attack, stroke or car accident. The two-year trial of this project was evaluated at both participant and clinical level (Li, Wilson et al. 2006; Westbrook, Coiera et al. 2008).

The ECHONET project installed mobile cardiac ultrasound units in the emergency and intensive care departments of two hospitals in Tasmania. The hardware and software for this project were purpose-designed. The units were identical and could be networked over broadband connections to allow a cardiologist at one site to direct an ultrasound investigation of a patient at another site. Tasmania, with a small population, may have only one cardiologist on duty within the whole public health system, especially outside normal working hours. The project implementation addressed both the social and the technical issues involved with introducing broadband telehealth technology into a hospital network. A trial was conducted during 2007/2008 (Hansen 2007; Hansen, Robertson et al. 2008).

2.3 Conventional telehealth

Technologies

The field of telehealth has a long history, starting with simple voice communication by telephone and moving through broadcast and television technologies and digital telecommunication links to Internet-based technologies (Bashshur 2002). It is a broad field, covering the remote delivery of health expertise in many forms. It can be asynchronous (for example using store-and-forward technology for remote interpretation of radiology data) or synchronous (where interactions between clinicians, data and patients happen in real time). In addition to clinical delivery, it can include teaching, guiding and mentoring of clinicians.

A survey of the "telecommunication revolution in the medical field" notes that the future will demand "much more than a rapid exchange of information" (Pande, Patel et al. 2003). The scenarios they describe are extensively built on real-time interactive collaboration between the parties involved. Rosser and colleagues, in their survey of tele-mentoring and tele-proctoring, observe that "telemedicine is poised to make a large positive impact on healthcare delivery" (Rosser, Gabriel et al. 2001). They note that most of the current applications of telemedicine are based on teleconferencing capabilities augmented by transmission of still images and that the video is "not of full motion quality", an observation that was still current during this telehealth pilot trial.

Broadband connectivity has the capacity to overcome the technical limitations of conventional telehealth systems identified by these authors. Higher bandwidth will support full motion video. Integrating multiple, low latency video streams with application data will support the communication, spatial and activity awareness needed for "real-time interactive collaboration between the parties" (Pande, Patel et al. 2003).

Organisational issues

Telemedicine in general is located in an organisational context which influences its overall take-up in the wider community. In many countries, medical practitioners are licensed on a regional or state basis. Rosser and colleagues raised this issue in the context of the USA, where licensing is done on a state-by-state basis, and described additional measures that were needed to permit telemedicine activities to cross state boundaries (Rosser, Gabriel et al. 2001). Similarly, in Australia medical practitioners are registered by state. Examples of confining telehealth to state boundaries are the widespread use of tele-psychiatry in South Australia and the South West Alliance of Rural Health initiative within Victoria (www.swarh.com.au).

The South Australian example shows the strong pressures of organisational limitations. The population distribution is highly skewed towards the state capital, Adelaide. In February 2006, when I visited the main public psychiatric hospital in Adelaide, there were no psychiatrists working in the public sector outside that city. The health sector's response was to establish a tele-psychiatry network using the videoconferencing facilities present in the state's health system. Provided that the patient could comfortably sit and talk at a videoconference facility located at one of the many rural and regional clinics, all initial psychiatric consultations outside Adelaide were conducted over the videoconference network.

A second organisational issue is that of payment, where health funding requires personal attendance of the healthcare provider. In Australia many telehealth initiatives occur within the public hospital sector which does not operate on a fee-for-service model and, therefore, is not constrained to face-to-face delivery of health services. Apart from a small set of exceptions, Medicare, the national health insurance system (www.medicare.com.au), does not have government approval to reimburse fee-for-service telehealth activities.

A third issue, also raised by Rosser and colleagues (ibid.), is that of medico-legal responsibility for the patient on the part of the local and remote clinicians. Some clinicians are unwilling to rely solely on a telehealth intervention to discharge their duty of care for the patient while telehealth activities remain in the research field. In the trial of remote echocardiology (ECHONET), described in Section 2.2, some physicians felt that their duty of care to their patients required them to follow up a remote consultation with a face-to-face consultation (Dr Laurie Wilson, pers. comm.)

Additional issues of coordinating the patient care between the local and remote nodes of a telehealth implementation include scheduling patient appointments, shared access to patient medical records and continuity of care for the patient. Examples of trials reported in the literature show that explicit effort was required to deal with these issues (Boulanger, Kearney et al. 2001).

2.4 Evaluating human-computer interaction

There are many ways to evaluate human-computer interaction. Boehm-Davis, in her article reviewing the developments in Human Computer Interaction for the 50th Anniversary issue of the journal "Human Factors", says:

> Over almost 30 years, human factors researchers have evaluated innumerable systems, comparing human performance using a 'new' system with performance using an 'old' system. (Boehm-Davis 2008).

Many human-computer interaction evaluations have adopted a hypothesis-testing approach to the comparison task described by Boehm-Davis in the quote above. This is a standard approach in psychology and medicine. A "null hypothesis" is assumed, namely that there is no difference between the 'new' and 'old' systems. A random sample of the user population is taken and the two systems are used to perform identical tasks. Comparative statistics on the performances of the two systems are gathered and, using appropriately matched statistical models, statements are made about the probability of the particular outcomes that were observed given the null hypothesis. If these probabilities are below a threshold, it is concluded that the observed differences between the new and old systems did not occur by chance and the null hypothesis is rejected.

When conducting a comparison-based evaluation of advanced Information and Communication Technologies applications, we are not necessarily able to identify matching performance measures for the "new" and "old" systems because the "new" system may be radically different in structure from the "old" system. In these cases it is reasonable to compare the outcomes of each system rather than the performance of components within each system.

The following example of comparing two methods of surgical training is a case in point. The two methods were markedly different and there were no meaningful comparable training measures. The outcomes, however, were identically comparable, being the performance the trainees demonstrated in the operating room. A virtual-reality training simulator for laparoscopic surgery was developed, which allowed the trainees to practice a procedure as often as they needed until they could repeat the procedure a given number of times with no errors (Seymour, Gallagher et al. 2002). The corresponding "old" method was for the trainees to observe and assist while senior surgeons operated on live patients, with their learning phases limited by the broader context of the operating room and by the number of patients with that condition. To evaluate this "new" system two groups of trainees were recruited: one group was trained on the simulator and the other received conventional operating-room training. Each of the trainees was then asked to perform the procedure on an actual patient and their performance was rated on pre-defined surgical criteria. Comparisons were then made between the ratings of the members of each group and the appropriate statistics used to reject the null hypothesis (ibid.)

Evaluations of humans interacting with computer-based systems do not, however, need to be comparative. This second example concerns a virtual-reality training simulator which was developed for teaching the surgical approach to dissecting the temporal bone (O'Leary, Hutchins et al. 2008). The temporal bone sits behind the ear and houses the organs of hearing, which are easily damaged during surgery and knowledge of the correct surgical approach is essential to avoiding such damage. The approach involves finding anatomical landmarks in sequence as the bone is drilled away. The "new" virtual-reality training system allowed the trainees to repeat the dissection as often as needed and to use a number of different cadaver-derived patient-data sets. It was decoupled from the skills acquisition task of accurately drilling the bone under a surgical microscope. The "old" system required actual drilling of scarce and expensive cadaver samples as the learning method, with no opportunity to backtrack and repeat any step. In a trial of this system a cohort of surgical trainees, with no prior experience in the particular surgical procedure, was trained on the virtual-reality simulator. Each was then asked to demonstrate the procedure on a cadaver and their performance was rated on pre-defined surgical criteria. The outcome of this trial was a statement of the training transfer from the virtual-reality trainer to the dissecting table, expressed in terms of counts of anatomical landmarks found in sequence and counts of specific steps in the procedure performed correctly. An exit questionnaire gathered responses from the trainees about the acceptability of specific aspects of their experience using the virtual-reality trainer.

2.5 Evaluating telehealth systems

Evaluation approaches vary across reported telehealth case studies but they generally combine clinical outcomes and patient satisfaction. Many were essentially pilot studies intended to explore whether or not a particular telehealth idea would work in practice. These often had to deal with sceptical clinical participants as well as volunteer patient participants and the case study by Boulanger and colleagues is an example (Boulanger, Kearney et al. 2001). They saw 19 patients for a post-discharge follow-up after hospital treatment for trauma (gunshot wounds, blunt trauma) over 22 appointments. Their paper presents the average duration of consultation and lists examination instruments and imagery used. In 15 appointments there was no further follow-up. The other seven appointments generated referrals to further telemedicine follow-up or other face-to-face treatment. One author performed 20 of the 22 telemedicine assessments and acknowledged that this produced a "biased assessment of physician satisfaction" with much prior "scepticism as to the use of this new technology" amongst his colleagues. The exit interviews with the patients showed high levels of satisfaction. In particular, all patients gave the maximum positive rating to the assertion that "Telemedicine makes it easier to get medical care" and several said that they would not have made the effort to travel the long distance back to the hospital where they had been treated to attend this follow-up appointment.

A second example concerns delivery of Cognitive Behaviour Therapy (CBT) to rural and remote mental health clients (Griffiths, Blignault et al. 2006). A psychologist based in a regional city conducted between six and eight Cognitive Behaviour Therapy sessions with each of 15 mental health clients using a videoconference system, with the clients' case managers present at the remote site. Using a standard Mental Health Inventory they found significant improvement in their clients' scores before and after the treatment. The clients and case managers rated the experience as "average" to "much better than average" on a five-point scale. The authors noted that their study "demonstrated that it was possible to deliver CBT via videoconference" for this range of patients but that, in the absence of a control group, they could not quantify the improvement. They noted that the case managers had not had any prior experience with videoconferencing (and by implication, though they did not say so, no experience with telehealth) and they conducted a single training session for each case manager prior to this trial. They did not describe any prior telehealth experience on the part of the psychologist. The PC-based videoconferencing system used 128 kilobits/second telephone lines and this low bandwidth caused "a slight delay in speech and movement".

In his review of telemedicine and health care, Bashshur discussed systemic organisational barriers to traditional evaluation methods for a deployed technology (Bashshur 2002). He noted that "many projects have been funded for the short term" and have "incomplete or nonexistent plans for long-term sustainability". This lack of mature telemedicine programs prevents "adequate and definitive cost-benefit analysis, particularly in terms of health outcomes, patient-borne costs and total costs". He continued this discussion in a paper on telemedicine evaluation (Bashshur, Shannon et al. 2005) where he looked at public policy on investment in telemedicine programs, noting that it should be based on "scientific evidence of their benefits and costs as compared with alternatives".

Pawson and Tilley noted in their book on evaluation that program evaluation of large-scale, publicly funded interventions is very difficult (Pawson and Tilley 1997) and that accumulation of results across studies is difficult because each study typically has its own foundations, assumptions and methodologies leading to incompatible descriptions of outcomes. They also noted that the high-level reporting typical of such program evaluations tends to mask the underlying mechanisms driving the phenomena being evaluated and that knowledge of these mechanisms is often the key to successful replication of the program elsewhere.

Klecun-Dabrowska and Cornford addressed the role of public policy in the emergence of telehealth using the United Kingdom as their case study (Klecun-Dabrowska and Cornford 2000). They observed that policy documents set the context for the development of new technologies, such as those involved in telehealth, and that these policies provided the framework in which telehealth would be judged a success or a failure. As an example, if "policy emphasises efficiency and cost-cutting, services that do not contribute to these goals, even if offering a better service for the population, may be deemed as failures" (ibid.). This is an important point to keep in mind when considering the cost-benefit analyses that Bashshur and colleagues advocated (Bashshur 2002; Bashshur, Shannon et al. 2005) because the outcome of a cost-benefit analysis depends entirely on the values that are allocated to those costs and benefits.

In medical informatics the gold standard for evaluation is the randomised controlled trial (Friedman and Wyatt 1997). This standard can indeed be applied to health situations that have a heavy use of Information and Communications Technologies. An example from the use of simulation technologies for surgical skills training, described in Section 2.4.1 above, illustrates this point (Seymour, Gallagher et al. 2002). In this study, 16 trainee surgeons were divided into two groups which were controlled for potentially confounding factors. One group received standard laparoscopic training for a basic procedure and the other group received simulator-based training for the same procedure. In a double-blind trial in the operating room, the simulator-trained group outperformed the control group in all aspects of the evaluation of their surgery. The study produced results strong enough to alter the attitude of the peak surgical body for the USA towards simulator-based training (Gallagher, workshop presentation, Royal Australasian College of Surgeons Annual Scientific Congress, Brisbane, 2004)

In one review of the methodology of telemedicine evaluations the authors said that "the focus of the evaluation is on the patients' health status" and they advocated that these trials should be conducted in a randomized controlled manner comparing conventional and tele-treatment (Huis in 't Veld, van Dijk et al. 2006). However, as MacFarlane and colleagues had earlier pointed out, a randomised controlled trial "can determine only whether an intervention works according to predefined criteria. It cannot explain why or how an intervention succeeds or fails". They argued for the benefits of a qualitative approach to telemedicine research (MacFarlane, Harrison et al. 2002). They studied telehealth consultations between primary and secondary health providers by interviewing 15 hospital specialists, 24 general practitioners and 30 patients and by recording 60 tele-consultations. Their results showed that the participants (specialists, general practitioners and patients) had "different perceptions of the same tele-consultations" which in turn were different from the perceptions formed by the researchers conducting the evaluation. They found that some groups thought a consultation went well but others thought it went not-so-well. Awareness of this difference only emerged during the data collection.

Nelson and Palsbo discussed the issue of "diagnostic equivalence" studies in telemedicine using data from five specialty telehealth clinics (Nelson and Palsbo 2006). The issue here was whether the clinicians were able to make a correct diagnosis of a patient's condition using telehealth systems. The authors focused on issues of study design, patient and clinician involvement, measurement issues and the role of the "presenter" (the person presenting the patient to the distant clinician). Their model of telemedicine was one of outreach to "underserved populations who would otherwise not receive specialty medical services". They looked at the initial diagnostic stage of the patient engaging with the health system, i.e. at the start of the patient's health trajectory (Corbin 1998).

Smith and colleagues presented a study which compared diagnostic outcomes between telehealth and face-to-face consultations (Smith, Dowthwaite et al. 2008) in paediatric otolaryngology. A total of 68 patients received an initial diagnostic consultation with a telehealth system (videoconference plus specialist camera for ear, nose and throat examination) followed some time later by a second full examination at the hospital. They mentioned in passing that "outcomes, including patient satisfaction … are all substantially improved with the use of telemedicine" but their primary focus was on the agreement between the diagnoses arising from the pairs of consultations, which in their case was high.

The work presented in this thesis is located much further along the patient's health trajectory than those of Nelson and Palsbo or Smith and colleagues. Patient data are already present and the telehealth event can draw on existing patient-clinician relationships. Nelson and Palsbo made an interesting observation about the role of the "presenters" (their term for the assistants located remotely with the patients) who "needed to be socialized to the rationale for strong research design in order to encourage strict adherence to the protocol" and they noted the resulting difficulty of using real-life presenters in their research. They also wondered whether the clinician and patient could develop sufficient rapport during the telehealth session to adequately complete the diagnostic interview.

By contrast, in the hospital pilot trial described in this thesis the consultations occurred in the context of an existing relationship between the surgeon and patient/family. The research design was for the consultation to proceed naturally and appropriately for the particular patient's situation. The role of the presenters (i.e. clinic assistants) was to look after the best interests of the patients according to their own professional judgement and the research was based on observing what they actually did. Smith and co-authors do not discuss the interactions between the specialist and remotely located patient, family and assistant other than to note that the specialist could "undertake a complete patient history and ask specific questions during the videoconference appointment".

2.6 Computer supported cooperative work

2.6.1 Media Spaces – video based telecollaboration

Telehealth systems that link clinicians and patients via video and audio streams can be regarded as "media spaces". The concept of a media space, linking separately located groups of people using real-time video and audio communications, arose from "a concern for both the social and technical practices of collaborative work" (Bly, Harrison et al. 1993) and it is this concern for both the social and technical practices that makes a media-spaces approach relevant as the basis for building a broadband telehealth system. Mackay cites the first use of the term "media space" by R Stultz and colleagues at Xerox PARC in 1986 (MacKay 1999). The concepts presented in this media spaces work are directly applicable to broadband telehealth for tertiary outpatient consultations because the underlying face-to-face model for these consultations is a room-based model.

The original intention of the Xerox Media Space was to support "informal types of communications that occur in hallways and common areas" and an important design feature was that "the [video and audio] connections were always there" (MacKay 1999). They linked people who already knew each other and they were intended for long-term use. Behaviour and ways of using them developed over time, evolving through the "use of the link rather than through *a priori* … design" (ibid.). Examples include a 30-node audio and video network within a large R&D network called "CRUISER" (Fish, Kraut et al. 1992; Fish, Kraut et al. 1993), the "RAVE" video environment at EuroPARC (Gaver, Moran et al. 1992), the "Portholes" system at PARC and EuroPARC (Dourish and Bly 1992) and a system which connected colleagues located in two American cities, Portland (Oregon) and Palo Alto (California) (Bly, Harrison et al. 1993). Long-term studies looked at office-to-office connections (Adler and Henderson 1994; Dourish, Adler et al. 1996).

Other media spaces researchers used short-term studies to explore the way a media space environment might be used for more active collaboration over a specific task. Gaver argued that the "affordances" of the video and audio technology should be studied to "complement … analyses which emphasize social and cultural influences" (Gaver 1992). He and colleagues conducted a study which explored these affordances using what they called a Multiple Target Video system, in which users could switch the displayed view from multiple cameras located in the remote site (Gaver, Sellen et al. 1993). The study involved participants who were located in each of two rooms linked as a media space and who undertook two collaborative spatial-awareness tasks ("room drawing" and "furniture placement"). Subsequently these tasks were extended (Heath, Luff et al. 1995; Heath, Luff et al. 2001) in a series of Multiple Target Video experiments.

Gaver and co-authors (Gaver, Sellen et al. 1993) observed that a single face-to-face or close-up view is not enough to support a collaborative task. They concluded that there is a need for an overview of the people involved, showing the context of the task being performed, and also for a detailed-view of the task itself. In this paper they drew on their observations of participants working on shared experimental tasks to conclude that the multiple views from one room into the other gave a discontinuous representation of the space in the room being viewed. They were, however, working with two limiting factors:

- Even though they had more than one video camera installed in the remote room, hardware and space limitations meant that they were only able to view one image at a time on their video monitor in the near room. This meant that the viewing direction onto the monitor in the near room did not represent the camera direction of video cameras in the remote room.
- They were fitting their video cameras and monitors into already crowded office spaces and so did not have the options of matching the viewports of the cameras to meaningful directions of viewing from within the other room.

In constructing our telehealth application we, too, concluded that we would need multiple views of the spaces and multiple views of the data and workspace from the patient's room. Because we were designing the furniture for an empty room, we did not have the constraints of fitting multiple cameras into already crowded office spaces. We were able to reduce the level of spatial discontinuity by aligning our close-up displays with room overview display. In addition we installed multiple viewing monitors which were always turned on. This removed the temporal discontinuity seen in their installation with its single main monitor and video switch.

Gaver and co-authors (ibid.) made another observation that highlights a difference between a laboratory media spaces experiment with volunteer participants and a real-world media spaces application being used in its actual context. They note that their laboratory participants "rarely used the face-to-face views" and that "even more rarely were they truly 'face-to-face' with both members simultaneously using the face-to-face views (about 2% [of the overall time])". In our hospital trials, the interpersonal relationships between surgeon and patient/family and the dialogue concerning past experience and future expectations dominated the outpatient consultations, as was seen in extensive use of the close-up video links that supported face-to-face dialogue.

Shared access to actions, artefacts and frames of reference

Heath, Luff and colleagues published a sequence of papers on laboratory media spaces experiments (Heath, Luff et al. 1995; Heath, Luff et al. 2001; Luff, Heath et al. 2003). In the 2003 paper they focus on strategies for dealing with what they refer to as "fractured ecologies". These strategies were intended to support mutual understanding amongst participants in the media space as they go about whatever tasks they have been assigned. They include support for the following:

- The ability to determine the location, orientation and frame of reference of others
- Determining their standpoint with regard to other participants

- The ability to discriminate the actions of others when these actions involve shifts in orientation and reference to the space
- Reference to objects and features of the space in a way that coordinates with the real-time actions of others
- Provision of a stable constellation of relevant objects, artifacts and scenes within the spaces (Luff, Heath et al. 2003)

Robertson, in her paper on the "public availability of actions and artefacts", approached the problem from the "perspective of technology design" (Robertson 2002). She began with a quote from an earlier paper by Moran and Anderson which noted that "people deal with a complex environment by *not attending* to most of it most of the time" (Moran and Anderson 1990) and then quoted from Suchman, whose premise was that, for participants in a particular situation, their perceptions of phenomena are related to "a publicly available, collaboratively organised world of artefacts and actions" and that the significance of these artefacts and actions and the "methods by which their significance is conveyed" are directly related to the specific circumstances of the situation (Suchman 1987).

Robertson explained that, for participants to be aware of something in a collaborative process, it must be "publicly available to them" and this availability depends on the "perceivability" of the artefact or action. She further explained that this depends on the way that the significance of the artefact or action is conveyed in practice and that this significance differs for different people involved in the situation.

This concept is important for telehealth delivery of outpatient consultations, where there are multiple participants, each with their own point of view and their own understanding of the situation. Two examples from our hospital trial illustrate this point:

- When surgeons (remotely located with respect to the patients and families) and clinic assistants (located with the patients) were examining patients we often saw a rapid exchange of questions, instructions and observations couched in formal medical Latin, describing attributes of the joints, muscles and tendons. Although both clinicians and parents had access to the same data (spoken words, voice tones, video images) the significance varied. To the clinicians, these actions, observations and video views of the patients had significance in terms of their mental model of the patients' internal anatomy and of the patients' surgical histories. To the parents, these actions signified the process of gathering data about their children's conditions which supported their confidence in later discussion between them and the surgeons.
- One examination focused on the externally visible posture and gait of the child and the surgeon explicitly included the parents in the discussion during the examination by using lay terminology. In this example, the situation gave public access (i.e. for all participants) to the details of the patient examination and the surgeon, assistant and parents discussed the examination and conclusions together.

Robertson emphasized that if participants in a cooperative endeavour are to own the process of structuring the interaction then they need to be aware of what other people are doing, and of the artifacts in the workspace. She said that designers of collaborative systems should "explicitly and deliberately" support this awareness (Robertson 2002).

An observational case study of medical team meetings conducted between two hospitals highlighted these issues, observing the satellite medical team's frustration with the single video link that prevented them seeing both the people present and the clinical artefacts under discussion at the major hospital (Kane and Luz 2006). Kraut and co-authors emphasised the importance of participants at both sites having a shared view of the task space. They conducted experiments using collaborative remote repair of machinery as the experimental task and concluded that "… shared visual space is essential for collaborative repair because it facilitates situational awareness and conversational grounding" (Kraut, Fussell et al. 2003).

Space and place

Harrison and Dourish discussed the difference between "Place" and "Space" in collaborative systems and their roles in collaborative system design (Harrison and Dourish 1996) and revisited the issue a decade later (Dourish 2006). In a media spaces context, "Space" is the sum of the physical rooms and the spatial metaphors ("… desks, offices, hallways…") created by the placement of audio/visual equipment or implemented by software. "Place" is the sum of "cultural understandings about behaviour and action" associated with the Space by mutual agreement among the participants.

Both concepts are important in designing a media spaces application such as our telehealth system. The space needs to be able to accommodate:

- The physical requirements of the participants: examples are a large turning circle for wheelchair patients, room for an extended family to be present during the consultation, room to complete an active examination of the patient
- The logical spatial requirements relating to placement of the representation of the remotely located surgeon within the patient's room.

The sense of "place" for our telehealth system inherited much from the sense of "place" for the hospital itself. For example, there was continuity of the outpatient appointment process where the patients were re-directed to a patient reception centre close to where we conducted the trial, and from where we called patients in the normal manner. We researchers modelled our dress and behaviour on our observations of clinic observers – conservative formal dress, hospital security ID on lanyard, sitting back in the clinic and leaving the action to the clinicians – so that we filled a clinic observer role with which the patients were familiar.

Privacy

Notions of privacy in a media spaces setting are linked with those of "place". Bellotti and Sellen discussed designing for privacy, including being aware that you are on-camera and being aware of the people at the remote site who are off-camera (Bellotti and Sellen 1993). Boyle and Greenberg presented a general vocabulary for talking about privacy in terms of the aspects that a person might wish to control in a media space situation. They discussed three basic elements of privacy: how a person regulates their social interactions, how a person manages others' access to information about themselves and how they comport themselves so that they match the norms for the particular social situation (Boyle and Greenberg 2005). Palen and Dourish presented the issue of privacy in terms of "the continual management of boundaries between different spheres of action and degrees of disclosure within those spheres" (Palen and Dourish 2003).

Dourish and Anderson drew attention to the “social and cultural practices that lie beneath technical specifications of privacy and security” (Dourish and Anderson 2006). The social and cultural practices are well established for outpatient consultations in any particular cultural setting, covering physical exposure of one’s body as well as personal exposure of data about oneself. In the relatively homogenous setting of our hospital trial, where both patient and surgeon were actually in the same hospital building, this may not be an issue. In situations where the telehealth delivery crosses cultural boundaries, as it already does in the emerging global environment, it is important to pay attention to the local “social and cultural practices” relating to privacy at both ends of the telehealth link.

Video-based remote guidance

Video-based remote guidance forms an important part of our telehealth system, both in terms of remote guidance of physical actions or attention to objects in the actual space, and in terms of remotely guiding people to pay attention to and understand abstract information such as diagrams, photographs and X-rays. Early work in this area was done by Ishii and colleagues with the “Teamworkstation” system (Ishii and Miyake 1991) and “Clearboard” (Ishii and Kobayashi 1992) using a shared drawing surface and face-to-face eye contact, and by Kuzuoka and colleagues with “Sharedview” (Kuzuoka 1992), using an approach of manipulating objects in a workspace.

Kuzuoka and colleagues extended their work to construct a series of remote guidance systems: GestureCam (Kuzuoka, Kosuge et al. 1994), GestureLaser and GestureLaser Car (Yamazaki, Yamazaki et al. 1999) and GestureMan (Kuzuoka, Oyama et al. 2000; Heath, Luff et al. 2001). These systems involved remote control of steerable cameras, remote control of the direction of laser pointers and, in the case of GestureMan, laser pointers and cameras mounted on a mobile remotely-controlled robot. The experiments raised issues of the public availability of artefacts, shared frames of reference and mutual understanding of each other’s viewpoints; these issues are similar to issues raised in the context of media spaces as described above.

A particular issue that these papers discuss is the difficulty of remote shared access to the reflected dot of a laser pointer. The dot is small, relatively low in intensity due to eye safety requirements and, as the laser traverses a scene, the dot appears to local observers to have discontinuous motion due to the 3-dimensional nature of the objects in the scene that would reflect it. These issues arose when we constructed our laser-based guidance subsystem. We had the advantage of a laser system which could sustain a drawing mode, so that we were able to draw vector-graphics-based shapes, such as a circle with cross-hairs in it to represent a cursor, and we defocused the beam to give a broader patch of colour on the target. We also restricted our studies to a contained workspace which reduced the opportunities for the “cursor” to disappear.

Kuzuoka and colleagues, in their paper on GestureCam, foreshadowed the importance of including face-to-face communication between participants in an application of remote guidance (Kuzuoka, Kosuge et al. 1994). They used as an example an industrial setting with an expensive digitally controlled milling machine. The remotely located instructor and local operator needed to be sure of each others’ understanding of the instructions before going ahead with them because the consequences of a misunderstanding could be expensive. The authors discussed the concept of a sympathetic interface:

> In the case of remote instruction, if operators and an instructor can feel sympathy with each other, operators will listen to an instructor's instructions carefully and they will be able to ask questions frankly; therefore an instructor will be able to give instructions more efficiently (ibid.)

They proposed that a face-to-face link between operator and instructor would enhance this feeling of sympathy between the two.

This contrasts with observations by Gaver and colleagues (Gaver, Sellen et al. 1993), noted earlier in this section, that the participants in their experiments made minimal use of the face-to-face views. This observation again highlights the difference between participants performing an experimental task that is isolated from their real-world activities and participants working in the context of a real-world application task.

Various technologies have been used to support gesture-based remote guidance. The DOVE system (Ou, Fussell et al. 2003) used drawing over live video of the task space. Bauer and colleagues presented a head-mounted display with attached camera, with pointing gestures from the "expert" being displayed to the "worker" via the display (Bauer, Kortuem et al. 1999). The "Sharedview" system had a similar head-mounted camera and display (Kuzuoka, Kosuge et al. 1994). Kurata and colleagues presented a shoulder-worn camera and laser system (Kurata, Sakata et al. 2004) worn by a "field worker". A remote expert could pan and tilt the camera and the laser pointer. A feature of this system was that the expert's pointing gestures appeared in the workspace of the "field worker". The authors hypothesized that "the laser spot will allow the fieldworker to remain focused on the task space rather than having to look at a video of the workplace in a head-mounted display".

A series of experiments have explored the use of remote guidance in laboratory settings. Fussell and colleagues conducted experiments with both pointing and drawing gestures over video of the task space and measured variables such as time-to-completion of the task (Fussell, Setlock et al. 2004). They implemented both manual and automatic erase of drawings. Kirk and colleagues conducted experiments on remote gestures to support remote physical tasks (Kirk, Crabtree et al. 2005; Kirk, Fraser et al. 2005; Kirk and Fraser 2006) in which they compared various types of remote gestures. Performance metrics included time to completion, accuracy of completion and number of mistakes made during the tasks. Kraut and colleagues measured task performance and also measured the extent to which conversations between the participants were grounded, which refers to there being evidence of common ground between the participants in their dialogue (Kraut, Fussell et al. 2003).

In contrast to these experiments, the laboratory studies presented in this thesis placed the remote guidance tasks in the wider context of a collaborative approach to a task, paralleling the real-world application that would become the focus for the trials of our telehealth system. In this real-world application, gestures were integrated into the overall task of conducting an outpatient consultation in which success was measured in terms of examining the patient, agreeing on an interpretation of the examination in the patient's historical context and devising a treatment or management plan for the subsequent time period. Assembly-line performance metrics on the gesture components were not appropriate in our setting.

2.6.2 Collaborative work and health applications

Health trajectory

Collaborative work in a healthcare environment requires tools and support for communication between the participants whether the collaboration is collocated or via a telehealth link. One such tool is the "Corbin and Strauss Chronic Illness Trajectory Model", originally published in 1991 and updated by Corbin in 1998 (Corbin 1998). In this model, the "trajectory" maps out the various phases of the clinical conditions (from pre-trajectory through to dying) and describes "the actions taken by various participants to shape or control that [trajectory]". The concept of illness trajectory was initially intended to provide a tool for nursing staff to manage the care of the patient.

Reddy and colleagues demonstrated the use of the health trajectory concept in their analysis of whole-of-treatment of patients in a surgical intensive care unit, citing earlier work by Anselm Strauss (Reddy, Dourish et al. 2006). They identified three temporal features - temporal trajectories, temporal rhythms and temporal horizons – which they use to frame their observations. Their temporal trajectories concern the events associated with a particular patient. Temporal rhythms are the aggregated patterns over many patients that help the healthcare providers frame plans and expectations and temporal horizons are the equivalent of mental Gantt charts that identify the critical temporal path for delivery of patient care. Their temporal trajectories correspond to those of our hospital patients but at a different time scale – six days versus several years – and different temporal rhythms apply to any one patient at different points on their trajectory.

In our work with paediatric surgical patients at the Royal Children's Hospital we had a similar concept of a health trajectory starting with referrals from primary or secondary healthcare providers and finishing with discharge of the patient. We used this concept to identify patients at a particular point on the trajectory to be invited to take part in our telehealth trial (for example post-operative, surgical rehabilitation progressing according to normal expectations and scheduled for review consultations). In terms of conducting a long-term clinical trial of our telehealth concept, we would also use this concept to identify points in the future part of a patient's trajectory, where they might be suitable for telehealth consultations even if, at the current moment, their situation required face-to-face treatment.

The evaluation of the pilot trial also drew on this trajectory concept. For each patient on a trajectory, there is a past and there is a future. The past will typically contain memories of a number of previous face-to-face consultations because the complex surgical treatment provided at this tertiary level of healthcare has long treatment and rehabilitation times. This equips the patients and their families to competently judge the qualities of the telehealth consultations that we provided for them during the trial. The future also will be mapped out, with whatever combinations of certainty and uncertainty, in the minds of the patients, families and clinicians. This equips the people concerned to judge the outcomes of these telehealth consultations in terms of matching the treatment or management plans and adjustments to the trajectory with their expectations.

Medical team meetings via videoconference

Kane and Luz studied multi-disciplinary medical team meetings between a tertiary hospital and two regional hospitals using a proprietary product that supported this type of meeting (a "Telesynergy" workstation) (Kane and Luz 2006). The primary data for the meetings - radiology and pathology images - were visible to participants at the main hospital and could be seen by participants at the remote hospital by switching the single video stream from showing participants to showing the data item. They observed that, for the participants at the tertiary hospital, it was important for participants to see the radiology and pathology images and also see the remote people, regardless of the stage of the case discussion, and that during case discussions across the teleconferencing link people benefited from seeing each other. They conclude that "these findings make a strong case for the use of multiple displays at an MDTM [Multi-Disciplinary medical Team Meeting] in teleconference". In terms of picture quality they noted that, when all three hospitals were participating, the system was able to display video from both of the other two sites but that the picture quality was poor. This became important when a remote participant needed to follow a discussion between people at the main hospital. The audio quality varied with distance from microphones and it was not easy to tell who was speaking to whom.

Kane and Luz defined their Multi-Disciplinary medical Team Meeting (MDTM) structure as a system within the overall process of managing the patients, occurring after the preliminary preparation for the meeting, being conducted in a synchronous fashion amongst the participants and being followed by further dispersed post-meeting activities (ibid.). They wrote explicitly about the boundaries between this "MDTM" system and its "external environment" and used this system concept to structure the language with which they discussed its components.

Li and colleagues also addressed multidisciplinary medical team meetings through an observational and interview study of cancer clinicians working between two hospitals (Li, Robertson et al. 2008). They identified the issue of social cohesion of the group as a whole (i.e. participants from both ends of the videoconferencing link) and found problems of visibility, identity and audibility of the remote participants. Their analysis showed that "the lack of awareness of [the] remote situation could affect the spontaneous interactions and open discussion". They suggested that these problems could be dealt with by paying attention to the video and audio production qualities of the rooms used and even by "constructing a built-for-purpose configuration in this specific context". Their second finding related to shared access to the medical images and the need for some form of shareable pointing device. Access to this data was of high importance to the decision-making process of the meetings. They noted that, at the time of writing, the two hospitals involved stored this form of imagery in hard-copy because neither had a Picture Archiving and Communication System (PACS) for digital storage and retrieval.

The observations in these two papers emphasise the need for providing adequate video and audio quality in a room-based telehealth application. They also emphasise the need for adequate video and audio coverage of the rooms.

Training to use telehealth systems

The issue of training the participants involved in a telehealth research project is not covered extensively in the literature. For example, Huis in 't Veld and colleagues conducted a systematic review of the methodology of telemedicine evaluation for their particular field, selecting 22 papers from an initial retrieval of 549 papers to meet criteria which focused on interaction between patients and clinicians (Huis in 't Veld, van Dijk et al. 2006). They make no mention of the training processes which led to the conduct of these 22 trials.

Many case study reports assume implicitly that the clinicians are competent to use the technology. Often these clinicians are the same people that designed the telehealth research activity. Where the patients become active participants over, say, a longitudinal study, they may receive training. An example is a tele-monitoring system for childhood asthma (Jan, Wang et al. 2007), where the patient and family were given explicit training in using the electronic peak-flow meter and in using the website to complete daily logging. In cases where the technology to support the telehealth activity is new to the participants, training may be given explicitly. This was the case for remote delivery of Cognitive Behaviour Therapy, where the remotely located case managers were given a dedicated training session (Griffiths, Blignault et al. 2006).

Training to manage interpersonal relationships at a distance is not often mentioned. In one report, where a general practitioner conducted clinics for remotely located patients supported by a clinic nurse, 30 consultations formed the basis of the paper. Most of the discussion concerned the difficulty that the doctor and nurse had in communicating with each other, a situation which might have been resolved earlier or prevented with appropriate training in managing their professional relationship over distance (Torppa, Timonen et al. 2006).

Prior to deploying the Virtual Critical Care Unit (ViCCU) the clinicians from Nepean and Blue Mountain hospitals spent two months training the teams in both hospitals using full role-play with instrumented anaesthetic manikins in place of the patients. This training extended the skills of the regional hospital's nursing staff, taught all participants about using the technical features of the system and established how the participants would relate to each other over the broadband telehealth link (Dr Laurie Wilson, pers. comm.) (Li, Wilson et al. 2006; Westbrook, Coiera et al. 2008).

Distance

In their paper titled "Distance Matters", Olson and Olson reviewed "over 10 years of field and laboratory investigations of collocated and non-collocated synchronous group collaborations" (Olson and Olson 2000) and highlighted four key concepts: common ground, coupling of work, collaboration readiness and collaboration technology readiness. While they discussed collaborative work in general and used examples of collocated or distributed teams working in industrial settings the concepts can also apply to telehealth. They made a number of relevant observations:

- Human interaction has a spatial component, with gestures at people and objects and abstract gestures illustrating concepts or processes. In our telehealth consultations there is a focus on the patient and on data about the patient which is expressed in movement, gesture and words. There is also a high level of interpersonal communication supported by gestures to express concepts such as concern, persuasion, devolution of responsibility, optimism and understanding.
- They note that "universally, in our fieldwork, people complained about the quality of communication over audio and video conferences". This observation reinforces findings in other studies that high-quality video and audio links are important in telehealth applications (Shimizu, Nakashima et al. 2009).

- A major observation in their discussion is that “possibly the single biggest factor that global teams need to address is cultural differences”.

Interpersonal communication

Nardi drew attention to three “dimensions of connection” between participants that support their readiness to communicate with each other – affinity, commitment and attention (Nardi 2005). She used studies of the use of Instant Messaging in the workplace and of “personal social networks in the workplace” and her dimensions of connection drew on existing relationships between pairs of participants. Tang raised the issue of “negotiating contact in computer-mediated communication” (Tang 2007). This is an important issue in tertiary-level telehealth applications which rely on the relationships between patients and clinicians.

3 Methodology

3.1 Overview

I explored the research direction for this thesis with a series of case studies (Section 3.2) involving participants engaging in a telecollaborative scenario. The studies were broadly structured around an approach used in Media Spaces research (Section 3.3), where participants are placed in a telecollaborative situation and asked to undertake certain tasks, with various levels of prescription on how they should perform those tasks. Observational and interview data form the base material for the analysis. I analysed the observational and interview data from my case studies using methods drawn from Grounded Theory (Section 3.4). For the hospital case studies, the relationship between the CSIRO research team and the hospital staff followed an Action Research model (Section 3.5).

The evaluation approach in these studies focused on the participants, on what they did and on what they reported in exit interview responses. I used the broad concept of acceptability to construct the exit interviews, tailoring them to the situation for each group of participants. This concept was broad enough to encompass professional acceptability (for example, whether the clinical outcomes were acceptable to the surgeon) and personal acceptability (for example, whether the parents were satisfied that their child had been adequately cared for). I used observational data to understand the priorities and issues of importance for each of the participants.

3.2 Case-study approach

I chose a case-study approach to evaluating the main work presented in this thesis. This approach allowed me to focus separately on the different stages of the development and pilot trial of the telehealth system that my colleagues and I produced in partnership with staff of the Department of Surgery at the Royal Children's Hospital in Melbourne. My purpose at each stage was to explore the use of a human-centred approach to evaluating the work. The case studies are listed in Table 1.1 and their relationships to the laboratory and the hospital are shown in Figure 1.1, both located in Chapter 1.

Robson used the term "case study" to mean:

> … a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence. (Robson 1993).

He noted that "the case is studied in its own right, not as a sample from a population" and that the sources of evidence commonly produce both quantitative and qualitative data. I treated the evaluations of the phases of the development of the telehealth system as separate case studies.

Each study was conducted in the context of its stage in the development and pilot trial of the telehealth system. In turn, this pilot trial was conducted in the wider context of a working tertiary hospital. These nested contexts were important for two reasons:

- Within the overall telehealth project the individual case studies had a specific purpose. The three laboratory studies were conducted to establish the progressive suitability of the work at those particular points in time. The three hospital studies were conducted to investigate how the participants would adapt to and respond to the use of the telehealth system for actual clinical work.

- The wider hospital context influenced both the laboratory and hospital studies. The laboratory studies were conducted using tasks that were representative of the actions that we had observed during our early field observations at two hospitals. These studies were evaluated by matching their outcomes with our observed or inferred requirements of hospital outpatient consultations. The hospital studies gave proper access to the actual patients and their clinicians and to current and historical patient data. In addition, they gave access to the ambience of the hospital, including the location of facilities within the hospital, procedures for managing patients and attitudes to the patients and their families.

3.3 Media Spaces

All of the case study situations can be described as “media spaces”, a concept described in detail in Section 2.5.1. I have followed the broad approach within the Computer Supported Cooperative Work community for researching media space situations wherein participants in the research are placed in the “space”, i.e. in the two or more rooms that are connected by audio and video links, and they are then observed as they conduct whatever collaborative activity it is that they are to do.

As described in the previous chapter (Section 2.5.1) there have been two broad variants on this approach. In one approach the participants are colleagues in some wider enterprise, such as a university research department, studied over periods of months or years. The media spaces link is set up in the background of the participants’ attention, is always turned on, and it mimics their remote colleagues being present in an extension of the room. The other approach is to explore technology components that have been incorporated into an instance of a media space, such as multiple cameras and remote laser pointers. Participants, recruited for relatively short-term studies, are given certain tasks to perform with their remotely connected counterparts under a range of study conditions.

In my work I used both of these approaches. In both the laboratory studies and the hospital studies the participants had specific tasks to perform. The observations and exit interviews provided data about how those tasks were performed in the context of the telecollaborative system. The participants had emerging or pre-existing relationships with each other. An important aspect of the case studies in this thesis was observing how the participants drew on those relationships to complete the work that they had to do.

In the laboratory studies the participants were generally strangers to each other. The experimental tasks, however, were designed to require collaborative behaviour between participants at each node of the telecollaborative system. The purpose of these experiments was to foster that collaborative behaviour in order to be able to make inferences about the system. For these studies, the physical layout of the room and equipment represented the intended layout of the telehealth activities, the experimental tasks were abstractions of component tasks drawn from observations of actual consultations and the evaluation of these experiments was done with respect to the intended purposes within the telehealth system, as described in Chapter 5.

In the hospital studies, the participants mostly had pre-existing relationships with each other: surgeon with clinic assistant, surgeon with patient/family and sometimes clinic assistant with patient/family. There was emphasis both on the way the pre-existing relationships supported the activities and on the activities (i.e. outpatient consultations) themselves, though the time-frames were much shorter than in traditional media spaces studies.

3.4 Grounded Theory approach

A Grounded Theory research approach involves developing a theory/model/explanation about the situation under study by grounding that theory/model/explanation in the results of the data analysis. This is in contrast to other research approaches, sometimes called "positivist" or "scientific", where a theory/hypothesis about the situation is available from the start and is tested against the data gathered. In a Grounded Theory approach, the data analysis begins as soon as data is available, an early understanding/explanation of the situation under study is developed and, if there are gaps in the understanding, then data collection may be targeted specifically to fill them. This again is in contrast to hypothesis testing approaches where, typically, randomly sampled data is intended to represent the entire population under study and effort is actively spent to avoid skewing the sampling of the data (Corbin and Strauss 2008).

Major case study at Royal Children's Hospital, Melbourne

My approach to analysing the exit interview data and the video data from the Royal Children's Hospital case studies broadly followed the Grounded Theory approach described by Corbin and Strauss in the third edition of their book on qualitative research (Corbin and Strauss 2008). Exit interview data were collected immediately after the patient and family had taken part in the telehealth phase of the outpatient consultation with the surgeon and the face-to-face phase with the same surgeon. Video recordings were made of both phases of the consultation and the exit interviews were audio-recorded. From this data I aimed to assemble an understanding of the participants' responses to this experience – patient and family, surgeon and clinic assistant.

We had observed an existing pattern in normal face-to-face consultations [greetings, review progress since previous consultation, raise concerns, patient examination, review radiology or other data, propose and agree on a treatment or management plan for the next time period, final call for questions, close]. We designed the telehealth system to support this pattern. While I was able to use knowledge of this pattern to understand what was happening during the consultations, I had no pre-conceived notions of how the participants would respond to the experience, or of the issues that they would flag as being important to them. I therefore developed my understanding of the situation through an evolving analysis of the data.

I analysed the exit interview data in late 2007. The interviews were designed to answer a number of questions about the participants' use of the telehealth system and their personal experiences with it. The questionnaires (Appendix A) began with a few Likert-Scale items about features specific to the participants' situations, followed by semi-structured questions intended to get a broader explanatory response from the participants. The responses to the Likert-Scale items and the Yes/No inferred responses from the answers to the semi-structured questions were tabulated to give an initial picture. The audio recordings of these interviews were transcribed and the transcripts used as raw data for a coding/category/concept/memo process which drew out aspects of the participants' situations that explained their positive, negative and sometimes apparently contradictory responses to the questionnaire items. This analysis is described in detail in Chapter 11.

I analysed the video data in mid 2008, following the Corbin and Strauss approach more closely. The purpose of analysing this data was to see what the participants actually did and said during the telehealth and face-to-face phases of the consultations. My knowledge of the basic pattern of these consultations assisted me in understanding what happened during the consultations. In addition, I had been present in the patient's room for about half of the consultations as an observer (and dealing with occasional technical resource issues) so I had first-hand knowledge of the way the surgeons had managed the telehealth and face-to-face phases of the consultations.

I watched the video recordings for each session, first from the camera in the patient's room then from the camera in the surgeon's room. For each recording, I made time-coded notes about actions, events or behaviour, including transcribing fragments of conversation to illustrate what had happened. These notes became the raw data for coding. For consistency, I followed the clinics of each surgeon, observing how their use of the telehealth system and their allocation of time and tasks between the telehealth and face-to-face phases evolved over the trial. I started with the surgeon who had conducted the most clinics and finishing with the two surgeons who conducted only one clinic each. From these codes I developed concepts and themes that were present across multiple consultations and captured these in memos. Where possible I referred to the coding that I had performed on the transcripts of the exit interviews. This evaluation component is described in detail in Chapter 12.

Telehealth system training case study

The data for this study consisted of video recordings of the one-hour training sessions conducted for the clinical staff in the week prior to the pilot trial, supplemented by some brief field notes that I wrote during that week. I viewed the video recordings in May 2008, several months after the training sessions, and made notes on each session which served as my raw data for coding.

My colleague, with whom I conducted the training sessions, and I had had no strong preconceptions of what would happen during these training sessions. Our intention was to loosely base the sessions on our prior experience of giving demonstrations of the telehealth system to visitors, and to include information about the protocols for the pilot trial. In the event, the training sessions were very much driven by the clinicians themselves as they took a hands-on approach to working out how they were going to use the system for their particular specialties. The purpose of analysing the video recordings was to understand what they actually wanted and how they went about achieving it. I used a coding/concepts and themes/memos approach to analysing the raw data; the results are presented in Chapter 10.

Remote live surgery presentation

The data for this preliminary study consisted of video data and exit questionnaires. A room overview camera, located with the audience in Sydney, captured the dialogue from each site. It also captured the actions of the audience, the 3D projected display of the surgical site and the displayed communication video stream from Stanford. The communication video stream that was captured by a camera at the front of the audience's room was recorded, as were the actual communication video stream from Stanford and one channel of the 3D view of the surgical site.

The exit questionnaires recorded the audience members' professional opinions about this mode of presenting live surgery in a training situation. The video recorded the actions of the audience, their focus of attention and their remarks made during the session. I made notes from the video and used these as raw data for coding and developing concepts and themes. The results of this analysis are presented in Chapter 4.

Theoretical sampling

The concept of "theoretical sampling" is an important part of the Grounded Theory approach (Clarke 2005).

> Theoretical sampling has been integral to Grounded Theory from the outset, remains a fundamental strength of this analytic approach, and is crucial for situational analysis (Prologue, p xxxi).

As Corbin and Strauss explained in Chapter 7 of their book, in a Grounded Theory approach to research, analysis begins as soon as practical using the initially gathered data (Corbin and Strauss 2008). As concepts or themes emerge from that data which require further development, additional data is sought which is intended to shed further light on those concepts. In defining theoretical sampling they said:

> The purpose of theoretical sampling is to collect data from places, people and events that will maximize opportunities to develop concepts in terms of their properties and dimensions, uncover variations, and identify relationships between concepts (p 143)

In contrast to a random sampling approach, where researchers aim to characterise a whole population through that sample in order to address some pre-defined hypothesis about that population, theoretical sampling is driven by the emerging concepts from earlier analysis of the already-collected data. In this spirit, and at the suggestion of the Chief of Surgery at the hospital, we modified our plan prior to the trial to include patients from four surgical specialties rather than just the original specialty with which we had been working. This was done not in any sense to get a "representative" sample of surgical patients but rather to broaden the variety of patients and therefore broaden the variety of clinical demands that would be placed on the telehealth system.

Corbin and Strauss addressed the situation where all the data has been collected before analysis begins. Although the team conducting the trial discussed the experience of taking part, and of conducting the exit interviews, we did not have the resources to conduct any serious analysis of the data until after the trial had finished. During the time that I spent analysing the interview data I found myself doing as Corbin and Strauss suggested and returned many times to previously analysed data for a fresh look at concepts that had since emerged. When analysing the video data some time later, I revisited both the video data and the interview data.

Within the constraints of the plan for the pilot trial, we were able to make one change to the data sampling. By the third week we had not completed our quota of allowed patients and we had additional patient volunteers for one clinic. The surgeon in charge decided to double the number of patients he would schedule for that clinic to explore what it was like to use the telehealth system under a near-to-normal patient scheduling load.

Corbin and Strauss observed that theoretical sampling can include augmenting field data with other forms of data. In both the hospital trial and the earlier surgical presentation case study, I used follow-up telephone interviews with selected participants to fill gaps in my understanding of the situations. In the telehealth system training case study there was no opportunity to train additional staff but there was an opportunity to use observational data from the pilot trial to follow up on some of the expectations voiced during the training sessions by the clinicians about using the system.

3.5 Action Research

Defining or describing Action Research

In the introduction to their “Handbook of Action Research” Peter Reason and Hilary Bradbury said that “there is no ‘short answer’ to the question, ‘What is Action Research?’ (Reason and Bradbury 2001). They listed phrases that might be used in a working definition, such as “a participatory democratic process” and “developing practical knowing in the pursuit of worthwhile human pursuits”.

Ernest Stringer began his book on Action Research with:

> Action research is a systematic approach to investigation that enables people to find effective solutions to problems they confront in their everyday lives. Unlike traditional experimental/scientific research that looks for generalizable explanations that might be applied to all contexts, Action Research focuses on specific situations and localized solutions. (Stringer 2007)

Reason and Bradbury said in the preface to their Handbook of Action Research:

> The Action Research family includes a whole range of approaches and practices, each grounded in different traditions, in different philosophical and psychological assumptions, pursuing different political commitments.

In the foreword to Stringer’s book, Egon Guba described Action Research, and in particular the community-based Action Research on which Stringer focused, as a form of “*human* inquiry” that exhibits decentralisation, deregulation and cooperativeness in execution, and he defined these terms in detail. Stringer himself emphasised a further feature of Action Research that differentiates it from research based on a hypothesis-testing approach, which is that Action Research should deliver a tangible outcome to the participants of the community wherein the problem being tackled resides.

To summarise, Action Research is typically focused on areas of human inquiry where:

- The participants (researchers and members of the community within which the research problem resides) work together to address the research problem;
- The research aims to find a local solution to the research problem which takes into account the specific characteristics of the situation at hand; and
- The research delivers a tangible benefit or outcome to the community.

The Royal Children’s Hospital pilot study as Action Research

Two consultant surgeons from the Royal Children’s Hospital in Melbourne approached my colleagues and me at the CSIRO ICT Centre in May 2005 to describe the situation facing their patients who lived outside Melbourne, which was that the effort of bringing their children into the hospital for outpatient consultations was placing a heavy burden on the children and their families. Based on field observations in the hospital and discussions with the surgeons, we researchers took the lead in developing a telehealth system that would meet the clinical and interpersonal requirements for conducting remote outpatient consultations, under guidance and review from the surgeons. During the pilot study at the hospital the roles were reversed, with the surgeons taking the lead as they conducted their outpatient clinics using the telehealth system under technical guidance and support from the researchers. In the exit interviews after each clinic, the surgeons and the researchers discussed together what had happened during that clinic and, where necessary, planned fine-tuning for subsequent clinics.

The aim of the project and the resulting pilot study was to explore the telehealth concept that had emerged from the interaction between researchers, surgeons and other clinical staff at the hospital in the very specific context of post-operative paediatric surgical outpatient consultations.

The benefit of this research project to the community of clinicians in the Department of Surgery at the hospital was two-fold. The evaluation of the pilot trial showed that it was indeed possible to conduct outpatient consultations of this type over a telehealth link and that those consultations could be satisfactory to both patients and clinicians. This evaluation is embodied in the initial report on the trial presented by CSIRO to the hospital in December 2007 (Stevenson, Hutchins et al. 2007). Based on this evaluation, the hospital approached the state government for financial support to develop a full clinical trial of this concept between it and one of the regional hospitals in Victoria. The second benefit accrued directly to the clinical staff involved in the project in that they now have direct personal experience of using a broadband telehealth system to conduct their clinical practice. This puts them in a situation where they can make judgements about issues of telehealth in their field based on their own experience.

In view of the three-point summary above, this research project can be regarded therefore as an Action Research project.

Involvement of the differing groups of participants in this research

There were three distinct groups of participants involved in this research – the consultant surgeons, the staff who took the role of clinic assistant, and the patients and their families. Each group had a different level of involvement and this involvement had different time frames:

Consultant surgeons. The consultant surgeons were involved at an early stage of this project and took an active part in shaping the way the system would support their work during the training sessions. During the trial they took the lead in running the consultations, within the limits and opportunities of the telehealth system, and engaged deeply with the researchers during the exit interviews. After the pilot trial they actively engaged with their hospital and state government to pursue funding for a one-year trial of this telehealth method. When I interviewed two of them nine months after the pilot trial, both reflected extensively on their experience during the trial. One commented, “We miss it more now than we did at the end of the trial”.

Clinic assistants. The staff who took the role of clinic assistant – registrars, surgical fellows, a clinic nurse and a specialist physiotherapist – had a different style of involvement in the trial. Within their role of clinic assistant, they took their responsibilities seriously in responding to the situation and the needs of their lead surgeon. They were generous and thoughtful with their comments in their exit interviews. When I contacted the hospital nine months later to request follow-up telephone interviews, most of these people had moved on to other roles within the public hospital system as part of their overall surgical training.

Patients and families. All the patients and families had agreed to take part in this research trial and played a supportive role during the consultation. In the exit interview, one parent observed that the hospital had been so good to her and her family during the treatment of her child's condition that she was glad that she could contribute something back by being part of the trial. While they engaged willingly during the 45 minutes of consultation and exit interview, there was no opportunity to engage with them prior to the trial and the trial did not last long enough to re-engage with them at their next appointment.

In addition to the three communities who took part in the trial there is a fourth community: the support staff within the hospital, who recruited the patients, scheduled them for our clinics, relocated them within the hospital and coordinated the clinicians around our pilot trial requirements. Supported by their close working relationships with the clinical staff, these people went out of their way to make sure the logistics of this trial were put in place and maintained.

From an Action Research point of view, these involvements and time frames will have a major bearing on the design and conduct of any future long-term trial of this telehealth concept. While the current pilot trial engaged with the community of surgeons in this particular hospital's Department of Surgery, it drew upon existing relationships (surgeons-junior surgeons, surgeons-patients and surgeons-support staff) and existing goodwill to carry the other participants into and through the trial. If a year-long trial between two different hospitals (for example, the Royal Children's Hospital as the tertiary hospital and a regional Victorian hospital to host the remote patient's clinic) were undertaken then an Action Research approach would require the researchers to consider how to sustainably engage all four of these communities.

3.6 Participant-focused evaluation

The evaluation of the major case study at the Royal Children's Hospital focused on each group of participants in a different manner, based on the broad situation of each group.

The surgeons each had extensive experience in their particular specialty. They could see the whole of an individual patient's health trajectory in the context of many similar patients, corresponding to the temporal rhythms of Reddy and colleagues but on a time scale of years rather than a time scale of one week (Reddy, Dourish et al. 2006). In most cases the surgeons had existing relationships with the patients, reaching back to the start of treatment. Their focus was on conducting the consultation and reaching an agreed plan for moving forward in managing each patient.

The clinic assistants were generally less experienced in the particular specialties but were nevertheless able to place the patient's condition in the context of many previous patients. They did not necessarily have an existing relationship with the patient – some did, some did not. They generally had existing professional relationships with the surgeons but found themselves re-establishing those relationships in terms of using the telehealth system in collaboration with the surgeons, especially when conducting examinations of patients. Their focus was on supporting the surgeon-patient consultation and on presenting the examination of patients in an appropriate manner.

The patients and family had experience of their own health trajectory, including pre-operative consultations, surgery and recovery, and periodic consultations to manage long-term rehabilitation, often at three, six or twelve-month intervals. Many had interactions with other clinicians elsewhere in the hospital – allied health workers or specialists treating complementary aspects of their condition. Their focus was on the welfare of their children

Both surgeons and clinic assistants had an accumulating experience of using the telehealth system, starting with their training session and increasing as the trial progressed. The patients and families had no prior experience of using the system and the trial was too short to pick up repeat consultations for any of the patients.

These interleaving time lines, periodicities and ranges of experience and primary foci created a situation where there were multiple valid points of view of the same overall event. Participants were competent to answer questions of fact, questions of personal opinion or impression and to answer hypothetical questions about their future use of such a system.

The situation was near-to-realistic. The telehealth phase of each consultation was a genuine step in managing the patient's conditions. The face-to-face phase was equally a genuine opportunity to contribute to managing the patient's condition. The participants could, therefore, make judgements and comparisons both between the telehealth and face-to-face phases and between either of these phases and the prior outpatient consultations that they had experienced. They recognised the artificiality of the situation whereby the two phases were conducted within the same part of the hospital on the same day. They made choices to raise issues in one, the other or both phases of the consultation. They also gave seemingly contradictory answers in the exit interviews – for example, being hypothetically willing to have had that consultation in an actual remote setting if it had been available, yet insisting that the face-to-face phase was important on that day. These apparent contradictions were sometimes resolved by reaching outside the bounds of the trial to find issues of social closure for the children (for example, avoiding disappointing the child if he or she did not see their friend, the doctor, in person) or linking the availability of the face-to-face phase with other appointments scheduled that same day in the hospital.

Study designs for broadband telehealth

There is a wide range of possible study designs for telehealth research, ranging from early investigative studies through to randomised controlled trials (Friedman and Wyatt 1997). The choice of study design, however, is in the hands of the researcher and depends on the situation of the study, the research question, the maturity of the topic of the study, the data available and the audience for whom the study results are being prepared.

This range and choice should also be present for broadband telehealth. The situation of broadband telehealth for tertiary healthcare alters the scale of the situation but it does not necessarily mandate or preclude any particular study design. For example, frequently there is a high level of interpersonal interaction and multiple participants. This would give broad scope for gathering data on personal interactions and opinions. The time-frames of treatment are often long, which can give added weight to subjective judgements and comparisons from participants. The treatment trajectory can have differing phases, which may be more or less amenable to a telehealth implementation.

3.7 Human Research Ethics Committees

Gaining prior approval from the Human Research Ethics Committees (HREC) of the participating institutions is an essential part of conducting any trials of systems that involve human participants. This process protects the participants of the trials, it protects the reputations of the institutions involved and, by acting as an independent review process, it protects the researchers.

For the work presented in this thesis we had two separate ethics approval stages, one for our laboratory experiments and a second for our hospital trial. For the laboratory trials we dealt with ethics committees for both the Australian National University and for CSIRO. Because the laboratory experiments were conducted as part of a CSIRO-funded project we used the CSIRO ethics committee as our primary approver and the university's committee agreed to recognise their eventual approval.

An important point is that the ethics committee process is very formal. Ethics committees meet on a pre-defined schedule and cutoff dates for submissions to those meetings are generally advertised some time before the meeting to allow the allocated reviewer to assess the submission. It is, therefore, important for any research project that will require ethics committee approval to contact the committee well in advance of the proposed experiments and to prepare the submission to that committee in time for the appropriate cutoffs. In our case we needed at least two cycles of the ethics committee meetings to address the required revisions to our submission.

3.7.1 Laboratory experiments at CSIRO

The CSIRO ethics approval process was based on a series of pro-forma documents which we completed and sent to the committee for consideration. The committee's concerns were the selection process for inviting the participants, the settings and tasks involved in the experiments, the data recording and exit interviews, any incentive we might be offering the participants and the storage of the resulting data. In the recruiting process we were allowed to invite, but not intrude upon, potential participants. For example, we proposed to recruit parents at the CSIRO child care facility in Canberra; we were permitted to place invitations on noticeboards and on tables in the reception area but not permitted to include invitations in message packs sent home to the parents. We were permitted to video record the sessions and record the exit interviews and we were required to submit the text of the interview questions to the committee prior to the experiments. We decided to not offer incentives, but noted that we would provide refreshments (tea, coffee, biscuits) during the exit interviews. We were required to store the evaluation data, including video and audio, in locked cabinets and to include in our submission the names of the researchers who would have access to that data. An information sheet describing the experiments was sent ahead of time to the participants and, on the day, each participant signed a consent form. It was made clear to the participants that they could, at any time, withdraw from participating in the experiment.

3.7.2 Pilot trial at the Royal Children's Hospital, Melbourne

For our pilot trial the primary ethics committee was that of the Royal Children's Hospital and the Australian National University's committee agreed to accept the hospital's ethics committee oversight of our work. This committee met monthly, with a six-week lead time for submissions. The submission process was also based on pro-forma documents and Dr Annette Da Costa, a hospital staff member, helped us extensively to complete the submission documents. Our initial submission came back with several pages of review comments and we were required to revise and resubmit it. There were several points of concern to the committee:

- **Vetting researcher access to the hospital**. The submission forms required us to list each researcher who would be involved in the trial, together with a justification for their role in the trial. Each researcher was then subjected to a police check, which is a standard process with the state police forces in

Australia. This process, together with the sponsorship of the principal investigators (who were members of the hospital staff) was sufficient to give us independent access to the hospital and to allow us to be present during the actual patient consultations, and we were issued with hospital photo-identity cards and generic "RCH Team" lanyards. This process also gave us access to the video recordings of the consultations and to the raw evaluation data.

At the time of writing, this process has been augmented with a "working with children" vetting process managed by the Victorian State Government. This is compulsory for all people who work with children in Victoria, both professionally or in a voluntary capacity (www.justice.vic.gov.au/workingwithchildren).

- **Selecting the participants**. Because this was a pilot trial the committee required specific measures in the way patients were invited to participate in order to ensure that the patients would receive an adequate standard of clinical care during the trial. This meant that patients for whom it was likely that the telehealth process might be inappropriate would not be invited. The patients who were invited to take part were scheduled to attend review consultations following their surgery, their progress up to this appointment had been normal with no indication that major issues would arise and no major decisions were scheduled to be made during the consultations. The consultations were scheduled at the same time as the normal consultations and with the same clinical staff in order to minimise any impact on the patients and their families.

  The staff at the hospital who managed patient appointments took charge of inviting the patients and of scheduling those who accepted. The patients and families received information about the pilot trial and about the informed consent process prior to the scheduled appointment. During the trial each patient and family was met by a member of the research team who completed the consent process. Forty-six patients initially accepted the invitation to take part. One family withdrew prior to the scheduled clinic. Another withdrew after discussion with the team member and the surgeon conducted the consultation with the cameras and displays turned off and without the research team being present.

- **Trial protocol**. The protocol called for a follow-up by the surgeon in person immediately after the telehealth phase of the consultation, to ensure that the standard of care would be at least as high as in a normal consultation. There were no restrictions on what the surgeons would do during either phase of the consultation and it was left to the surgeons to do whatever was required to ensure that the best interests of the patient and family were met.

- **Video and interview data**. The vetting process for the research team, the support and direct involvement of the hospital clinicians in the project and the mandated storage and access requirements for the data were sufficient for the ethics committee to allow us to video record the consultations and audio record the exit interviews. We were required to return the original videotapes to the hospital for secure long-term storage and to keep digital copies in locked cabinets. We were also required to restrict access to the video and interview data to those researchers who had been vetted by the hospital. At the end of the evaluation process we are required to destroy all digital copies of the data.

The data was coded numerically to remove patient and clinical staff identifiers. Where interview comments from staff, patients or families are used they are chosen so that no identifying information (names, for example) is included.

The hospital's publicity unit took still photographs of the telehealth system with a particular family and patient. That family consented to making those images available for hospital publicity and some of them are included in this thesis.

- **Closure**. The ethics committee required that, at the end of the trial, we write a summary of the outcomes of the trial and the value of these outcomes using lay terminology. This summary was then sent, together with a thank-you letter, to each family who had participated in the trial.

I note the importance of the involvement and commitment of the hospital's clinical staff to ultimate acceptance of our submission by the hospitals Human Research Ethics Committee. Being helped to complete our initial submission by someone who understood the concerns of the committee was enormously helpful. Having a senior clinician (the Chief of Surgery) taking the role of Principal Investigator grounded our research plans in the reality of conducting our research in a working hospital.

I also note the value to the researchers of the Human Research Ethics Committee approval process. The pro forma documents that form the basis of submissions to the committee are, in themselves, excellent check lists of issues that need to be addressed and the submission process provokes those issues to be addressed in a timely manner. The review comments we received on our initial submission were every bit as good as the best reviews I have had from journal submissions and they contributed to the quality of our overall trial.

3.7.3 Presence of researchers in the clinical setting

Ethics approval had been given for the researchers to be present in the clinical setting, both to provide technical support for the clinicians and to make first-hand observations of the consultation for later evaluation. Such a situation is not unusual in Australian public teaching hospitals, where trainees and professionals might sit in to both learn and to contribute, and it was in this context that the patients and their families were invited to take part in the trial. The consent process explained to the patients and families the role of the researchers and that they would be present during the consultation.

What is important, however, is that the researchers be sensitive to the situation for each consultation rather than being bound by a rigid trial protocol. This means that the researchers should be aware of situations where the patient might be emotionally or physically exposed and, if appropriate, the researchers should leave the room to establish a higher level of privacy for the patient or family. While we did not have situations where the patient or family became emotionally distressed we did have several consultations where an older child needed to disrobe. In these situations, if the gender were inappropriate then the researcher quietly left the room for the remainder of the consultation.

In one case, the patient presented with a condition in her arms which had recently migrated to her legs. There were several issues of concern in the consultation, including absence of X-ray data for her legs (because the surgeon had not know to request it) and the physiotherapist acting as clinic assistant decided to pre-empt a stressful situation by closing the consultation and re-scheduling it for later in the day. The physiotherapist explained her decision by saying she felt that the patient would be more comfortable exposing her legs in a less threatening visual setting with just the surgeon and clinic assistant.

These examples show that, even though the presence of researchers in the consulting room may be permitted by the ethics committee and be consented to by the patient, it remains the responsibility of the researchers and clinicians to be sensitive to the situation and for the researchers to leave the consulting room when they sense that their continuing presence would be inappropriate.

4 Case study: Remote surgical training

4.1 Purpose and background

Purpose

This was a preliminary study for my research. It gave me the opportunity to work on a broadband telehealth project over intercontinental distances with a realistic scenario and practising clinicians. My colleagues and I worked to a high-level set of requirements gathered from discussions with some of the senior clinicians who would be involved. We developed and tested a specific telehealth system for these requirements in the laboratory, and we tested the mechanical aspects of the system *in situ* connecting the hospital's Operating Room at Stanford University and the auditorium in Sydney. Finally, we conducted and evaluated a demonstration of remote surgical training using our telehealth system. The surgery took place in the hospital at Stanford University and the audience of appropriately skilled surgeons was located in Sydney. This experience provided me with an initial understanding of the issues involved in conducting research in broadband telehealth at this specialist level.

This case study explored a particular approach to presenting live surgical training to a remote audience. This demonstration was a collaboration between the staff at the Stanford University Medical Media and Information Technologies group (SUMMIT), led by Dr Parvati Dev, surgeons from Nepean Hospital in Sydney, led by Dr Pat Cregan, and a team from the CSIRO ICT Centre's Immersive Environments group. The approach had the following features:

- The surgeon was operating in his home hospital, with its familiar, stable working environment.
- The audience was comprised of surgeons at various levels in their training, but for whom the surgical topic was highly relevant.
- The audience was located in their home city, at a venue that was convenient to their work location.
- A formal structure surrounded the surgical training:
    - Mutual professional introductions
    - A grand rounds lecture and detailed briefing on the actual surgical case
    - Mentors at both the hospital and with the audience, to moderate and manage the flow of dialogue at points when the surgeon needed to focus on the surgery.
- The surgery involved a novel aspect, in this case the use of a twin-camera laparoscope (for "keyhole" surgery) to produce a 3D view of the surgical site for both the surgeon and for the audience.

This approach was intended to minimise the inconvenience and disruption for the surgeon and for the audience (both were in their home environments), maximise the flow and exchange of information about the surgical issues, and ensure the wellbeing of the patient. The approach was based on previous work by Dev and her SUMMIT colleagues (Dev, Srivastava et al. 2004) in which live surgery was presented within California. It was adapted to represent the more intimate experience of accompanying the surgeon during the operation yet spanning intercontinental distances. The purpose of this demonstration was twofold:

- To explore the participants' responses to a telehealth implementation of this otherwise intimate surgical training experience
- To investigate how well the live 3D view of the surgical site integrated into the surgical training.

Background

This demonstration was the second such event presented to an audience in Australia from surgeons at Stanford University. The first event also used a surgical training scenario, but in a collaborative haptic virtual environment using a surgical simulator. The scenario was presented from Stanford University to an audience at the Simulation Industry Association of Australia's annual conference, which was held in Canberra in May 2004. This was conducted with a surgeon at Stanford and a small number of active participants in Canberra, watched by a larger conference audience. The audience could see and hear the participants (locally in person in the auditorium and remotely via live video and could see the virtual surgical workspace via projected 3D video seen through plastic cross-polarised glasses. The event was evaluated with exit questionnaires completed by the audience and by the participants (Gunn, Stevenson et al. 2004). The feedback gathered from these questionnaires focused largely on technical issues and on whether the audience was able to understand the presentation.

In contrast, the demonstration reported in this chapter was much more focused. It had a more complex surgical situation, illustrated with live surgery, and an audience of appropriately practising surgeons. In this way it was hoped that the evaluation would give more relevant feedback on the surgical training aspects than we had gathered in evaluating the previous event. The material in this chapter was first published as a full conference paper at OZCHI 2006 in Sydney, Australia (Stevenson 2006).

4.2 Method

A dedicated broadband Internet connection was established between the CSIRO Marsfield site in Sydney and Stanford University Hospital with help from the staff of the Australia Academic and Research Network (AARNet) (www.aarnet.edu.au). This research network connection provided a low-latency high-bandwidth connection that was equivalent to a broadband link. Four video channels were sent across this connection using the packet-based DVTS software (DVTS_Consortium 2004) to encode and decode the video streams. Two channels linked a fixed camera/display screen in the room at Marsfield with a camera/display screen mounted on a trolley at the hospital in Stanford. This provided a low-latency video-conference-style link between the audience in Sydney and the surgeon and discussion moderator in Stanford. The other two channels carried the left-eye and right-eye video streams from the twin-camera laparoscope in Stanford. These video streams were presented to the audience using a twin projector system, polarised filters and a polarity-preserving projection screen. The audience viewed the three-dimensional images and video with light-weight polarised glasses.

The event began with a dialogue between the moderator and surgeon in Stanford and the audience in Sydney, with the Stanford video trolley in the corridor outside the operating room where the surgeon presented his grand rounds lecture. The video trolley then moved into the operating room to give the audience a view of the surgical staff and surgeon (wearing a virtual reality headset) around the patient, with the moderator standing beside the trolley (Figure 4.1). An assisting surgeon gave a surgical case summary then the laparoscope video output was connected and the audience watched the 3D display screen as the laparoscope was placed inside the patient. The surgeon provided a commentary via a wireless lapel microphone as the procedure progressed, pausing to briefly discuss the surgical options at a particular point in the procedure. The audience followed the procedure on the 3D display screen (Figure 4.1).

Video recordings were made of the event. One channel of the output from the laparoscope and the video channel from the trolley camera in Stanford were recorded. A room overview video camera also recorded the scene in the Sydney room with the two display screens from Stanford in its field of view. At the end of the event the surgeons in Sydney completed an exit questionnaire. Follow-up interviews were conducted with the two moderators, the surgeon in Stanford and one of the senior surgeons from the Sydney audience.

Figure 4.1: Clockwise from top left:
Operating Room at Stanford with dialogue moderator in foreground
Operating Room at Stanford, showing surgeon wearing virtual reality headset
Audience in Sydney wearing polarised glasses to view surgery in 3D
Displays in Sydney – 3D display on left, view into operating room on right

4.3 Results

3D Video

The surgical audience's response to the 3D display of the laparoscopic surgical site had two components – their response to the relatively static display of 3D anatomy (static because the patient's internal organs were not moving and the laparoscopic camera was held steady) and their response to the display of the fast-moving surgical instruments in the field of view.

At three places during the surgery the surgeon commented on the quality of the 3D display in his virtual reality headset and asked about the quality as seen remotely. Each time the remote response was that the 3D picture was good. At one point the surgeon slowly released a droplet of water from the irrigator to show the 3D effect. One surgeon replied "Yes, you can see that difference [between 2D and 3D] quite clearly". Figure 4.2 shows a monocular view of this scene.

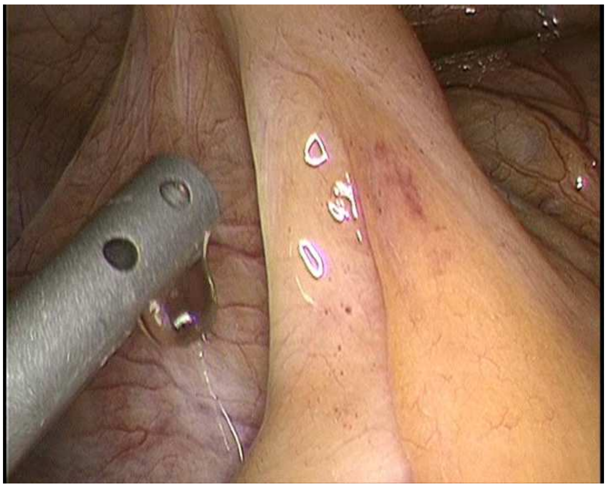

Figure 4.2 Irrigation tool showing a single drop of water

The audience's response to observing the moving surgical instruments, however, was not so positive and it highlighted an effect that was later found to be caused by an error in the decoding software for the 3D video. The visual effect was that movement of objects with clearly defined edges (for example, surgical instruments) appeared jerky, as if there were a low and intermittent frame rate. One surgeon noticed this effect within one minute of 3D video display starting "It looks jerky …" and again 24 minutes later "We are getting good pictures, good 3D [but] it's just a little bit jerky".

The main focus of the debriefing discussion at the end of the session was on this issue. One senior surgeon in the audience commented "I couldn't imagine being happy with that view". When asked to rate the added benefit that the 3D view might give, over the traditional 2D display, another surgeon replied "I would say 80% better [than the 2D view] but for the jerkiness" and continued "Jerkiness over a long time, say a 2-hour operation, would give eye fatigue".

In the exit questionnaire the surgeons ratings on the **usability** of the 3D video images on a 1 to 5 scale were widely spread (one 'difficult to use (2)', two 'moderately usable (3)', one 'reasonably usable (4)' and one 'highly usable (5)'. The ratings on the **usefulness** of the 3D video display, on a 1-5 scale, were two 'medium (3)', one '(4)' and two 'high (5)'. When asked to rate the **usefulness** of the 3D display as **compared to the normal**

2D display on a 1-5 scale three of them rated it ‘greater (4)’, one rated it ‘similar (3)’ and one rated it between ‘much less (1)’ and ‘less (2)’.

In a follow-up interview the surgeon who gave a low rating for the usefulness of the 3D display described his inability to use artificial binocular displays for depth cues. He noted that perhaps 10% of people do not use binocular vision to perceive depth (they use other cues such as lighting, shading, specular reflection, occlusion, parallax and relative motion) and that novel technologies like this 3D video could disadvantage these people. When asked if a quality 3D display of the surgical site for laparoscopic surgery would be of value he replied that it would be “a remarkable advance” in that it would address two major problems for the laparoscopic surgeon: limited 3D view of the surgical site and spatial disorientation.

Audio

The audio equipment was configured differently at each of the two sites. In Sydney there were a number of table-top microphones placed on the long conference table, as shown in Figure 4.1, facing outwards and connected to an echo cancelling system. In Stanford two wireless microphones were used, one for the surgeon and one for the mentor, and the receivers fed into an audio mixer. These microphones were very sensitive to direction and distance from the speaker’s mouth. There was no support for echo cancellation at Stanford.

The quality of the audio streams can be observed in the video recordings of the event. The audio stream from Stanford to Sydney was primarily spoken commentary from the surgeon and the mentor. This required initial, then occasional, adjustment but for large time periods the audio was good. Contrary to our expectations the background sounds from the operating room did not cause any problems. One surgical instrument (an electro-cauterising tool) emitted a clearly audible warning sound when it was used.

The audio from Sydney to Stanford was also spoken commentary and questions, primarily from the mentor who was sitting facing one of the microphones. The other surgeons sat across the table from him but facing the screens at the end of the room and they needed to turn to the microphones when they spoke. The Australian accent and casual speaking style caused some misunderstandings until the audience adopted a “presentation style” of voice (Prof Heinrich’s description). The primary problem, at the Sydney site, was an echo from Stanford, which can be heard on the video recording every time someone in Sydney spoke. [Note that echo cancelling systems act for the benefit of the far end, so the audio signal that Stanford received was largely echo-free]. In a follow-up interview the surgeon at Stanford was asked about the quality of the audio and video and he replied “Very good, just as if they were next door”. In the exit questionnaire the surgeons rated the usability of the audio, on a 1-5 scale. Two rated it ‘reasonably usable (4)’ and three rated it ‘highly usable (5)’.

Dialogue during the Pre-operative Discussions

The discussion before the operation lasted 30 minutes and was primarily led by the surgeon at Stanford. He presented his ideas on the technology that was central to this demonstration, then at three places asked for information about the audience by addressing the mentor in Sydney by name: “<Name>, will you tell us about the experience of your surgeons?” “How about your issues; do you use [a particular surgical technology]?” “<Name>, are you using simulators?” The mentor in Sydney answered initially then directed the questions to another senior surgeon. Another 30 minutes were spent waiting for the patient to be ready for surgery and this was filled with a discussion on surgical simulation for training between the two mentors. The previous senior surgeon spoke three times and a more junior surgeon spoke once.

Dialogue during the Demonstration

During the 45 minutes of presented surgery the primary communications were from the surgeon and from the mentor at Stanford. Occasionally the surgeon would ask a question or make a comment about what was happening and the mentor in Sydney would reply. The mentor in Sydney also made local comments about the visible anatomy and surgical actions.

Dialogue occurred twice between the two sites. In the first case the surgeon had isolated the appendix and was ready to choose a technique for sealing where it attached to the intestines before removing it. As an active teaching point he asked "<Name>, what do your residential fellows want us to demonstrate?" referring to the choice of technique. After a brief local discussion a request was made. The surgeon's reply was "Good choice."

The second section of dialogue occurred at the end when the mentor in Stanford asked for closing questions and for an assessment of the value of the 3D video. Two of the surgeons in Sydney took part in a short discussion on this point.

In a follow-up interview, the surgeon in Stanford said that when surgical trainees observe him in the operating room the junior trainees sometimes ask questions of the senior trainees rather than asking him, and that the senior trainees (fellows) don't usually ask questions. In a follow-up interview with a senior surgeon in Sydney he rated the level of interaction at this event to be greater than he normally experiences in the operating room.

Role of the Mentors

Analysis of the video record of the demonstration shows that the two mentors played a very active role. In Stanford, the mentor filled the continuity role of a "master of ceremonies" as well as providing expert commentary on the progress of the surgery. In Sydney the mentor managed the questions and answers and provided additional local commentary.

In the exit questionnaire the audience rated the usefulness of the information from the two mentors at 4 or 5 on a Low (1) to High (5) scale.

In the follow-up interview the surgeon at Stanford spoke at length about the value of having the mentor in the operating room. He has extensive experience in presenting his surgical work on video. In those there was always someone to handle the audio-visual issues but this was the first time he had someone to handle the clinical issues of the presentation, leaving him to concentrate on the surgery. He valued this aspect highly.

Ethical Considerations

Two important ethical considerations relating to in-vivo demonstrations of surgery are raised by Millat and colleagues (Millat, Fingerhut et al. 2006) namely concern for the proper care of the patient and concern for the correctness of the surgical information received by the audience. They raise these issues in the context of demonstrations at medical conferences and public events but it is just as important to consider them in the very specific context that was designed for this demonstration.

When asked in the follow-up interview about the level of intrusion into his surgery posed by the presence of the cameras and the video displays back from Sydney the surgeon made several points. Having a mentor in the operating room to manage the clinical information freed him to focus his attention on the patient, and he cited one instance where he was able to focus so closely on the patient that he was unaware of the mentor's presence. In terms of distraction for the other clinicians in the Operating Room, he specifically commented that the anaesthetic team and nursing team were very excited about presenting the surgery to an audience so far away and that they were specially focussed on their tasks to make the presentation a success. He also commented on the logistics of the event: "[This event] had less hassles and ran much more smoothly than other [similar events]." He said that "usually something goes wrong that I have to deal with but this time I could concentrate on the surgery."

Both before and during surgery the surgeon went to a considerable effort to reference and explain what he was doing. His presentation early in the session gave the broad background to his work, with many specific references. He established the relevance of the surgical procedure to the remote audience, and during the surgery he explained what he was doing.

Overall assessment of the demonstration

The video recording of the event shows that the audience paid close attention to both the pre-operative discussions and to the 3D video display from the laparoscope during surgery, as indicated by their gaze direction, attentive body posture and lack of distraction movements.

In the exit questionnaire the surgeons were asked how likely they would be to attend such an event in the future if it were conveniently located and on a topic in their surgical area of interest. On a 1-5 scale one replied 'not sure (3)', two replied 'Very likely (4)' and two replied 'Definitely would (5)'.

During a follow-up interview one senior surgeon described the event as "excellent as a pilot exercise" and said that he would be keen to attend another and would encourage his surgical colleagues to also attend. He noted that demonstrations like this increase the cross-fertilisation of ideas and that surgeons benefit from this but that after completing their training surgeons rarely observe their colleagues' work.

During the follow-up interview with the surgeon in Stanford he said that it "was a rewarding teaching experience".

During the debrief discussion the surgeons discussed what form of surgical presentation they might offer to Stanford. Their practice includes open surgery of parts of the body that are difficult to access and where an audience in the operating room has difficulty seeing what is happening, and they discussed using a close-up 3D camera such as the laparoscope used in this event but held outside the patient to observe the surgical site. They suggested that such a presentation would illustrate their own expertise and be of interest to both Nepean Hospital and Stanford surgeons.

4.4 Discussion

3D Video

The surgical audience distinguished strongly between the 3D view of the surgical site and the view of the motion of the instruments at the site. They rated the 3D view of the surgical site highly in their spoken comments during the event but were very critical of the displayed motion of the surgical instruments. The event organisers had not anticipated this distinction so the exit questionnaire did not cater for it. The audience responded by annotating their 1-5 ratings with specific comments about the problems with the motion display.

This demonstration was the first time that the system had been used to show real 3D surgical video to surgeons, and it highlights the importance of feedback from the application users. There had been no prior access to 3D video of live surgery and no facility at Stanford for pre-recording 3D video so much simpler laboratory test data was used, generated by moving small objects in the short depth-of-field range of the laparoscopic camera. The actual software development was done in Canberra, 300km from Sydney, and a surgical audience was not available to offer its opinion on the quality of the test data.

An issue which was raised in the debrief discussions confounds a simple assessment of the 3D video display. Surgeons in Australia have been trained to do laparoscopic surgery using a monocular 2D display from the laparoscopic camera, because this is the prevailing technology in Australia. They have, therefore, learnt to construct a 3D model of the surgical site in their mind using all the other visible depth and structural cues (light, shading, specular reflection, occlusion, relative movement) and they use this ability in their daily work. In viewing a single demonstration of 3D video they might find it difficult to identify the additional value of the artificial binocular view of the site, even if the motion of the surgical instruments was presented smoothly. This is an issue that will require a more controlled experimental environment to answer.

Audio

The evidence on the audio quality is apparently contradictory. The audience in Sydney rated the audio quality as either reasonably usable or highly usable in their answers to the exit questionnaire, and the surgeon in Stanford rated the audio [and video] quality as "very good". The evidence from the video recordings, however, shows that the voice link from Sydney to Stanford was hampered by a strong echo, that the audio levels from Stanford to Sydney rose and fell significantly due to the variable placement of the microphones, and the audio quality from Sydney to Stanford required the speakers in Sydney to turn towards, and focus their voice to, the microphones. This occurred even though the audio technician in Sydney was constantly adjusting the audio levels of the various components to minimise the problems.

An explanation for this is found in the conversation analysis. Key information components of the conversation (the surgeon's lecture and explanations before surgery, the surgeon's and the mentor's comments during surgery) originated from Stanford and were delivered in units of speech where the microphone placements were stable. The mentor in Sydney did most of the talking from there and he made a strong effort to talk over the top of the echo from Stanford. From the audience's point of view the bulk of the audio exchanges was, indeed, reasonably-to-highly usable. What this demonstration did highlight were the remaining deficiencies in the audio links and these should be addressed in any future events.

Structure of the Demonstration

The structure of the demonstration presented a realistic surgical teaching scenario. The surgeon was able to present his broad ideas at the time and place of the surgery, and during surgery he was able to explain and demonstrate to the audience what he was doing. The single location for the remote audience and the relatively small size meant that he was able to relate to them directly, though a more deliberate use of zoom and pan might have given him closer awareness of individuals when they spoke.

The role of 'mentor' at each site was important. The surgeon worked with the mentor during direct discussions between the sites, and was able to leave the medical communications to the mentor when he was focusing on surgery. In Sydney the mentor, who had been closely involved in setting up this demonstration, managed the flow of conversation and questions.

A description of the intent of the demonstration, included in the material handed out at the start, was that it hoped to "create a learning environment at the remote site that is closely connected to the ongoing surgery and at the same time has the freedom of a classroom, to interact with an instructor, have side discussions and consult textbooks and other learning materials." As it happened, the intended surgical case, which would have led to discussions around previously circulated medical documents, was postponed and the replacement surgery was much simpler. This aspect of the demonstration was intended to replicate the situation described by Dev and colleagues (Dev, Srivastava et al. 2004) but it remains untested for this audience.

Dialogue

The dialogue between Stanford and Sydney was focused around the surgeon, and this appears to be what happens when junior surgeons or surgical fellows observe surgery in person. The surgeon and the two mentors initiated almost all the commentary and conversation and when the surgeon asked if there were questions there were very few replies though this may be because the actual operation was relatively straightforward. The patterns of interaction do not show an even spread of the dialogue amongst the participants and this might lead the organisers of future events to fine-tune the communications links differently.

This is an important observation, and it goes against the original planning intention of the demonstration. As noted previously, this demonstration was modelled on the very successful teaching demonstration at the launch of the California Orthopedic Research Network (www.ats.ucla.edu/news/SurgeryPresentation.htm) and described in detail by Dr Dev and colleagues (Dev, Srivastava et al. 2004). This earlier demonstration was designed as a teaching event, with specific teaching presentations, questions and discussion prior to observing the surgery. Our demonstration took its sense of place from the Operating Room rather than from the classroom, and the participants matched this sense of place with their behaviour.

Equally importantly, the participants did not reflect on this in their exit questionnaires, other than a brief comment that there was more dialogue than they would normally expect during surgery. It was only by observing the event in person, then reviewing the video recordings of the event, that the researchers were able to see the patterns of dialogue and to notice that the more junior surgeons did not take part.

Overall Assessment of the Demonstration

The surgeons in both Stanford and Sydney gave a positive overall assessment of the demonstration and in particular its role as a pilot for possible future events. By presenting the demonstration to surgeons in a focused surgical training context the organisers managed to uncover several important issues which should be addressed before any subsequent event is held.

The surgeons in Sydney gave a strongly positive response to the question about whether they would attend a similar event in the future, and this is consistent with their actual discussions at the end of their event where they were already considering what form a return demonstration would take.

4.5 Contributions to this thesis

This preliminary study highlighted a major issue to be considered when demonstrating and evaluating telehealth at this level of complexity: It is important to place the demonstration in as realistic a setting as possible, and with participants who are qualified to take part in the demonstration, in order to maximise the value of the evaluation responses. This is in contrast to the two other possibilities which we might have considered in this study:

- A laboratory evaluation, with research participants role-playing the activities. We saw in this study that the success or otherwise of the 3D display of the surgical site was data dependent. The 3D video of objects used in the actual laboratory testing did not have the dynamic characteristics and texture of 3D video of live surgery and did not, therefore, uncover an important software error prior to the live demonstration.
- A live presentation to a generic audience from the health sector. Our original project plan called for this demonstration to be presented at the November 2005 Healthcare Symposium of the Simulation Industry Association of Australia, with a broad audience of conference attendees. Had we followed this plan we would not have seen the enthusiasm with which the audience discussed a possible return presentation to Stanford. Neither would we have observed the quite strict formal behaviour which the audience of surgeons brought to the event, in which the junior surgeons left it to their senior colleagues to ask and respond to questions.

From this preliminary study I took three important lessons forward into my work on the telehealth project with the Royal Children's Hospital, and these are reflected in the summary of my results presented in Section 1.6, pages 8-9:

- Firstly, it is important to trial telehealth systems with this high level of complexity in a realistic setting so that the data involve are true to life (Result 3.1).
- Secondly, it is important to have participants in the telehealth trial who are competent to make evaluation judgements from their experience in the trial (Result 3.3).
- Thirdly, it is important to complement exit interview or questionnaire responses from a telehealth trial with observational data from the event itself (Result 3.2).

5 Laboratory studies framework

5.1 Introduction

This chapter describes the purpose and approach of the three laboratory studies that we conducted during the development of the broadband telehealth system for remote outpatient consultations. These three studies are then described separately in the following chapters (Chapters 6, 7 and 8).

Purpose

These laboratory studies were conducted to resolve design and functionality issues that arose in the early stages of developing our telehealth system. The three specific issues all related to the way that generic elements of our telehealth system would support interactions between the participants, access to the physical spaces of the rooms in the telehealth suite and interaction with data about the patient. Each issue was addressed with a purpose-designed laboratory study.

1. **Fixed video and audio between the surgeon's and patient's rooms.** We needed to establish whether the video and audio links between the two rooms provided sufficient coverage of the rooms and awareness of what the participants would be doing during a typical outpatient consultation. The first study was designed to exercise the room coverage and situational awareness that wanted to achieve.
2. **User-interface design for tablet-based remote guidance**. We planned to use the electronic pen and tablet displays to let the surgeon guide the assistant to conduct an examination of the patient, using pointing and drawing over displays of live video of the patient. The second study explored three different user-interface designs for tasks that mimicked the actions that we expected the assistant to perform during the examination.
3. **Support for collaborative behaviour between surgeon and assistant.** We expected the process of examining the patient to be a collaboration between surgeon and assistant, rather than the expert-novice guidance scenarios that had been used in previously published work on remote guidance. The third study repeated the tasks of the user-interface design study, but in a collaborative manner rather than a directed manner.

These issues all related to the way the participants in the eventual telehealth scenario would use these aspects of the telehealth system. This is the reason that we carried out laboratory studies with human participants rather than just conducting technical testing with hardware and software test harnesses.

Approach

The approach we took in conducting these laboratory studies was characterised by five features:

- The studies were intended to answer specific questions about our telehealth system and its planned trial at the hospital.
- The tasks used in the studies were abstractions of activities that we had seen during our early field observations of outpatient clinics at Royal Children's and

Royal Hobart Hospitals. These abstractions addressed the generic use of the telehealth system's components and had no clinical content.

- The settings in which the studies were carried out approximated in size and use of physical space the counterpart settings that were observed in actual outpatient consultations.
- The studies were evaluated in terms of the ways that the system components under investigation supported the participants to perform actions that corresponded to the actions which we expected the clinicians and patients to perform in the actual hospital trial. This is in contrast to the performance-based comparative studies that have been published in areas such as remote guidance.
- The study participants were generic adult volunteers with no specific clinical training.

Motivation

Two aspects that were directly related to our broad application domain – tertiary-level telehealth – motivated us to conduct these laboratory experiments in the manner described here.

- **Ensuring a workable telehealth system for the very first patient in the hospital trial**. We had observed that there was a high level of personal and professional pressure on the patients, families and staff at this tertiary level of healthcare. The patients present with potentially very serious health situations, and they and their families are both emotionally and physically exhausted by their day at the hospital. The clinicians have a high case-load, driven by a demanding schedule during their outpatient clinics, with little room to deal with extraneous problems or to repeat consultations. For these reasons it was important that the basic communication pathways of our telehealth system work in practice at the very beginning of the trial.
- **Minimising the demand we placed on the hospital clinicians during our system development**. Access to the hospital clinicians' time was scarce, and we reserved our demands on their time for application-level evaluation of our progress work. We therefore designed our laboratory studies to be accessible to non-clinically-trained participants so that we could conduct them in our own laboratory without making additional demands on the hospital staff.

Abstract tasks

The tasks that the participants performed during these studies were abstractions of the activities that we had observed the surgeons and patients perform during normal outpatient consultations. These tasks involved access to and management of the large spaces in the two rooms (the patient's room and the surgeon's room) that formed the nodes of our telehealth system and collaborative performance of three-dimensional tasks in smaller spaces within one of the rooms. We had observed the way the surgeons and the patients and families made use of the space in the consulting rooms at the hospital – sitting together to discuss issues, using the whole of the room to allow for examining the young patient and using specific examination procedures in a more bounded space within the room and we designed the study tasks to match what we had observed.

The intention of the tasks was that they be performed using the resources provided by the three fixed video/audio links between the two rooms, the steerable pole-mounted camera above the designated examination space in the patient's room, the pen and tablet tools for pointing and drawing over live video and, finally, the laser drawing system in the patient's room that was controlled by a pen and tablet interface in the surgeon's room. Figure 5.1 shows the relationships between the abstracted tasks and their associated real-world conclusions.

The tasks that we devised were in a sense free of external meaning and so there was no way for prior knowledge or learning on the part of a participant to skew the outcomes of the study. This is in contrast to many remote guidance studies, such as those of Kirk and colleagues (Kirk, Crabtree et al. 2005), where the task involved teaching someone to assemble components such as Lego and where prior experience with this toy could dramatically change a person's ability to perform the task. We drew inspiration for this approach from some of the early media spaces work, such as the "room drawing" and "furniture placement" tasks of Gaver and his colleagues (Gaver, Sellen et al. 1993) where the tasks were dependent only on the placement and contents of the rooms and where completing the tasks required collaboration between the two participants – one in each room.

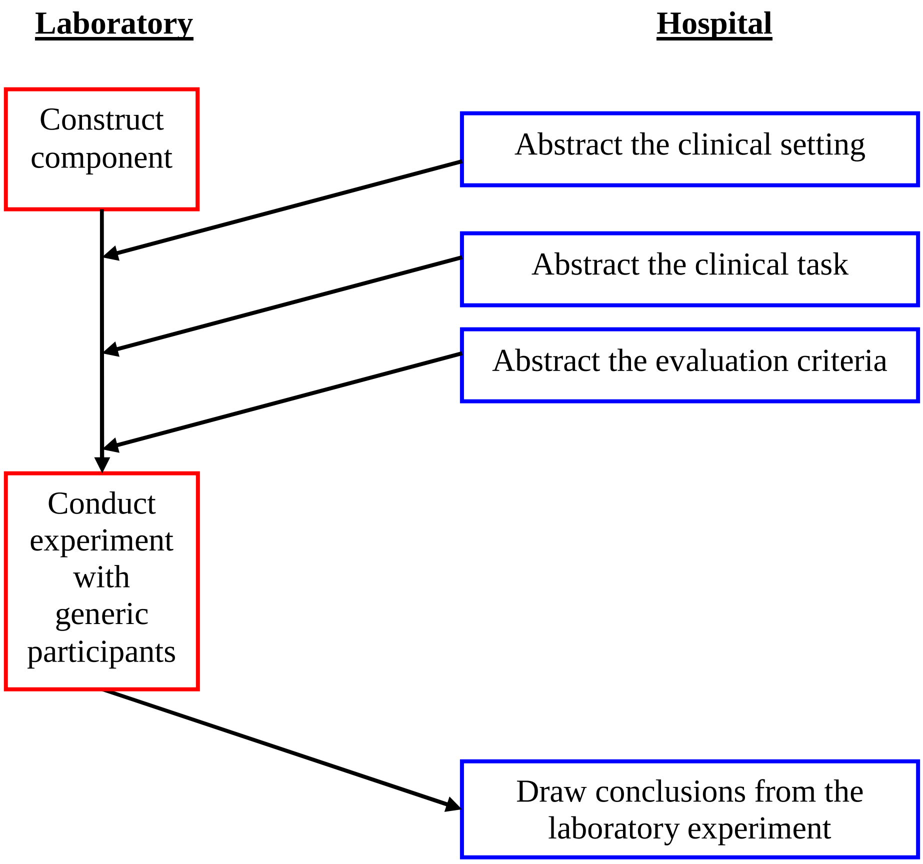

Figure 5.1: Schematic for component evaluation in the laboratory

Generic participants

For participants in these laboratory studies we invited adults with normal or corrected-to-normal vision, with no other special requirements. We recruited from our local region – colleagues at CSIRO, staff and students on the Australian National University campus, friends or acquaintances from within the Canberra community. This approach to recruiting matched the generic nature of the tasks to be performed in the laboratory studies.

We particularly avoided limiting our recruiting to medical practitioners for these studies even though the ultimate purpose of the studies was to guide the development of our telehealth system. There were two main reasons behind this approach. Firstly, the features of the telehealth system that we were testing were themselves generic in nature and we had designed the studies so as to not have any explicit "health" content. Secondly, the health professionals who would be using the telehealth system were a scarce and heavily committed resource which would be wasted evaluating our system at its generic level. Not only were they scarce, but they were also located 600 kilometres away in Melbourne and therefore they were in practice not available.

This issue highlights the levels at which it is appropriate for the highly skilled and heavily committed clinicians in the tertiary health sector to be involved in review or evaluation activities. For example, one reviewer of our paper on the third of these case studies (Stevenson, Li et al. 2008) commented favourably on the paper then noted that the next step would be to repeat this study using medically trained people as the participants. My response is that this would not be an appropriate use of such a scarce resource in this field of tertiary health care. A more appropriate approach would be to match the evaluation situation to the skills and scarcity of the participants, with abundant generic participants to evaluate generic or content-free features and scarce clinicians to evaluate the clinical application of the system.

5.2 Three laboratory studies

This sub-section contains an overview of each of the three laboratory studies. These studies were conducted during the first half of 2007 using the telehealth system at the level of development that it had reached at the time of the studies. The first two were conducted between two rooms at the CSIRO site on the Australian National University campus in Canberra and the third was conducted between the Canberra and Marsfield (Sydney) CSIRO sites.

Video and audio communications study

The first study treated the two rooms of the telehealth system (surgeon's room and patient's room) as a media space. The concept of a media space, as described in an earlier chapter, is that two physically separate rooms are connected by a number of video and audio channels to form one larger "media" space in which the occupants of each room can relate to the actual space of the other room as if it were an extension of their own. The actual configuration of the video and audio channels will determine the coverage and continuity of access of one room to the other, and will determine the quality of access to people and objects in the other room.

At the time of this study we had developed a furniture and video layout for the two rooms of the telehealth system based on observations of normal outpatient consultations at two hospitals – the Royal Children's Hospital in Melbourne, which was the main hospital for this work and the Royal Hobart Hospital in Hobart, Tasmania, which served as a feeder hospital for the more complex paediatric surgical cases. The furniture partitioned the patient's room into two regions, each with a close-up two-way video/audio link to where the surgeon would sit in the surgeon's room. A wide-angle camera and large-format display pair were located on the far wall of each room to provide an overview "window" from each room into the other room.

We wanted to know whether this arrangement would provide the participants in each room with sufficient visual understanding of the other room that they could make judgements of the relative position of objects within the rooms and perceive a form of continuity of the space spanning the remote room. We also wanted to know whether the perceived directions of the two close-up video/audio links matched participants' global perception of their room and the other room.

Remote guidance user interface study

The telehealth system design contained four different tablet-based methods of letting the surgeon give gesture-based guidance to the clinic assistant. In this study we looked at three different styles of user interface for the surgeon to control these guidance methods in a unified manner. The volunteer participants took the place that the surgeon would occupy in the telehealth system and a researcher took the place of the clinic assistant. The purpose of the study was to have people who were not part of the design team use these interfaces to instruct someone in the tasks that we devised in order to see how the three styles compared. In particular we were looking to uncover any problems with these interface styles that might interfere with the interactions between guider and guided.

Collaborative guidance user interface study

We used the results of the previous study to refine our user interface style for controlling the gesture-based guidance methods and we then explored whether our approach supported emergent collaborative behaviour between people in the role of surgeon and of clinic assistant. Pairs of participants were recruited for this study, which was conducted with minimal involvement on the part of the researchers. After an initial explanation and demonstration of the guidance technologies the participants completed a self-paced training session and then completed the task itself, following a sequence of high-level computer-based instructions. It was left to the pair of participants to decide when the task was completed. By devolving the training and task completion to the participants we were intending to create opportunities for collaborative behaviour to emerge.

5.3 Summary

This approach to using laboratory studies demonstrates a way of dealing with the tension between the need to ensure a workable basic telehealth system prior to conducting trials with actual patients, and the scarcity of tertiary-level clinicians' time to conduct evaluation reviews. It differs from published studies in video-supported collaboration in the Media Spaces literature in that it has a specific target application against which to perform the evaluation. It also differs from published studies in remote guidance in that it is not seeking to present performance-based comparative assessments of remote guidance techniques but, rather, it assesses the usability of a specific remote guidance system to perform application-related activities.

6 Case study: Video and audio communication

6.1 Purpose

The purpose of this study was to explore the way in which our underlying video and audio communication sub-system supported participants who were conducting collaborative tasks between the two rooms of the telehealth system. The specific layout (video/audio streams, furniture, other objects) represented an abstraction of the way we had observed surgeons conduct outpatient consultations. The tasks used in this case study were abstracted from the actions and communication patterns that we had observed between surgeons, patients and families. These tasks were evaluated in terms of the expected use of the telehealth system.

The use of video and audio communication channels to link two or more spaces (typically rooms in different buildings) is referred to as a “media space”. This study matches the spirit of previous media space research. Media space systems were constructed and deployed for both short-term and long-term studies.

- For short-term studies, such as this one, they were populated with experimental subjects who were given specific tasks to perform in order to explore the capabilities of the media space (Gaver, Sellen et al. 1993; Heath, Luff et al. 1995; Heath, Luff et al. 2001).
- Longer-term studies treated the media space as a background communications medium and observations concerned the way the participants related to each other across this medium as they went about their daily work.

In this study I use both task and observational approaches, albeit with a short time frame. I look at how the participants used the video displays of the remote room to understand its layout and to refer to objects in it, and I look at how they use the combination of video displays to interact with each other.

The earlier media spaces research used a human-centred evaluation approach, with observations of the participants who occupied the media spaces and interviews with those participants. In this case study I continue with a human-centred evaluation approach precisely because the purpose of the study is to explore the way that the participants use the resources of our system to collaborate on the study tasks. The primary outcomes of the tasks – sketches of the remote rooms and relocation plans for the furniture – have no absolute meaning in relation to the wider telehealth application and therefore it would not be appropriate to use a performance or measurement based evaluation.

6.2 Method

Telehealth system

The telecollaborative system described in this chapter and used for this laboratory study formed the basis for the telehealth system that we used in our hospital pilot trials. In this study we evaluated the basic video and audio communication patterns supported between the two rooms as show in Figures 6.1 to 6.4. My colleague, Matthew Hutchins, first suggested the room layouts shown in Figures 6.2 to 6.5 at an early project review meeting with hospital surgeons, and he drew the diagrams in these Figures. He also drew the diagram in Figure 7.1 in the next chapter.

The complexity of the telehealth application arises from both physical actions and personal interaction. The physical actions occur at scales from whole-of-room (several metres) down to small hand movements (several centimetres), often in different locations within the room. The personal interaction and dialogue use voice, expressions, gestures and references to representative and abstract data. The application may involve multiple participants, observers and transient participants.

Our field observations showed that support for face-to-face dialogue, spatial awareness and privacy are required for these applications. Face-to-face dialogue underpins the clinical consultation. Spatial awareness provides information about what is happening in the local and remote places and who is involved, and explicitly supports the spatially-focused collaborative task of patient examination. Privacy includes both knowing who is watching and listening and also knowing how the individual is perceived by others in the space.

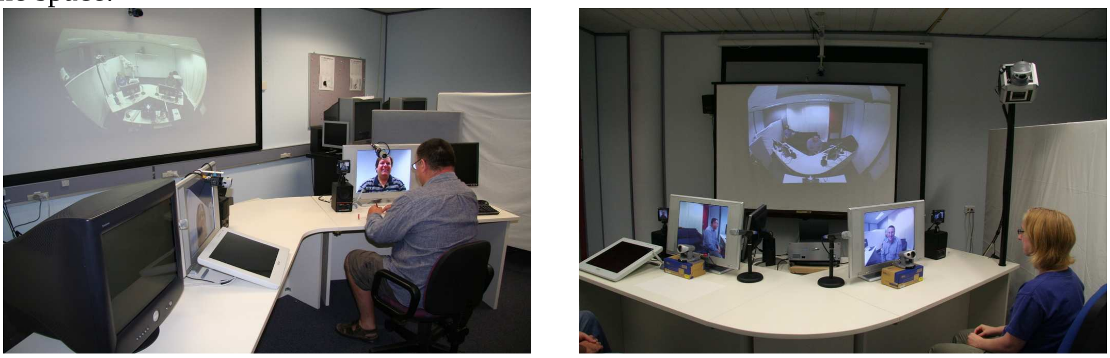

Figure 6.1: Photographs of surgeon's room (left) and patient's room (right)

Our telehealth system was designed to support remote paediatric clinical examinations and consultations between a surgeon's room in a hospital and a patient's room located in a regional healthcare facility. In the terminology of Harrison and Dourish (Harrison and Dourish 1996) the "Space", or physical description, includes a paired wall-mounted camera/display giving matching room overviews, similar V-shaped desks oriented so the surgeon sits on the inside of the V (in the surgeon's room) and the patient, family and assistant sit on the outside of the V (in the patient's room). Two pairs of close-up camera/display systems link corresponding wings of the desks. Figure 6.1 shows photographs of the two rooms at the time that we conducted the media spaces study. Ultra-short-throw data projectors were used for the room overview displays in this media spaces laboratory study. The room overview displays were not used in the two guidance laboratory studies and the data projectors were replaced in the final telehealth version of the system by plasma displays for improved image and colour resolution.

I note here a potential confusion of terminology. In the media spaces literature several authors use the term "face-to-face" to refer to videoconferencing style video/audio links where each person's face fills the screen. In this thesis I use the term "close-up" to describe these video links (examples are seen in Figure 6.1 above) and I reserve the term "face-to-face" for situations where the participants physically meet in the same space. Thus I refer to the *telehealth* and *face-to-face* phases of our main hospital telehealth trial.

Corresponding to the concept of "Place" described by Harrison and Dourish (ibid.) there are specific design intentions for the way the space would be used and Figures 6.2, 6.3 and 6.4 illustrate these modes of use.

Figure 6.2. The surgeon can look up from the desk and address the patient and family, via the room overview display, as they enter the patient's room. Figure 6.2 shows the surgeon looking at the room overview display. The pair of chairs (shown in dark red) in the patient's room is where the assistant would sit while examining the patient. The three chairs on the other wing (shown in dark blue) are where the family would sit. The head and shoulders view of a standing person in the patient's room indicates where people might pass as they enter the room. Similarly, all participants in the patient's room can look at their room overview display to see the surgeon.

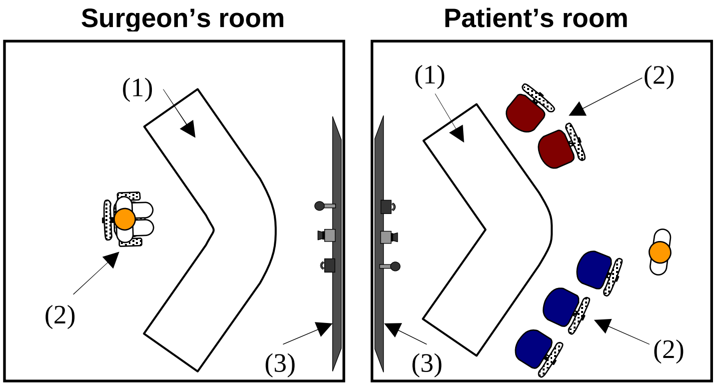

Figure 6.2: **Room and furniture layout and room overview connection** including: (1) desks; (2) chairs; and (3) combined screen, camera, speaker, and microphone.

Figure 6.3. The surgeon sits at the right-hand consultation wing of the desk and uses the close-up video and audio subsystem to talk to the seated patient and family. Figure 6.3 shows two people in the patient's room but in our observations at the hospital we often saw whole families (parents and other siblings). To cater for this we provided space for several chairs (dark blue) and we set the zoom on the close-up subsystem to a wide enough a viewing angle to cover the whole family. The zoom on the surgeons' video camera was set to approximately fill the screen with his or her head and shoulders, allowing visual space for hand gestures.

Figure 6.4. This shows the surgeon sitting at the left-hand examination wing of the desk using the second close-up video/audio subsystem to talk to the patient and the assistant who are sitting at the corresponding examination wing of their desk while the parent remains sitting at the consultation wing. In the final telehealth system a number of additional cameras were placed in the examination wing space of the patient's room, including hand-held, arm-mounted, tripod-mounted and overhead pole-mounted cameras.

The photographs in Figure 6.1 show the pole-mounted camera. Figure 6.1 also shows a tablet display on the desk in front of where the parents would sit. In the full telehealth system this tablet display would show examination camera view that the surgeon was seeing and this would enable the family to follow the details of the examination without needing to move from their seats.

The cameras used in the room overview and close-up video systems were constantly operating with fixed positions and zoom settings, providing the stable frames of reference that Heath and his colleagues recommended (Heath, Luff et al. 2001). The close-up cameras were placed centrally on the horizontal edge of the display to support face-to-face eye contact. In the version of the system used for this study the close-up cameras were placed on plinths on the desk; in the final version smaller barrel cameras were suspended from the upper edge of the display and hung a few centimetres down over the display screen to improve the support for eye contact.

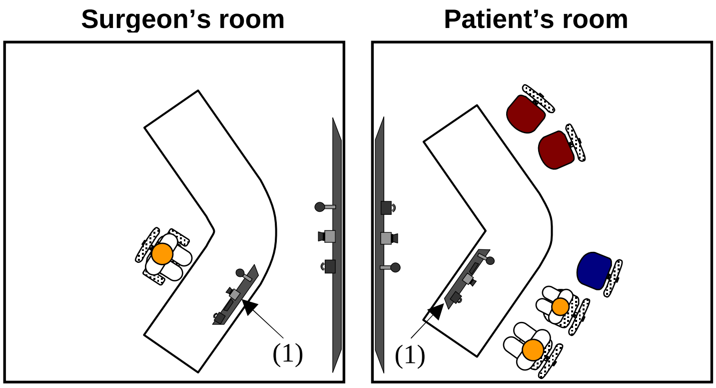

Figure 6.3: Consultation wing including: (1) combined screen, camera, speaker, microphone, and foldback monitor.

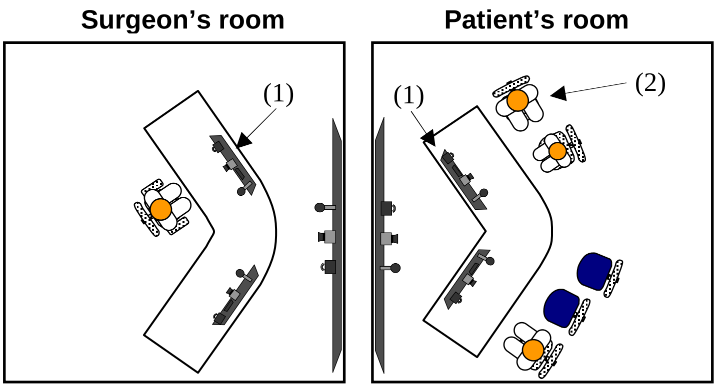

Figure 6.4: Examination wing including: (1) combined screen, camera, speaker, microphone, and foldback monitor; and (2) assistant and patient.

The room overview camera had a wide-angle lens which captured the whole of the room, including the doorway. Each pair of camera/display systems had a microphone/speaker system beside it and an echo cancellation system was used to suppress echo and cross-talk between speakers and microphones. Provision was also made (detail not shown in the Figures) for observers in each of the two locations. Chairs could be placed at the back of each room and ancillary displays could present details of any of the fixed or guidable cameras so that the observers could understand what is being discussed.

The room overview cameras gave the broad context of each room, its participants and the objects located there. Remote participants could see who was present, who was talking and whether they were referring to objects in the room, issues which Kane and Luz had raised in a medical conferencing situation (Kane and Luz 2006). Together the three camera/display systems enabled the people, objects and actions to be publicly available to all participants (Robertson 2002).

Expectations of the system design

The intention behind this design was to make the far wall of each room like a window into the other room, and to have the directionality of the close-up video subsystems match in an approximate way with the corresponding direction of view to the room overview display on the far wall. This concept is an extension of that shown in the "Hydra" system (Sellen 1992) where multiple small cameras and displays are arranged in an arc, each camera showing a different person involved in a multi-way videoconference. In the Hydra system, turning your body to look at a particular person indicated to that person that you were talking to him or her, and indicated to all the others that you were not talking to them. In our situation we have just two camera display pairs because there are only two regions of interest in the patient's room – the consultation space and the examination space. Our camera/display pairs are defined by their location in the two rooms rather than by who is sitting at them, and these locations match their position in the overview displays.

The Hydra system does not necessarily have a concept of adjacency. For example, if two displays are adjacent on your desk, the people presented on those displays are not necessarily adjacent in the remote location. In our system, the two close-up displays on the surgeon's desk are adjacent; the surgeon sees people in the examination space as being to his or her left of the people in the family space. This same relationship holds in the room overview display – there is a consistent placement of people in both the video representation and in the actual rooms. This means that, when the surgeon turns to speak to the people in the examination space (for example), both those people and the people in the family space are aware of whom the surgeon is addressing. In addition, people in the examination or consultation space can turn to talk to each other and this act can be interpreted by the surgeon due to the actual spatial relationships within the patient's room.

Study protocol

The telehealth system was modified for this study by removing the additional technology for conducting a patient examination and by including some items of furniture. The study was conducted between two laboratory spaces located on different floors of the same building. These spaces are referred to as the "Upstairs Lab" which contained the layout for the surgeon's room and the "Downstairs Lab" which contained the layout of the patient's room. Figure 6.5 shows the arrangement of equipment and furniture in the two rooms for this study. We refer to the volunteers helping with the study as "participants" and to the people conducting the study as "researchers".

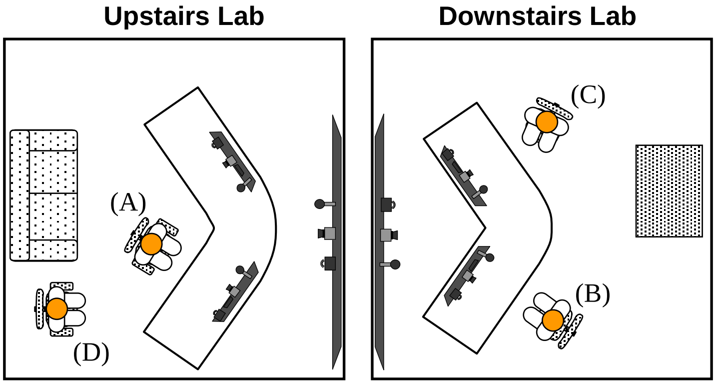

Figure 6.5: Schematic diagram of the seating plan for the experiment, showing participants sitting at (A) and (B) and experimenters at (C) and (D). The couch, which was the subject of the furniture placement task, is shown in the Upstairs Lab and a small table is shown in the Downstairs Lab.

Twelve participants took part in the study, grouped into six pairs. For each pair the study consisted of a short initial meeting to complete demographic and consent forms, about 25 minutes to perform the tasks and a 15 minute debrief session to answer the written and oral questionnaire. The participants initially sat at matching close-up video camera/display systems so that they had a close-up view of each other (positions A and B on Figure 6.5). One researcher sat at the other close-up video camera/display (position C) with the role of giving instructions and provoking three-way conversations that bridged the media space. The other researcher sat at the back of the other room and managed the task timing (position D).

Study tasks

The room sketching and furniture placement tasks used in this study were based on the "room drawing task" (draw a plan of the remote room using the video streams and each other's explicit help) and the "design task" (collaboratively re-arrange furniture to fit in part of one of the rooms) used in Gaver and colleagues' early study and replicated in other studies (Gaver, Sellen et al. 1993; Heath, Luff et al. 1995; Heath, Luff et al. 2001). After initial introductions, the participants were each asked to draw a sketch map of the remote room with help from their partner. It was left to the participants to decide how best to make use of each other and of the video and audio links. The purpose of this task was to see how the participants would use the communications technology, what use they would make of pointing and other gestures, how they would use their own space and what sort of dialogue they would conduct with their partner.

The participants' attention was then drawn to the 2-seater couch (sofa) in the Upstairs Lab and to the open space in the Downstairs Lab. They were asked to work out the best place to re-locate the couch into the Downstairs Lab 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 this experiment. This task was to provoke a discussion about spatial locations, relative sizes and location context to see what use the participants made of pointing, gesture, focus of attention and grounded conversation.

During the tasks the researcher at position C created a series of interruptions, both as events unrelated to the tasks and as boundaries between task components and the next set of instructions. The purpose of these interruptions was to explore three-way conversations across the Internet boundary between the two Labs. In particular we were interested in studying how the participant in the Upstairs Lab handled changes in direction of attention between the partner and the researcher in the Downstairs Lab (at positions A and C). Of interest was the way the participant used the two close-up displays (giving a close-up view of partner and researcher) and the room display.

Two external interruptions were also scripted. A third researcher entered the Upstairs Lab and handed an object to the researcher at position D. He then exited the Lab and proceeded to the Downstairs Lab. He entered the Downstairs Lab and sat in a chair at the back of the room.

This protocol was approved by the CSIRO Human Research Ethics Committee – reference code 06/40.

Data collection and analysis

Observation notes were taken by each of researchers during the runs of this study and the study runs were also videotaped. At the end of each run the participants met individually with the researcher who had accompanied them to complete a written and oral questionnaire. These exit interviews were audio recorded.

I analysed the video recordings of the study by recording what the participants did and said during the phases of the study task. I looked in particular for pointing, gesturing and spatial referencing in both the local and remote spaces and for how the video channels were used to communicate them. I also looked at how the participants responded to the scheduled interruptions and at how the participants recovered from misunderstandings in their communications.

6.3 Results

During the study we observed grounded conversations concerning space and objects, use of the close-up display for direct discussions and use of the room display for discussions about the space. We also observed pointing, gesturing and spatial referencing into both the local physical space and the remote space.

The twelve participants ranged in age from 23 to 60 years old. Nine of them had never used video-conferencing, two had used it rarely and one used it once a week. Their experience of computers ranged from a retired person’s “very little (email)” to full-time computer science students and professionals using them every day.

Grounded conversations

Four pairs of participants began talking at the start of the room sketching task and quickly established some common frames of reference. The conversations were grounded in shared perceptions of objects in each of the rooms. They asked about objects (“You’ve got some furniture up the back, haven’t you?”), offered descriptions of items in their room using pointing, touching and size gestures, and used humour grounded in the space to bridge the artificiality of the laboratory setting. One pair agreed on a North/South convention for directions within each Lab but soon abandoned it in favour of pointing, gestures and relative location descriptions (“Behind, on my right hand side …”). Two pairs began sketching using only visual information. During this task they engaged in minimal conversation, preferring to sketch and only to ask directed questions about objects.

The furniture placement task, however, brought all six pairs into active dialogue. They each had spatial information not directly available to the other that was needed to solve the problem. Eleven of the twelve participants got up from their chairs and moved about the Lab, using their body and reaching/touching gestures in the discussion. An example of the dialogue:

W: How big is the couch?
V: Can you see it?
W: Yeah, I can see it behind you.
V: (Moves to, and lies on the couch) Can you see me? (Gestures along her body length to show the length)

For each pair, the dialogue was sufficiently robust that the scripted interruption by the researcher did not disturb its flow.

Close-up and room overview camera/displays

The participant in the Upstairs Lab was interrupted (by the researcher in the Downstairs Lab) at three places during the furniture placement task. Firstly, the task was explained by the Downstairs researcher with pointing and gesture into both spaces. She then asked "Does that make sense?" directing the question to the Upstairs participant through her close-up display. Five of them explicitly turned their attention from the room display to the close-up display in response to the question. The sixth was confused about the instructions and continued gesturing into the room display.

The second interruption was an unrelated question directed at the Upstairs participant early in the task. It used material shown on the close-up display. All six responded to the interruption by turning to the close-up view, replying to the unrelated question then turning back to continue, with no noticeable break in the furniture placement dialogue. In the post-experiment interview these six participants were asked about the interruption event. Three said that their response was triggered by the researcher's voice. All of them knew to look at the close-up display. Their comments included:

"I looked at the [display], it was J's proxy. No thought involved"
"It was coming from her … no, that wasn't difficult at all"
"Because of the visual on the big [room display] screen and seeing that that was where J was"

The six participants in the Downstairs Lab were asked for their impressions of the interruption. They were aware that the researcher was talking to their remote partner, taking his/her focus away from them, and wondered what the researcher was doing.

The third interruption occurred at the end of the task. The Downstairs researcher asked them how they could tell how much space there was in the Downstairs Lab (for placing the furniture). In response, four turned and spoke directly to the close-up display and two explained their answer by speaking to and gesturing to the room display. All participants agreed that it was easy to tell when the Downstairs researcher was talking to them.

A third researcher entered and left the rooms to explore participants' awareness of people in the space. In the questionnaire the participants were asked to say how many people a) were in each room for the duration of the study, b) came in and sat down and c) came in and left before the study ended. Eight noticed and remembered these correctly, two were not sure if the person entering the remote room had sat down or not and one person was aware that someone had entered the rooms but was not sure what they had done.

Most participants made extensive use of the room display even though its resolution was not as fine as the close-up displays. One commented “I felt compelled to look at the major screen [even though I] can’t pick up many subtleties.” One who did not make much use of the room display asked her partner to describe the remote room in detail for the room sketching task, even though she could see it. She commented “I don’t trust what I see”. Some participants commented on the closeness of their partner through the close-up display.

> “… at one point I thought it was very like we sit and have a meal together – we are sitting across a table from each other and able to sit and chat.”

All six pairs moved between using the room display and the close-up display during the sequence of tasks, matching the moment of dialogue with the choice of display. The following extract illustrates this use:

> T: (Looking at close-up) Where do you think is best? (Turns to look at room display to listen to the answer)

A little later the participant engaged in a dialogue sequence involving looking at a remote room feature in the room display, asking a question about it then turning to look at the close-up display to listen to the answer. In each case the body gesture matched the purpose of the dialogue rather than being locked into a particular display.

Pointing, gesturing and spatial referencing

All six pairs used pointing, gesturing and spatial referencing and they wove these references meaningfully into their dialogue. They pointed at and then sometimes moved to touch an object 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 also pointed at objects in the remote space, used spatial referencing terms (“in front”, “behind” “put it over there”) and movement gestures. Sometimes they combined all three in the one component of dialogue.

> V: Put the … move the white thing … over there (points to the remote space and gestures a sideways movement)
> W: (Interrupts V) Apparently we aren’t allowed to move the white monitor thing

In most cases the dialogue continued, showing that the partner had understood. Gestures were sometimes used with dialogue to bridge the two spaces.

> A: I guess the task is to move that couch (points to remote space) into this room (points into the room where he is sitting)

Overall, participants seemed comfortable including pointing, gesturing and spatial references in their interaction with their partner.

Some misunderstandings occurred. Where a reference to an object in the remote Lab was misunderstood this misunderstanding could be traced to a mismatch of frames of reference. An example was the use of “back” and “front”. The wall nearest the desks had the remote room view projected onto it and, in room terms, was the “front wall”. Some participants, however, felt that they were sitting at the “front” of the desks, giving “front” the opposite directional meaning. Mismatches could also be transient. Participant A had turned around to look at the back wall just as his partner referred to “[the data projector by] the wall you are looking at” (meaning the front wall with the remote room display). The back wall had an unused data projector on a shelf reinforcing the misunderstanding. After several turns of the conversation this misunderstanding was corrected.

Objects in the two spaces that were similar but not the same sometimes caused confusion. The “V” shaped desks were similar in construction but in one room the apex faced the remote room display whereas in the other room the apex faced the rear of the room. Two pairs of participants were expecting the same configuration for each and conducted conversations to establish the actual situation. The two Labs were partitioned regions of actual rooms in the same building but were aligned differently. The long wall of the actual room ran across the main line of sight in one and parallel to it in the other. The entrance door was in the back wall in one and in the side wall in the other. One pair initially tried to use the walls and doors as their spatial references but abandoned the idea when it did not seem to work.

Understanding spatial information

All participants felt that they could understand the layout of the room remote to them (Figure 6.5). Two pairs conducted the first five minutes of sketching in silence using only the room display. When they sketched objects that were indistinct, distorted by the wide-angle lens or partly obscured they asked their partner questions. This resulted in sporadic dialogue within longer periods of quiet sketching. The other four pairs maintained a dialogue that combined questions, information, social interchange and humour.

Vigorous dialogue was observed for all six pairs during the furniture placement task. This included gesture, pacing out the space and moving objects in the Downstairs Lab, gesture and body movement to show the furniture item in the Upstairs Lab and voice, pointing and gesture from the Upstairs Lab to the Downstairs Lab’s display. The dialogue contained spatial reasoning, suggestions and criticisms of placement options. At the end of the task each pair was able to agree on a suggested location for the furniture item in the Downstairs Lab.

6.4 Discussion

The system was designed to meet three requirements: support for face-to-face dialogue, spatial awareness of both spaces, and appropriate handling of privacy concerns. Further, the corresponding application scenario involved untrained users so these requirements needed to be met even for novice users. The results of the study indicate that overall the requirements were met. I discuss the evidence for this below. I then discuss the freedom of the use of space which was an unexpected benefit of the design and some key expectations that the design created and suggestions for better supporting these expectations in future systems. Like the target user group, most participants were new to video-conferencing and all were new to this system. The study participants were representative of the target user group in this regard.

Support for face-to-face dialogue

The study provided clear evidence that the system supported communication between the two sites. During the room sketching task the participants who chose to discuss the room contents and layout were able to do so with relative ease, as suggested by their use of humour. The participants were comfortable using pointing and directional gestures to refer to objects in their own location and objects in the remote location. They did not, however, point or gesture in isolation – they did so in pursuit of the study task and embedded in a dialogue with their partner. They could tell from their partner's response, spoken or otherwise, whether they had been understood. When this communication failed (examples are the misunderstanding of the desk shapes and the confusion over front and back) they were able to recover using turn-taking conversation.

Generally, pairs interacted more during the furniture placement task than during the room sketching task. Rich conversations developed in which participants not only made suggestions but also critiqued their partner's suggestions. Participants were able to engage fully in the task with their partner. During this task, participants continued the discussion often whilst moving about the room. This demonstrated an ability to communicate using a combination of the available channels and to switch between them with relative ease. Perhaps the strongest evidence of the strength of the communication was the response to researcher interruptions. In particular, interruptions were noticed and dealt with as necessary but did not disrupt the conversational flow. Participants' subjective reports of their ability to communicate with their partner matched up with the study observations. One participant volunteered that it was like her and her partner were sitting across the table from one-another.

Support for spatial awareness

The participants' mutual awareness of the two locations was demonstrated by their conduct of grounded conversations during the collaborative spatial tasks and by their ability to reach an agreed conclusion on the furniture placement task. It was also supported by their questionnaire response, in which all twelve participants either agreed or strongly agreed that they could understand the layout of the other location. Further support comes from their use of the two close-up displays and the room display, especially the six participants in the Upstairs Lab who were able to maintain a conversation with their partner, refer to the remote room layout and interact with the researcher by shifting their attention between the three displays.

As suggested by Heath and colleagues, the participants were able to use fixed frames of reference (fixed video camera/displays) and stable objects in the rooms (the desks, seating and display screens) to place their spatial dialogue (Heath, Luff et al. 2001). They occasionally used potentially misleading terms such as "my left" and "your right" but they accompanied these with gestures that overrode any incorrect meaning. The spatially-focused collaborative task was to find a place in the Downstairs Lab for a couch located in the Upstairs Lab. This drew upon their familiarity with both locations from the earlier task and on their ability to conduct a spatially referencing dialogue across the network link between the two Labs. They successfully shared spatial information with their partner both by reference to known objects, in the room or from real life, and by reference to their partner's space. This sharing of information about the objects and each other's actions suggests that we have succeeded in "explicitly and deliberately" designing the system for object and action awareness (Robertson 2002).

Privacy – support for awareness of people

The privacy issue that we were addressing was that the participants should be aware of who was in each location and of what they were doing. This required that they both see who was in the room and observe people entering and leaving. The volunteers were all able to recall that a researcher had entered both rooms. This suggests that the system supports a basic level of awareness of people in both spaces.

Not everyone was able to recall whether the person entering the room had sat down. Of the twelve participants eight correctly stated the numbers of people present, entering and leaving the rooms and what the transient people did. The other four were aware of the intrusions but did not pay enough attention to be confident of what had happened. One participant explicitly commented that she had noticed the person enter but was not concerned with what he did since she believed it irrelevant to the task. This ability to observe the presence of someone coming and going and to deliberately ignore their actions if they are not considered relevant to the situation may be desirable in a clinical setting. During our clinical observations, a nurse quite frequently entered and left the examination room. The patients, parents and clinicians continued the examination only paying attention to the nurse as required.

One potential problem for privacy uncovered during the study was the poor visibility of the door in the Downstairs Lab. One participant was not aware of it until the debriefing session. Where privacy is an issue a well marked door may be an important cue to support awareness of people entering or leaving the space.

In response to the numerically rated question about their level of awareness of who was in the rooms (on a range of 1: Low to 5: High) most of the participants recorded 4 or 5. This question was asked directly after the question that required the participants to indicate how many people had entered and left and sat down in the room. Of the two participants who reported lower awareness one was the participant who intentionally ignored the intruder. Both stated as they were filling in the questionnaire that they must not have been so aware since they had trouble recalling if the extra person had sat down in the other room. Given that this level of awareness is not necessary for the task and the high awareness reported overall these results suggest the system is meeting this requirement.

Freedom of movement and communication

The study environment was a simplified version of our intended telehealth system, without the sense of “place” of a clinical consultation in the sense that Harrison and Dourish use the term (Harrison and Dourish 1996). Nevertheless, there were cues in the way the system was presented to the participants that led them to develop their own sense of place. They were invited to sit in what would be the “consultation wing” seat, facing their partner’s close-up display. The Downstairs Lab researcher sat at the other close-up display and gave instructions from there. Objects relevant to the study tasks were placed invitingly within the open space.

By the end of the room sketching task all six pairs had appropriated the space for themselves. During the furniture placement task, volunteers moved around both rooms. Regardless of their position in the room they were able to communicate with their partner. Use of voice and gestures from various places in the rooms were understood. Depending on where participants were located and what they were discussing they switched their attention appropriately between views. This occurred with no visible effort; one participant, however, commented that there was some adjustment required when switching views. Overall this observed interaction suggests that the system supports a variety of collaborative interaction over the whole space.

Similarity expectations

The use of familiar objects and similar objects in both the rooms helped participants to understand the remote space. Difficulties sometime arose, however, when the objects were misleadingly similar and when participants chose frames of reference outside the expected bounds of the study. For example, they used the long walls of the spaces as references. One was the room’s depth and one the room’s length but this difference was not apparent to all participants. This suggests that, in future systems, any apparently similar objects should indeed be the same and that any fittings (chairs, for example) should be of standard office size. Further, objects that are different should have cues to indicate this. For our long wall example, the overview camera image could be displayed such that it made the remote room shape more apparent.

6.5 Conclusions

The preliminary analysis had identified three main requirements for the video and audio communications aspects of the telehealth system (support for "face-to-face" dialogue, support for mutual awareness of participants' actions and located objects, and support for privacy). A study was conducted in a laboratory setting to evaluate the telehealth system against these requirements.

The video and audio arrangement in this study, with fixed room display and two fixed close-up displays, allowed the participants to develop a mutual understanding of each other's location, to conduct three-way conversations, and to use grounded conversation to complete a collaborative spatial task. Face-to-face dialogue was supported between the two sites from each of the two wings of the system and participants switched their focus of attention between the two close-up video systems and the room display appropriately to their discussion. While the close-up displays supported effective person-to-person dialogue the intended metaphor (of sitting on opposite sides of a desk) was only observed explicitly by one of the twelve participants. Support for a wide awareness of the other people in the two rooms was made available to the participants and, while most participants observed this, a few chose to ignore it as irrelevant to the study tasks.

A major impediment to the participants' ability to conduct their tasks was the misleading similarity of aspects of each of the two locations. A second impediment was the absence of easily observed directional markers to resolve ambiguities of direction. These two issues need to be addressed in the final version of the telehealth system and, in particular, the locations of the doorways to the two rooms need to be made explicit to the participants.

This study demonstrated the use of a human-centred evaluation approach in scenario-testing the shared space of a telehealth system. It illustrates the artificiality of this type of laboratory test with respect to the intended real-world application. It illustrates the value of using a human-centred rather than a performance or measurement-centred evaluation approach when the corresponding activities in the real-world application are human-centred rather than performance or measurement-centred. A summary of the major results of this thesis is given in Section 1.6, pages 8-8, and this case study supports result R1.

7 Case study: User interface for remote guidance

7.1 Purpose

The purpose of this study was to evaluate the usability of three candidate user interfaces for the remote guidance technologies that formed a sub-system of the overall telehealth system. The application context for this remote guidance was to help a surgeon guide a remotely located assistant to examine a patient, and to support dialogue between the surgeon and assistant about artefacts and actions relevant to that patient examination. The tasks used in this study were abstractions of the actions observed in normal outpatient consultations, and the physical task space corresponded to the immediate space around a seated child. An account of this study was written as a CSIRO Internal Report (Smith, Stevenson et al. 2007) and I have drawn on this report in writing this chapter.

The role of this case study in my thesis is to illustrate a human-centred approach to evaluating user interface components in the laboratory, where those components are exercised through human activity scenarios and those scenarios have corresponding meaning in the target application.

7.2 Method

Details of the study

The basic scenario for this study was for a volunteer participant (referred to here as the instructor) to instruct a remotely located actor, leading the actor through a sequence of tasks using the remote guidance technologies that were part of the telehealth system. The study was conducted within the one building – the instructor was located in the Upstairs Lab and the actor in the Downstairs Lab. This study used three sub-systems of the telehealth system:

- A close-up audio and video link supported personal communications between the instructor and the remotely located actor
- The tablet and electronic pen subsystem hosted the user interface for the instructor and presented tablet-based instruction to the actor.
- The pole-mounted laser drawing sub-system presented laser-drawn instructions to the actor.

The diagram in Figure 7.1 and the photographs in Figures 7.2a and 7.2b show the three people involved in each run of this study:

- The instructor, shown in position A in Figure 7.1, sat at the close-up audio and video link and used the electronic pen to control the user interface on the tablet. Figure 7.2a shows an instructor in the foreground of the photograph.
- The researcher, shown in position B in Figure 7.1, sat next to the instructor and managed the sequence of events. Figure 7.2a shows the researcher in the background of the photograph.
- The actor, shown in position C in Figure 7.1, sat at the other end of the close-up audio and video link. The actor is seen on-screen in Figure 7.2a and sitting at a

table in front of an arm-mounted tablet display in Figure 7.2b. The actor's audio and video link is off-camera to the left in Figure 7.2b, but is shown at position 2 in Figure 7.1. The role of "actor" was filled by two members of the research team, alternating sequentially with runs of the study. Differing data sets were used for each run of the study and neither actor had seen the data sets prior to the study.

This study followed the concept of abstracting the situation and the study tasks from observations of actual outpatient clinics, which in our case were observed at the Royal Children's Hospital and at the Royal Hobart Hospital in Tasmania. The observed tasks included examining the head and face of a seated child and discussing X-rays and photographs. The working volume of the tasks was about $1/3^{rd}$ of a metre cubed and the actions included sensitive dextrous examinations and hand-scale pointing and movement gestures. As described in Chapter 5, the tasks used in this study were abstracted from the application setting so that the study could be conducted in our laboratory, away from the hospitals, and could be performed by non-clinically-trained participants.

This study was conducted to evaluate three candidate user interface designs for the remote guidance subsystem that was being developed for our telehealth system. These interfaces controlled two modes of instruction and two styles of instruction within each mode. The broad differences between the interfaces were in the way the modes were managed:

- For the "Pen Turning" interface, each end of the electronic pen (the "nib" end and the "eraser" end) was used to control the two modes of remote guidance. The user turned the pen in his or her hand, bringing one end or the other to the tablet, to change modes.
- The "Button" interface used an external pair of physical buttons to switch modes.
- The "Panel" interface had two panels displayed in separate windows on the tablet, one for each mode.

The reference data for all the remote guidance options was the video stream coming from the camera mounted on the pole, next to the laser drawing sub-system. This camera gave a live video view of the actor and of the actor's workspace, which consisted of a tabletop, paper and material on the surface of the table and a manikin the size of a small child placed on the table. In the corresponding telehealth application, this camera represented the view of a seated child as seen by a standing surgeon.

The user interactions involved floating the electronic pen over the window on the tablet showing the video stream, or touching the tablet's surface in that same window. The user had four guidance options:

- Pointing to an object in the field of view of the video camera, causing a red dot to appear in the video window. The actor could also see this red dot and therefore could see to what the instructor was pointing.
- Drawing over a region of the video display. This caused a red line to be drawn in the video window, which both the instructor and the actor could see.
- Pointing to an object in the actor's workspace. This caused the laser drawing sub-system to draw a green cursor (circle enclosing a cross) onto that object.

- Drawing over objects in the actor's workspace. This caused the laser drawing sub-system to draw a green line over the objects.

The pointing dot or cursor remained present while the pen was in use, and disappeared when the pen stopped being used. The drawn lines remained in place for five seconds, and then they faded automatically.

As we observed during our early hospital observations, pointing and drawing are used as different gestures. The first indicates a choice or points to the presence of an artefact and the second typically indicates spatial attributes about an artefact.

Several research groups have published work on using remote gestures over video or projected into remote workspaces as guidance methods (Kuzuoka, Kosuge et al. 1994; Ou, Fussell et al. 2003; Kirk, Crabtree et al. 2005; Kirk and Fraser 2006). In contrast with many of these papers our remote gesture work was built in the context of a complex target application in which an instructor and an actor (surgeon and clinic assistant) collaborate over a complex physical and information task (examining a patient with a complex clinical condition) to reach a conclusion about the patient's condition and to contribute evidence towards a treatment plan.

The overall goal of pointing and drawing in the hospital outpatient consultations is essentially qualitative. The remote gesture components do not have a measurable task performance or a meaningful time to completion. Instead, they contribute as part of the dialogue between the remotely and locally based clinicians to the overall completion of the task. For this study we used the examination space of our telehealth system because that is where the actual patient examinations would take place in the deployed system.

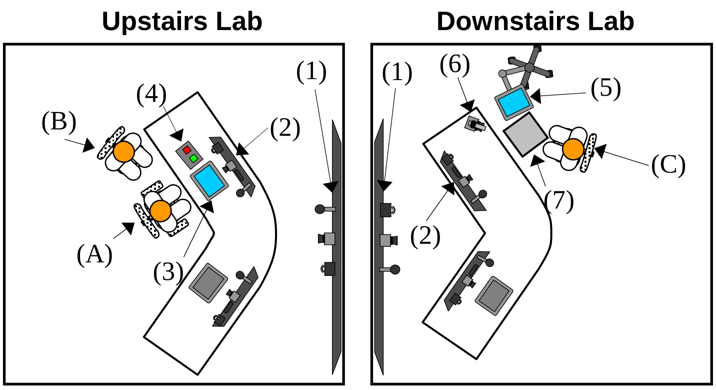

Figure 7.1. Schematic diagram of the context of the interfaces and setup for the study.
(1) Room overview audio-video link including camera, screen, microphone and speaker
(2) close-up audio-video link including camera, screen, microphone, speaker and video fold-back monitor
(3) tablet display and pen input device for the instructor (shown in light blue)
(4) external buttons for the Button interface
(5) tablet display for the actor (shown in light blue)
(6) workspace camera and workspace marker projection system
(7) workspace table
(A) instructor; (B) researcher; (C) actor

Figure 7.2a: Upstairs lab showing instructor (foreground), researcher (background) and actor (on screen)

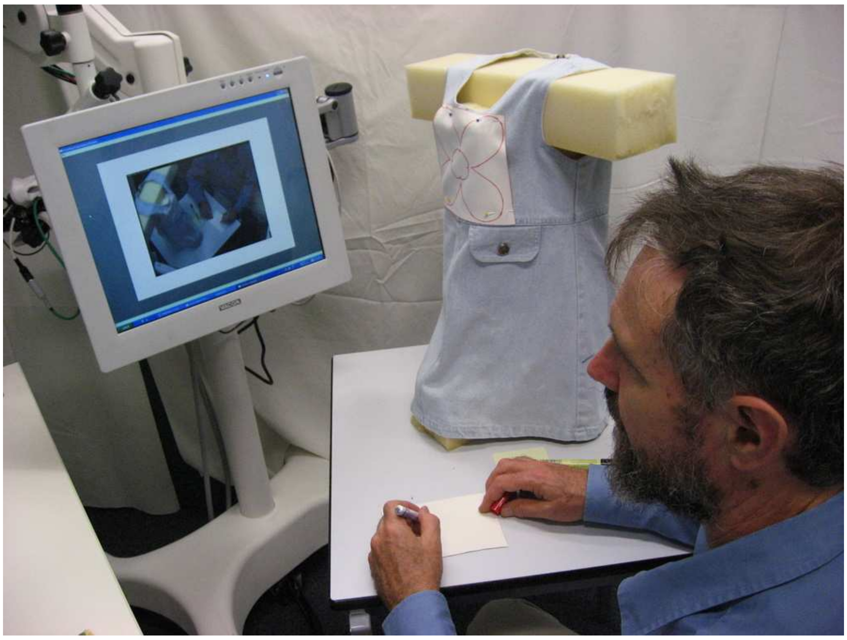

Figure 7.2b: Downstairs lab showing actor. The tablet display shows the pole-mounted video view of the actor's workspace, hands and manikin, as seen by both the instructor (in the Upstairs lab) and by the actor himself.

The three interfaces

The primary difference between the three interfaces was the way that the instructor selected between the four guidance modes: using the on-video marker as a cursor, using the on-video marker for drawing; using the workspace marker as a cursor; and using the workspace marker for drawing.

The pen input technology used for the interfaces had several features that influenced the three designs. The pen could be tracked both when held just above the tablet, and when touching the tablet. The pen also had a pointy drawing nib on one end a wider eraser-style knob on the other end, both of which could be tracked. There was a function button on the pen that could be pressed with the index finger while drawing with the nib end.

The "Pen Turning" interface was the most simple and direct, using features of the pen for all guidance mode switches, that is floating or touching with the "nib" end or the "eraser" end of the pen over or onto the window on the tablet which displayed the reference video stream:

- Float the nib end => on-video pointing (using a small red dot as cursor)
- Touch the nib end => on-video drawing (showing a thin red line)
- Float the eraser end => in-workspace pointing (crosshair cursor drawn in green by the pole-mounted laser)
- Touch the eraser end => in-workspace drawing (drawing a defocused green line with the pole-mounted laser)

The on-video pointing and drawing were displayed on both the instructor's and the actor's tablet displays. The pointing cursor tracked the floating tip of the pen in real time on both displays and disappeared when the tip of the pen was pulled away from the tablet surface. The drawn line followed the tip of the pen as it touched the display, fading after five seconds.

The in-workspace pointing and drawing were displayed directly into the actor's workspace and were, therefore, visible directly to the actor. They were also visible to the instructor as a green line drawn on the objects in the field of view of the pole-mounted video camera.

- The pointing cursor tracked the floating tip of the pen with a small lag due to the video latency and with a variable offset due to the three-dimensional geometry of the workspace and the sideways offset between the laser display and the axis of the video camera. The method of calculating this offset is described by Palmer and colleagues (Palmer, Adcock et al. 2007).
- The drawn line followed movement of the pen tip on the tablet with this same offset and persisted for about five seconds. The name "pen turning" refers to turning the pen in the hand to put either the nib or eraser tip to the tablet surface.

The "Button" interface used an external pair of physical buttons for switching modes between pointing/drawing over live video and laser projected pointing/drawing over objects in the workspace. For consistency the red button activated the on-video mode which used red for the cursor and lines, and the green button activated the laser projection into the workspace which used a green laser light.

The function button on the electronic pen controlled the switch between pointing and drawing (i.e. filling the same role as turning the pen in the previous interface). Touching the nib end of the pen on the tablet surface activated the on-video pointer and displayed a small red cursor at the point of the nib. Holding down the function button on the pen and then touching the nib end of the pen on the tablet surface activated the on-video drawing and displayed a red line where the nib end of the pen moved over the surface.

The "Panel" interface provided two separate windows on the tablet:

- The first window displayed the reference video stream. Touching the pen on the video display surface activated the on-video cursor. Pressing the pen's function button and touching the video display surface activated the on-video drawing.
- The second, smaller window provided the interaction space for controlling the laser drawing sub-system. Touching the smaller window with the pen activated the in-workspace pointer at the corresponding point in the video display and touching with button pressed activated the in-workspace line drawing. The two windows had the same XY proportions but the second window did not display the video stream. The user needed to estimate proportional positions from the larger to the smaller window to locate the pen when controlling the laser pointing or drawing.

The in-workspace laser projected pointing and drawing were offset from where the pen touched the surface and the instructor experienced a short one-way video lag in seeing the actual location of the laser projected item. As a method of stabilising the on-video drawing this interface was designed to freeze the video on both tablets from the moment when the instructor started drawing until five seconds after the drawing had finished.

In all three interfaces the drawing faded out a fixed time after drawing (set to five seconds in the study). This was true of both the on-video marker drawings and the workspace marker drawings. The intention was to support ephemeral gestures rather than permanent instructions and the fade was set to happen automatically rather than under user control. This is consistent with previously reported work that found efficiency benefits in an automatic erase feature in remote guiding (Fussell, Setlock et al. 2004). The ability to create a fixed static drawing would also have undermined the task chosen for the study, where we were interested in immediate and continuous instruction, rather than the up-front provision of a blueprint for the work.

Study tasks

We had identified three component tasks which the surgeon might wish to guide remotely during a consultation or patient examination: indicating an area or feature of concern on a clinical chart or patient or choosing an object or feature, indicating a position and orientation of a moveable object and requesting the position and movement of a close-up examination camera. In the patient's room these tasks would occur on the 2-dimensional surface of a document or X-ray or in the 3-dimensional space occupied by a child. The study tasks, therefore, were designed to generalise these actions and to take place on a surface the size of an X-ray film or in a region the size of a seated child. At this stage in our development of the telehealth system we concentrated on craniofacial surgery on young children where, typically, post-operative examinations have the child seated in an adjustable chair or lying on a parent's lap.

The literature describes many studies that involve manipulating mechanical objects such as LEGO (Kirk, Fraser et al. 2005), robot models (Ou, Fussell et al. 2003), computers (Kuzuoka, Kosuge et al. 1994), and control panels (Kuzuoka, Oyama et al. 2000). The tasks for this study (and the case study described in the next chapter) used softer, less well-defined shapes and components. The tasks were:

- A **training task**, to familiarise the instructor with the four remote guidance options
- A **dress patching task** in three steps:
    - **Select** the fabric for the patch
    - **Draw** the shape of the patch on the rectangle of fabric (under guidance from the instructor)
    - **Place** the patch on the dress in the correct position and orientation

This set of tasks was designed to minimise the effect of prior experience on the part of the instructors and actors, and to minimise the use of spoken short-cuts. It involved both two-dimensional and three-dimensional components, organic shapes, and it was on the spatial scale of a young child. This task was designed by my colleague Jocelyn Smith and she is the first author of the CSIRO Internal Report (with myself and Matthew Hutchins) on which this chapter is based.

The training task involved tracing a flower petal design on a square patch on the dress, which was placed over a basic torso model (Figure 7.3). This task used all four of the guidance modes and let the participants become familiar with the user interface they were given, and with using the pointing and drawing guidance modes.

Figure 7.3: The flower pattern was traced with each mode during the training phase.

The first step in the dress patching task was to select the fabric from which the patch would be made. Participants were told to direct the actor to pick up the rectangle of fabric in the workspace that matched the photograph which appeared in their instruction panel.

The next step was to draw the patch shape on the back of the fabric. The shape was displayed in an image window visible to the instructor but not the actor. The participants were told to direct the actor to draw the design on the white side of the fabric patch and not to worry about extra pen marks. Once the design was drawn to the instructor's satisfaction the actor cut it out. Figure 7.4 shows an example of the in-workplace laser drawing being used to guide the actor to draw a line on a rectangle of material. Figure 7.5 shows one of the shapes that the instructors guided the actors to draw.

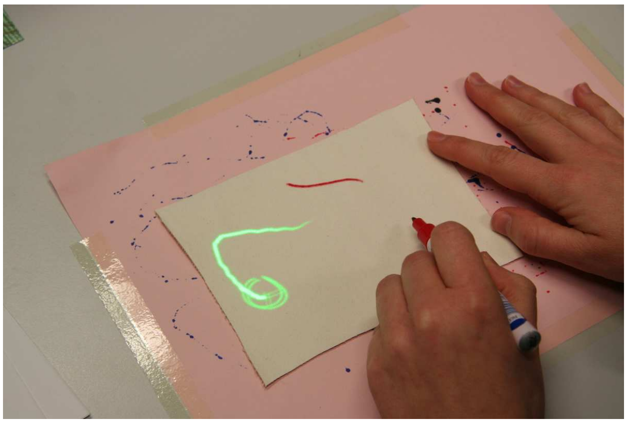

Figure 7.4: In workspace guidance mode the green laser-projected line will guide the actor to draw an irregular shape

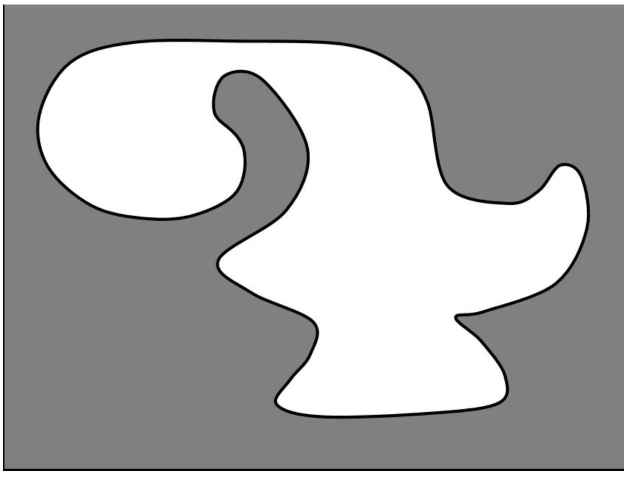

Figure 7.5: One of the shapes that the instructor guided the actor to draw

The final step was to place the patch on the dress. Participants were told that the patch was one of many shapes to be added to the dress and a photo showed the patch to the participant as one of many on a dress. The participants were told to direct the actor to place the patch with the coloured side out as close as possible to its position and orientation in the photo and then to pin the patch to the dress. Figure 7.6 shows an actor being guided to place the patch on the dress.

Figure 7.6: Placing a fabric patch on the dress. In workspace guidance mode the green laser cursor (below her left thumb) shows the required position of the patch directly in the workspace

Study protocol

The participants had been given an information sheet about the study before they arrived. When they arrived, they were given an opportunity to ask questions and then filled in a consent form and a brief demographic questionnaire. The researcher then took them to the Upstairs Lab and the actor was located in the Downstairs Lab (Figure 7.1). The video channels in the room were pointed out to them and they were introduced to the actor. Following a simple script the researcher introduced the participants to each guidance mode.

For each mode the researcher explained how to use the mode and what the actor would see. The participant was directed to try out the mode and to complete the training task. After training with each mode, the participant was directed to complete the training task again changing modes during the task.

Next the fabric select task and patch drawing task were completed. The researcher explained both tasks with the help of a task information window containing photos of the desired task outcome. During the study tasks, participants could switch guidance modes at will and the researcher noted when they used each.

At the end of the first two steps the researcher conducted a brief interview with the participant which included questions about their reasons for using the tools they did. The patch placement task was then similarly introduced and carried out and a second brief interview conducted.

This protocol was approved by the CSIRO Human Research Ethics Committee – reference code 06/41.

Video links

The instructors had a window on their tablet display that showed the view of the actor's workspace table from above, taken from the pole-mounted camera. This was the video view over which they pointed and gestured with the electronic pen. The actors had a copy of this window on their arm-mounted tablet display.

The actor and instructor could see and hear each other via the close-up video subsystem which was part of the examination wing in each of the rooms.

Participants

The nine participants ranged in age from 20 to 46 years old. Their experience with video conferencing ranged from two who had never used video conferencing to one who uses it daily. Three of the nine were female; two were left-handed. Five indicated that their major course of study or work domain related to computer science. The other four were from a variety of fields: art school, bio-chemistry, law and administration. We used two members of the research team as actors for the study, doing four and five sessions respectively.

Data collection and analysis

Video recordings were made of the participant who took the role of instructor. During the study there were places where the researcher asked the participant questions about their impressions to that point.

The data analysis for this, and for the next case study, was relatively simple. The video recordings of the study were watched and notes made about what the participants did and what they said to each other as the tasks were completed. We were looking specifically for which guidance modes the participants used, at what points did they change to using other modes and whether there were obvious reasons for those changes. We listened for spoken guidance interleaved with gestures or reinforcing gestures. We listened for dialogue that showed the participant and actor working together. We listened for dialogue that highlighted misunderstandings and that showed how those misunderstandings were repaired. We created the equivalent of field notes by recording these events, including fragments of dialogue, and with a simple coding scheme we used these notes, together with the participants' responses to our structured questions, to write the results sections of the CSIRO Internal Report.

7.3 Results

The three component tasks

Fabric selection task. Instructors used a variety of strategies for indicating the appropriate fabric to the actor: three used the workspace pointer, two the on-video pointer, two the on-video drawing and one the workspace drawing, while one used no gesture options and relied solely on verbal description. This task was generally quick, taking between 25 and 70 seconds. One case where this task took longer (135 seconds) was when the instructor initially misunderstood the task and tried to select the fabric by clicking on the study's data window.

Shape drawing task. We observed a variety of approaches to this task. Initial strategies varied and some instructors formed their strategies as the task progressed, based on the actor's behaviour and feedback. Before the start of the task, six instructors gave the actor an overview of the patch shape. One instructor gave a verbal description of the shape, one drew it with the laser and four drew it over the video.

At the beginning of the task, three instructors started to draw the shape without informing the actor of a strategy or discussing a strategy for drawing with the actor. The other six either described or suggested a strategy for drawing, or simply indicated how they were starting. Six of them began with on-video drawing, two began with workspace drawing and one began with workspace pointing.

The instructors displayed a range of strategies for communicating with the actor as the shape drawing task progressed. Three instructors almost immediately adopted a strategy of drawing in the workspace [using the laser]. One started with this strategy and two switched (one from pointing and one from on-video) after the actor hesitated or asked for clarification at the initial stages of the task. Two other instructors used on-video for the initial stages of the task but switched to using the workspace (one used pointing and one used drawing) and verbal directions at a later stage after prompting by the actor. Two instructors adopted a changing strategy. One began by using the on-video marker and when difficulties were encountered switched to using the workspace marker until difficulties were encounter again. This instructor switched numerous times during the shape-drawing task. The other instructor adopted drawing in the workspace as a default strategy but switched to drawing on-video for a segment that gave him difficulty.

Patch placement task. This was generally achieved within two to four minutes. One instructor who understood the task immediately was able to direct the patch placement in about one minute. Observed difficulties most often involved understanding the task. In particular, the picture of the desired patch position was quite small and instructors sometimes had difficulty matching it with the patch they had created with their partner. One instructor expressed confusion about whether the patch was placed as a rotation or a mirror image to the one in the picture. This confusion resulted in the task taking over seven minutes before he decided it was correctly oriented. In some cases when the patch was pictured on the back of the dress (zipper side), instructors directed the actor to place it on the front of the dress (side initially facing the camera – pocket side). Several strategies were used for this task with some instructors first orienting the patch on the desk, others getting the actor to orient the dress in a better position and some indicating the position on the dress. The majority of instructors made some use of in-workspace pointing in this task.

During the patch placement task all instructors made use of verbal descriptions. There were many examples of instructors integrating descriptive verbal directions with their gestures. Often the gestures were pointing gestures used to establish either a position to move to or a point on the patch to hold in place as in this quote, “keep that tip where it is” (points with workspace cursor). Other times a gesture was used to indicate the direction stated in a verbal instruction. Two examples of such gestures were lines drawn to indicate the direction to translate the patch and arcs drawn to indicate the direction to rotate the patch. Simple gestures were combined with statements such as “about there” to indicate a position. Parts of the dress were referenced to indicate placement with directions such as “on the hip of the dress” and “toward the hemline”. Similar language was sometimes observed to describe a part of the patch even though the patch did not have an identifiable shape:

> “Its feet are in a good position but rotate its head down" (draws arc with workspace marker).

In some cases, verbal directions did the job without the need for gesturing. One such direction was the use of up or down when the dress was upright on the table. In this case, the dress was providing an orientation to ground the directions. Other times verbal directions needed clarification. “Which way is back?”

User interfaces

Pen-turning interface. Instructors found that "floating" the pen over the tablet surface was quite natural as long as there was an edge for them to rest their hands. One instructor commented that the pen-turning action to switch between on-video and in-workspace modes worked well; another did not like it and would have preferred a separate button.

Button interface. The buttons that swapped between on-video and in-workspace modes could be pressed by the participants other hand even when they were holding the pen at the tablet. This caused the location of the marker to jump from under the pen (on-video) to a position offset from the pen (in-workspace) even though the pen itself had not moved, causing discontinuities in the guidance process.

Panels interface. Two issues arose with this interface. Firstly, the interface automatically froze the video while the instructor was using on-video drawing. This was observed to interfere with the collaboration between instructor and actor when the instructor was trying to draw segments of the shape for the actor to follow. Because the actor was watching the video of the workspace, he was using the video view of his own hands to get feedback on what he was doing. With the video frozen the actor was unable to follow the guidance because he would have needed to flip his attention back and forth between the workspace and the arm-mounted tablet display. Further, the instructor had no view of the actor's movements during the freeze and so was unable to offer immediate small-scale feedback. This feature also interfered with spoken communication. For example, one actor would point to a place on the fabric and say "Here?" but the instructor was unable to see the action. Secondly, the control panel for the in-workspace pointing and drawing was too small for the instructors to use easily. All three of these instructors described having to establish where the laser was pointing when they touched its control panel before they could use it.

Other issues

Shared directions and orientation. When the actor had selected the correct rectangle of fabric he often brought it to his working space in "portrait" orientation. The rectangle with the design to be drawn was presented to the instructor in "landscape" orientation and when the instructor did not correct the orientation for the actor he or she found it difficult to mentally rotate the shape so that they could draw it.

Network/video lag. This issue concerned the in-workspace pointing and drawing and was noted for all three interfaces. The instructor could only see what the laser projector was doing by watching the video which lagged slightly behind the projection in the workspace due to encoding and decoding the video frames to and from the network packets. In normal gesture dialogue such as pointing to the desired fabric rectangle this is not noticeable but when it was inside a tight collaborative loop of segment-by-segment drawing of an amorphous shape it created overruns.

Locating the workspace marker. The participants observed that the workspace marker often disappeared as it moved off the edge of the table or other surface, or moved unevenly in their field of view as it traversed across objects sloping towards the camera. This effect was caused by the 3-dimensional nature of the workspace, where new surfaces were closer to or further from the camera than the previous surfaces (combined with the offset between camera and laser and the differing angles of view and projection). Instructors who understood the physical situation in the workspace had less of a problem with this issue. One commented "… the reality of the physical world gets in the way".

Learning to use the tools. Many instructors indicated that they learned to use the tools better over time. This was expressed directly or as a comment about the helpfulness of the learning phase. Sometimes the learning described was focused on the interaction style rather than the gesture tools. The workspace marker was generally considered easier for the actor and the on-video marker easier for the instructor.

Responding to the actor. Many participants said consideration of the actor influenced the strategy and tools they used. When asked how the actor influenced them, instructors frequently mentioned the actor's feedback. Sometimes this feedback was based entirely on the instructors' observations of the actor's actions, for example seeing him hesitate, observing him going astray, or getting behind. Other times the feedback was more explicit, for example a suggestion to do it bit-by-bit, repeating directions, or letting [the instructor] know when he [the actor] did not understand.

7.4 Discussion

The four remote guidance modes

All four guidance modes were exercised during this study and when problems in communication arose with any one particular mode the instructors were ready to switch to an alternative mode. It was clear that the on-video modes were far easier for the instructor to use because of the precision of the pointing/drawing with respect to the tip of the pen and the immediacy of the display. The in-workspace modes, however, were easier for the actor because they did not require him to repeatedly reconcile looking across at the arm-mounted tablet and looking down at the workspace. The instructors found that over the course of the study they learned to use the different modes in ways that suited the timescale and spatial scale of this particular task. In particular, if the actor was having trouble with the mode being used the instructors were usually quick to change to another mode to see if that was easier.

Interface design issues

This study identified two main areas of support that the interfaces must provide:

Firstly, the interfaces must support the instructor by giving timely feedback linking their pointing/drawing gestures and the remotely displayed results. The on-video modes provided this, with immediate feedback (displayed red cursor or red line segments) located precisely at the tip of the pen. This was due to the implementation being entirely in software and the interface actions being a 2-dimensional interface to a 2-dimensional representation of the remote workspace. The in-workspace modes did not provide this quality of feedback to the instructor. The use of returned video to show the placement of the gesture in the remote workspace caused a small lag in the feedback to the instructor and the 3-dimensional nature of the in-workplace display created offset and viewing direction anomalies. The offset was largely due to the varying 3-dimensional depth of the reflecting surface from the laser/camera pair. The differing lines of sight (from the pole-mounted camera for the instructor and from the head of the seated actor) meant that each had a different visual understanding of the moving cursor or extending drawn line.

The panels interface caused additional problems because the control of the in-workspace modes required proportional estimation of the position of the projected laser in the scene (from the smaller control panel to the larger displayed video). The button interface also caused problems because the point under the pen jumped whenever the on-video/in-workspace buttons were pressed and this jump could not be corrected in software because it depended on the viewing depth of the particular reflective surface at that moment.

Secondly, the interfaces must support collaboration between the instructor and actor at a temporal frequency that matched the actions of the moment. The on-video modes provided this support for the segment-by-segment drawing of the shape. The in-workspace modes did also, but with a small lag that the participants were able to manage. The exception was the panels interface with its freeze-frame for on-video drawing, where the freeze delay time was much longer than the actor's segment drawing actions. The drawing fade time, five seconds, was a reasonable match for the actor's segment drawing time - the displayed line persisted long enough to draw a segment without rushing but not too long that it interfered with the next line segment.

The ease-of-use of the on-video versus in-workspace modes was not symmetric. The on-video modes were easier to use for the instructors and the in-workspace modes were easier to use for the actors. Importantly, the instructors were able to observe this and were able to make decisions based on the situation at the moment as to which to use, and were able to switch to the other style if difficulties arose.

Frames of reference

The media spaces literature describes the importance of shared frames of reference and shared public access to the artefacts involved in whatever collaborative task is being undertaken (Heath, Luff et al. 2001; Robertson 2002). In this study we see strong use of frames of reference in the patch placement task where the instructor combined voice and gesture about the position and location of the patch on the child's dress. The mistakes that they made, however, highlight the importance of understanding the shared artefacts. Some instructors had trouble noticing the subtle distinction between the front of the dress (with pocket) and the back of the dress (with zipper) when they looked at the placement photograph in their instruction panel.

7.5 Conclusion

This case study used a human-centred evaluation approach to evaluate the components of a telehealth system, in the context of the eventual deployment of those components in a telehealth application. The application task was abstracted to give a study task that could be performed by non-clinically-trained participants and the collaborative context of the eventual application influenced the style of the evaluation. Unlike many apparently similar evaluations of remote guidance technology, which used hypothesis-based approaches and measurement-based data situated in the laboratory context, this study was evaluated in terms of the support that the components could provide to the participants in the eventual application context.

The study demonstrated the role that a human-centred evaluation approach can take in a laboratory evaluation of the way that user interfaces would support a complex application task, where the laboratory activities and evaluation criteria are both based on abstractions of the actual application. A summary of the major results of this thesis is given in Section 1.6, pages 8-9, and this case study supports result R1.

8 Case study: Collaborative guidance

8.1 Purpose

The purpose of this study was to explore the way that pairs of participants used the remote guidance components of the telehealth system to work collaboratively. This study used essentially the same arrangement of equipment and the same set of tasks as the previous study (Chapter 7) but it involved two volunteer participants, one as the instructor and one as the actor, and it had a focus on collaborative interaction.

This study was driven by our expectation that, in the actual telehealth situation, the remote guidance technology would be an adjunct to support the examination of the patient. We envisioned that the clinic assistant, present with the patient, would collaborate with the remotely located surgeon to perform the examination and to reach an interpretation of their observations.

To exercise the underlying networking technology, this study was conducted between the CSIRO ICT Centre's laboratories in Canberra and Sydney, a distance of about 300km. An account of this study was published as a full conference paper at the Australasian User Interface Conference in January 2008 (Stevenson, Li et al. 2008).

Broadband tertiary telehealth systems which have components to support telecollaborative behaviour at the application level pose a challenge for their developers because testing those components directly is likely to require access to the application context – healthcare facility, data, clinicians, patients and so forth. This case study presents an example of human-centred evaluation of components for supporting telecollaborative behaviour using the approach, described in Chapter 5, of abstracting the setting, task and evaluation criteria from the real-world application.

8.2 Method

Details of the study

The main purpose of this case study was to explore the way that the four remote guidance modes supported emerging collaboration between two participants. One participant took the role of instructor. This person used the remote guidance modes to direct the other participant, referred to as the actor, to complete the study task sequence.

The task sequence for this study was the same as for the previous study and it is described again here for ease of reference:

- A **training task**, but this time to familiarise both the instructor and the actor with the four remote guidance options
- A **dress patching task** in three steps:
    - **Select** the fabric for the patch
    - **Draw** the shape of the patch on the rectangle of fabric (under guidance from the instructor)
    - **Place** the patch on the dress in the correct position and orientation

The study was structured to create collaborative opportunities for the pairs of participants to address the tasks. There were differences between this study and the previous study:

- This case study used pairs of volunteer participants, one as instructor and one as actor (where the previous study used one volunteer as instructor and a researcher as actor). Neither instructor nor actor had seen the study before and so neither came with any pre-conceived ideas about how it should be performed.
- The training focused on how the instructor would guide the actor to draw simple recognisable shapes in addition to teaching the participants how to use and follow the remote guidance. The training was self-paced so that a particular step in the training sequence was deemed completed when both participants agreed that it was.
- The training instructions and the actual task instructions were issued in a computer-generated window on the instructor's tablet display so there was no prompting (explicit or implicit) from the researcher to move on.
- Completion of each task step was also reached by mutual agreement of both participants.
- The user interface for the instructor had been redesigned to take into account the strengths and weaknesses observed in the three candidate user interfaces that were explored in the previous case study.

As with the previous study, the participants used body gestures and spoken words via the close-up video subsystem together with remote guidance tools and they conducted dialogue to make progressive decisions and finally agree on task completion. This is in contrast to the work reported on remote guidance where the authors use speed and measured task completion as metrics (Bauer, Kortuem et al. 1999; Kraut, Fussell et al. 2003; Ou, Fussell et al. 2003; Fussell, Setlock et al. 2004; Kirk, Crabtree et al. 2005; Kirk, Fraser et al. 2005; Kirk and Fraser 2006). The tasks in this study are in keeping with the reference application task of conducting a complex outpatient consultation, where neither speed nor measurable accuracy is a relevant criterion for success. By placing participants in both roles we avoided any preconceptions about how the tasks should be conducted and about how the task completion should be judged, and we focused on system support for the collaborative dialogue between them.

A further feature of this study is that it occurred in the physical context of the intended remote patient examination and in the structural context of the actual application. The participants sat at the actual furniture to be used in the hospital trial (the examination wing of the telehealth suite) and used the same close-up video communications subsystem as the clinicians would use. The pole-mounted overhead video camera was the main camera that would be used for craniofacial patients and the workspace was where those patients would sit. The structural context of the actual patient examination would include voiced direct instructions, dialogue, modulated speech (via the close-up video links), facial expressions, and body and hand gestures. The use of the remote guidance modes would be interwoven with these other communication modes. In this study we have a similar structure where dialogue and spatial gestures from both sides were intermingled with remote guidance gestures from the instructor.

The photographs in Figures 8.1 and 8.2 show the set-up for this case study. Figure 8.1 shows the instructor's configuration in Sydney and Figure 8.2 shows the actor's configuration in Canberra. The actor's table and arm-mounted tablet are placed on the other side of the line of view from the close-up video subsystem (with respect to the configuration of the previous case study) due to subsequent crowding of other equipment in that room.

Figure 8.1 Instructor using the tablet display and electronic pen to guide the actor

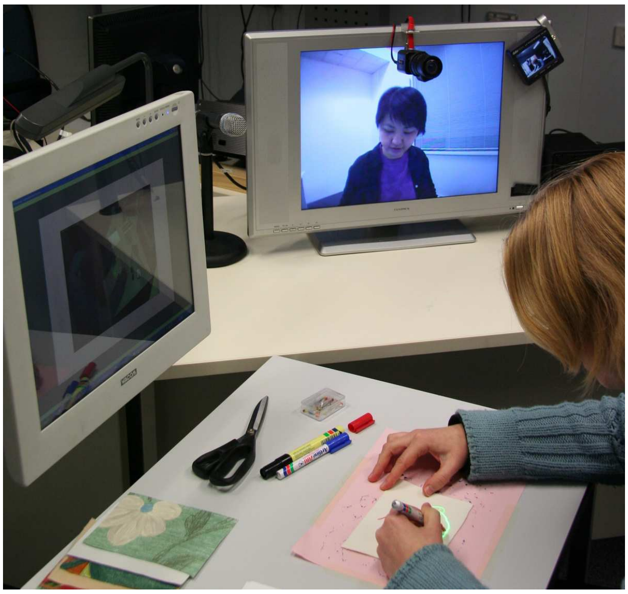

Figure 8.2: The actor's workspace showing tablet display in front of the workspace and a close-up video link with the instructor to the side.

These configurations were designed to support mutual understanding of the actor's workspace. Kraut and colleagues emphasise the importance of both participants having a shared view of the task space (Kraut, Fussell et al. 2003). In our study we extend this concept in the following ways:

- Both participants have similar views of the actual workspace – the actor can see exactly what is in front of him or her and the instructor can see the workspace via the overhead camera.

- The instructor can see the actor sitting at the workspace and the actor can see the instructor's view, which is replicated on the arm-mounted tablet display.
- The instructor and actor can, therefore, see the task space and can also see (and understand) what each other can see.

Study protocol

The following study protocol was observed:

- Information about the study was given to the participants the day before
- A brief initial interview was conducted to collect demographic data and sign the participant consent form
- The audio-visual equipment and tablet display interfaces were explained, and the two participants were introduced using the close-up video link
- The four guidance options (pointing and drawing, either on-video or in-workspace) were demonstrated
- The participants undertook self-paced training using a sequence of computer-screen instructions. This training consisted of four tasks each using one of the guidance technologies to guide the actor to draw relatively simple shapes onto paper, thus anticipating in a simpler form the actual task.
- They then completed the task using whatever combination of guidance techniques they chose, again following a sequence of computer-screen instructions. The task consisted of selecting the correct fabric, drawing the shape, cutting it out and placing it on the dress.
- Each participant completed an exit interview

This protocol was approved by the CSIRO Human Research Ethics Committee – reference code 06/41.

Data collection

The full study sessions were recorded on videotape at both sites. Each video record contains a view of the actions of the participant at the particular site as well as the audio of the whole interaction between the sites. Each participant was accompanied by a researcher for the whole time, and the researcher took notes of their observations. The exit interviews were also recorded so that the participants' full responses were available for analysis. The video recordings and exit interviews were analysed using the same methodology as for the previous case study (Chapter 7), but with a focus on emerging collaborative behaviour between the pairs of participants.

8.3 Results

Participants

Six pairs of participants took part in this study. They were recruited from within CSIRO and from the university populations nearby. The participants lived in different cities from their partners for this study and did not know each other. In the samples of dialogue quoted below "I" is the instructor and "A" is the actor.

Choice of Pointing and Drawing Options

In the fabric selection subtask the instructor directed the actor to choose one of six differently patterned pieces of fabric. Four instructors used purely verbal instructions, one used on-video pointing and one used in-workplace pointing together with spoken instructions. An example:

I: OK, so we need this piece of fabric. Look on your screen, we need that piece of fabric [indicates with on-screen pointer]

The instructors chose a range of drawing options to guide the actor to draw the shape. One used the in-workspace drawing mode, with the actor drawing directly onto the fabric. Another used the on-video mode to illustrate the shape, then the in-workspace mode to guide the actor to draw directly onto fabric. The four other pairs negotiated to draw draft shapes onto paper using spare paper from the training phase, transfer the shape to fabric then edit the shape. The instructors used a combination of all four modes (point/draw on-video/in-workspace) to guide this process. The final editing was mostly done using the more precise on-video drawing.

All six instructors used pointers to guide the actor to place the patch on the dress; three used on-video and three used in-workplace. All used a mixture of verbal direction and pointing to orient and shift the patch towards its correct location.

Decisions on these choices were based on the participants' perceptions of the tools, as these two dialogue fragments show:

I: Which tool did you prefer?
A: The laser that draws is pretty cool, but the red one's probably better
I: That's what I was thinking as well

I: Maybe if I use the red one [on-video] to show you, because it seems to stay on the screen longer, then I'll use the green one [in-workspace] when we go to do the real drawing

Guidance Strategies

All six instructors used the basic strategy of drawing the shape as a sequence of curved line segments and asking the actor to draw each segment, with spoken fragments like "in", "out", "around" and "here" as they drew the segments. All six prefaced this drawing sequence with a short discussion with the actor about the nature of the shape and how they would go about drawing it. Four pairs decided to co-opt the spare paper from the training tasks to draw draft versions of the shape.

A: Do you want to practise first, on a bit of paper?
I: Yeah, that would be good.

When an initial shape was in place, either on the fabric or on paper, the instructor framed the guidance with reference to the draft, which they could both see and to which they could point and gesture. To edit one feature, three instructors described it as "like a shark fin", and their actors immediately understood what they meant.

I: And up here has gotta go just a little bit farther out so it's a big bulbous sort of thing and then here
A: So like out here
I: Yup, [pause] and just a bit farther out there

To place the patch in the correct location and orientation on the dress the instructors all asked the actors to place the dress (previously fitted onto its foam core) onto the work surface and then to orient it so that they could see it clearly. They then used the pointing tools (either on-screen or in-workplace) to locate the patch followed by spoken instructions to rotate and shift the patch to its correct position.

Frames of Reference

The instructor's and actor's views of the workspace were approximately at 90 degrees to each other. In spite of this, all six instructors used words like up/down, top/bottom and across in their verbal directions. In one case the actor pointed out the mismatch between points of view but the instructor later reverted to his earlier usage.

At a smaller scale, the instructors used the centre of the shape as the reference point, with phrases "curve outwards" and "curve inwards". 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.

All six pairs modified the drawn shape to better match the required shape. This editing was done using instructions and actor responses made with respect to the draft shape. Both could point directly into the space and could see the editing instructions and actor responses. These formed a tightly coupled dialogue.

> I: You kind of see that little thing that juts out again, [gestures with in-workspace tool] just copy that shape, that's exactly what we need

> I: This here and this here are meant to be like sort of aligned [points with in-workspace tool]
> A: Here and here? [points with felt-tip pen]

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.

Collaborative Behaviour

All six pairs of participants exhibited collaborative behaviour throughout the study. The study started with introductions using the close-up video link, fulfilling the social meeting process. 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 instructors, 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 each shape. While drawing each shape they exchanged verbal confirmation of each curve segment.

All six pairs edited together the first version of the shape that they drew for the main task.

> I: This area there, a bit closer
> A: Closer? You mean further away from this side? [Points]
> I: Yes

During this editing process the actor sometimes took the lead.

> A: So from here [points with felt-tip pen]
> I: Yeah
> A: Can you direct me from here?
> I: OK from there …

The pairs were observed to negotiate the initial approach to the task and repairs when difficulties were encountered.

I: [Selects on video tool] How about if I draw it and you just sort of like have a look and then we'll, we'll start again
A: Yeah
I: [Under breathe] Na actually yeah it's probably
A: Could you actual give a demonstration using the green maybe?
I: I was just going to say you can see my red one on your screen can't you?
A: Yeah
I: Alright but if I [pause] if um, maybe with the demonstration if I just show you with the red one cause the red one seems to stay the lines seem to stay on a little bit longer
A: Yep
I: So if I use the red one and you just have a look and then I'll use the green one when we go to do the real drawing, ok?
A: Yeah

Exit Interview

An exit questionnaire was given to both instructor and actor during the exit interview. It covered the choice of the guidance tool, the guidance strategies, the participants' awareness of each other's view of the workspace and strategies for repairing task-based misunderstandings.

a. Instructors: What influenced your choice of tool?

Four said that they chose the in-workspace (laser) tool because they felt that it would be easier for their partner to follow. One pair had technical problems with the laser tool and agreed to use the on-screen tool. The last pair had zoomed the overhead camera, which created calibration problems in its 3-dimensional behaviour so they chose the on-screen marker to give the instructor more precision in giving instructions.

I: I guess it depended on what was easy for either party and we kind of just discussed which one was better

b. Instructors and actors: Did you change your strategy during the study?

Five instructors said that they did not change their strategy during the study. The sixth regarded the change from on-screen drawing of the overall shape to in-workplace editing of the shape as a change in strategy.

Four actors replied that they had changed strategies, referring to the editing process. One said that their pair had developed a strategy and stuck with it and the last said that there had been no change in strategy.

c. I understood my partner's orientation to the workspace.

On a 5-point Likert scale (strongly disagree to strongly agree) the six actors responded with either agree(3) or strongly agree(3). The six instructors' responses were agree(4) and strongly agree(2).

d. Instructor: How did you know when your partner was confused?
Actor: How did you let your partner know when you were confused?
Both: How did you and your partner deal with this confusion?

This set of questions explored their sense of working together. Three instructors did not think their partner became confused. Two others heard their partner express confusion verbally and the sixth observed confusion because of the mismatch of their respective viewpoints. They responded to the confusion by re-drawing the curve segments.

Five actors said something to their instructors when confused and the sixth actor said there was no confusion. Four pairs dealt with confusion with verbal responses and re-drawing the shape and the fifth pair resolved it verbally.

Training and Task Times

Both the training in the use of the four guidance modes and the actual study task were self-paced, with the instructor working through a sequence of instruction pages shown on the tablet display. The mean training time (in minutes:seconds rounded to nearest 5 seconds) was 9:15 (range 6:15 to 12:30). The mean task time was 8:15 (range 5:20 to 14:10).

This variation in training and task times reflects the different approaches that each pair of participants took. Some pairs were content to complete a single pass at drawing a shape, especially in the training phase, whereas others wanted to refine the shape until the instructor was happy with it. One pair completed three paper drafts of a training shape before moving on. During the actual task this variation was also obvious. One pair drew the shape in essentially a single drawing pass, whereas another pair took elaborate steps to draft and refine the drawing of the shape.

8.4 Discussion

Pointing and Drawing

All six pairs made their choice of pointing and drawing tool (on-video or in-workplace) based on their perception of the differing attributes of the tool. In particular, they were able to see the trade-off between the precision of the on-video tool against the immediacy of the in-workplace tool, and were able to make agreed decisions about when to use which tool. This was particularly so for the pairs who drew an initial draft on paper, where the situation changed as they moved from initial drawing to modifying the completed draft shape and finally drawing onto fabric.

Four of the six pairs drew various forms of draft shape first and then they used editing instructions to bring the shape closer to the desired shape. This had the effect of converting the task from low-level following of line segments to a higher-level shape editing action accompanied by verbal shape descriptions and confirmation dialogue. It also removed the temporal urgency created by the 5-second fade of the drawn lines.

This understanding and ability, or willingness, to switch between different tools and modes suggests that providing multiple technologies to support remote physical guidance is worthwhile. Just as people can decide whether to verbalise, gesture or both they also seemed able to decide between the four options offered in this study.

Guidance Strategies

The guidance strategies employed by the participants centred on creating a mutually visible artefact, initially a curve segment and later a full draft version of the shape, then conducting a discussion with words, drawings and directional gestures to converge on the required shape. This draft version of the shape corresponds to the "publicly available artefact" that Robertson refers to when she emphasises that the objects in a remotely collaborative environment need to be available to all of the participants (Robertson 2002).

Where the participants were able to recognise a describable shape component they used this higher level description to assist in editing the shape. Three instructors referred to part of the shape as "like a shark fin", which was easily recognised by their actors.

In this study we observed that the guidance strategy was often collaboratively established, both initially and as the task progressed. The actual guidance strategies would seem to depend on the initial training experience and on the personalities of the pair of participants, so we would expect quite a range of strategies to appear. This contrasts with other researchers' studies, where a small number of previously trained instructors worked with a larger number of study participants, and where we would expect the strategies to be heavily influenced by the experience of the instructors.

Frames of Reference

Heath, Luff and colleagues discussed the importance, for participants in telecollaborative environments such as this one, of being able to "determine the location, orientation and frame of reference of others" (Heath, Luff et al. 2001). The six actors in this study responded that they understood their instructor's orientation to the workspace, even though each instructor used directional words that were consistent with their own [instructor's] orientation but not consistent with their actor's orientation to the workspace. All six actors simply ignored the spoken words and followed the drawing gestures. Only one actor tried, unsuccessfully, to correct the instructor about this point.

We discussed this with a participant in our earlier guidance study, who had taken the role of "instructor". He noted that, as a trained teacher, he used terminology like "to your left" when talking to his partner. In this study we did not observe the instructors using their partner's body as a frame of reference.

Heath, Luff and colleagues (ibid) also refer to "stable reference objects" in the collaborative environment and the participants made frequent use of these. The primary reference object was the rectangle of fabric or paper on which the shape was to be drawn, together with the tip of the actor's pen and the display of the instructor's cursor and line. When a draft of the shape had been drawn it became both a stable reference object and a local frame of reference. Two participants conducted discussions with respect to the draft shape, and edits to it were made with reference to the inside and outside of the shape. It might be interesting to ask what they would have done if the shape's outline had not been topologically closed.

During the patch placement component of the task the participants demonstrated a comfortable grasp of the three-dimensional space around the foam-core dress and of its spatial orientation. The instructors pointed directly to the required location and used spatially appropriate words to rotate and adjust the patch, thereby treating the location marker and the dress itself as parts of a shared frame of reference.

Collaborative Behaviour

Collaborative behaviour emerged very early in this study, with the participants conducting the self-paced training task. This behaviour continued through the study task itself, finally reaching an agreed conclusion to the task. The behaviour was exhibited at the small scale with guidance, response and query gestures and words in the drawing of the curve segments, and at the larger scale with close-up video contact to discuss issues and make decisions.

The participants were also able to take their partner's situation into account when making suggestions about which guidance tool to use. This suggests that the training tasks had given them enough experience with the tools and enough observation of their partner's responses to effectively consider their partner's situation.

8.5 Conclusions

This study demonstrated that the remote guidance tools, as embedded in the communication suite between instructor and actor, can support emerging collaborative behaviour and problem solving.

In the study in Chapter 7 we addressed the question "Can someone use these tools for this task?" where:

- The focus was on the participant as instructor, using and making decisions about the use of the four guidance modes under one of three control conditions.
- Training reinforced this by focusing on the mechanics of handling the remote guidance tools (tracing out shapes in the actor's workspace).
- By placing one of the researchers as the actor we inserted expectations of being guided into the actor's behaviour.
- The data gathered from the study was about the actor being guided together with some emerging collaborative behaviour as the actor responded to and clarified the guidance.

In the study reported here we addressed the question "Can two participants use these tools in a collaborative manner for this task?" In addition to mechanically familiarising the participants with the guidance tools, the training included examples where the instructor guided the actor to replicate simple shapes. The two participants, coming with fresh minds to the situation, were able to look more broadly than those in the previous study, and they produced unscripted elements in their solution, such as:

- Drawing a draft shape first then editing it
- Using their newly-found editing capability to manage quality control
- Creating a higher-level verbal language to refer to the shape as they refined it
- Treating the draft shape as a frame of reference.

From the Chapter 7 study we found that the remote guidance tools could indeed be used to support the abstracted task and we identified strengths and weaknesses in the three interfaces. From this study we have found that the remote guidance tools, situated in the physical space of the actual telehealth system and with a task that allows integration of interpersonal communication with remote guidance, are sufficiently open that they can support a collaborative problem-solving approach to these tasks. They do so by supporting dialogue and exchange of ideas about the tasks at hand.

Together, this study and the study in Chapter 7 illustrate the use of a human-centred evaluation approach for laboratory evaluation in the development of a complex telehealth system, such as would be deployed in a tertiary healthcare setting. The studies demonstrated this approach at two levels, one at the component usability level and the other at the collaborative application level. A summary of the major results of this thesis is given in Section 1.6, pages 8-9, and this case study, together with the case study in Chapter 7, supports result R1.

9 Telehealth system for outpatient consultations

9.1 System requirements and review

This chapter describes the broadband telehealth system that was developed to support post-operative paediatric outpatient consultations. This system was based on the system used for laboratory studies as described previously and it was used to conduct the hospital pilot trial described later.

The system made extensive use of video communication, with ten hardware video transmit or receive cards in the patient's room and seven in the surgeon's room. At the hospital we used a virtual private network running over the hospital's intranet which had a maximum bandwidth of 40 megabits/second, limited by the capacity of the routers on the hospital's network. During the trial in the hospital we did not notice any delays or latency issues in the performance of our system which indicates that the hospital network was sufficiently lightly loaded that it was behaving in the way a broadband network would behave for a system with the demands of our telehealth system.

Requirements

Requirements were gathered from three rounds of observations of outpatient clinics at Royal Children's and Royal Hobart Hospitals and from discussions with the surgeons at those hospitals. The initial requirement for the telehealth system was for it to support a remote post-operative consultation for paediatric craniofacial patients. These patients typically have surgery in their first year of life and are monitored until they become adults. As babies they are examined sitting or lying in a parent's lap. As children or adults they sit in a chair and are examined by a standing doctor. Later, the scope of the system was extended to include paediatric orthopaedic and hand plastic patients. Examination postures for these patients included standing, sitting, walking and lying on an examination bed.

The telehealth system needed to support the presence of the patient's family or carers. These people needed to sit where they could take part in discussions with the surgeon conducting the consultation, and also where they could observe and understand the examination of the patient.

The telehealth system needed to share documents held by either the surgeon or by the patient and family. It also needed to display and share radiology data such as X-rays, CT scans and MRI data between surgeons' and patient's rooms. For our pilot trial, the radiology data was in digital form and was available through the hospital's PACS system.

Review

The initial design – layout of furniture and fixed video coverage – was reviewed by the senior surgeons at Royal Children's and Royal Hobart Hospitals in May 2006, because the intention at that time was to conduct a trial between these two hospitals. Progressive implementations of the system were constructed and reviewed in our Canberra laboratory – twice by Dr John Lambert, an intensive care specialist at Orange Base Hospital in regional New South Wales and once by Dr Wellington Davis, a surgical fellow at the Royal Children's Hospital. Figure 9.1 shows Dr Davis exercising the system with a test dummy during the day-long review at our Canberra laboratory.

Figure 9.1: Reviewing the telehealth system at a point in its development

A later decision to conduct the trial solely within the Royal Children's Hospital enabled a larger catchment of potential participants (patients and their families) to be invited to take part in the trial.

9.2 System description

Fixed video and audio links

The three two-way fixed video links used in the video and audio communication study (Chapter 6) formed the fixed communication links of the telehealth system. They were augmented with a small fold-back monitor on the two close-up subsystems as shown in Figure 9.2. The data-projector-based room overview displays of the laboratory studies were replaced for the hospital trial with large plasma panel displays. Figure 9.2 also shows the location of the close-up camera, suspended over the corresponding display screen, and the locations of the microphone and speaker for each close-up subsystem. A wide-angle room microphone was mounted on the ceiling of each room.

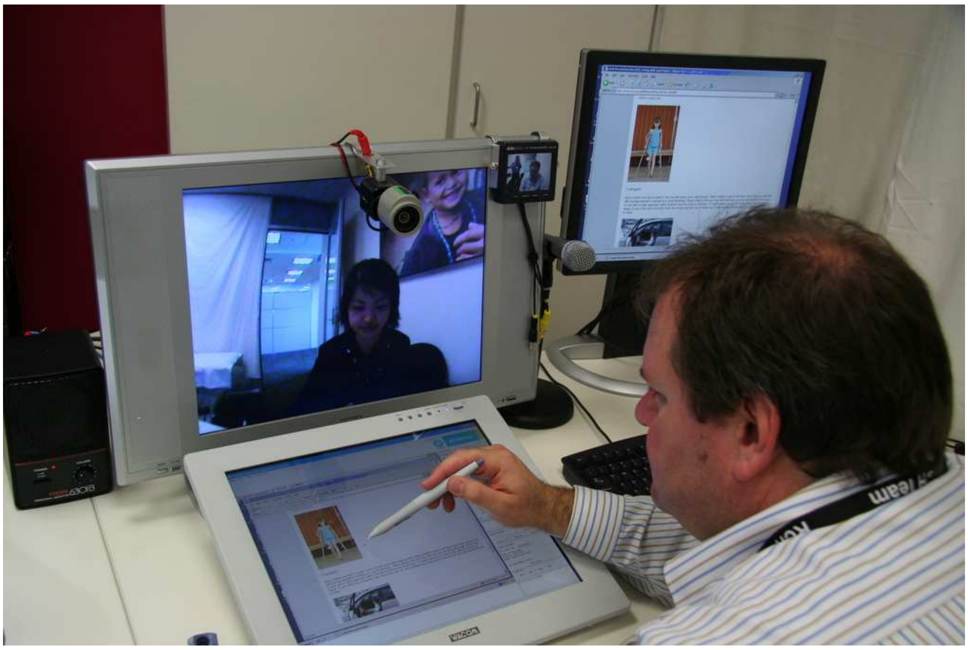

Figure 9.2: Close-up video/audio subsystem with tablet and pen display

Tablet display interface

Four tablet displays with electronic pen interaction capability were deployed in the system – two in each room – and configured so that all four showed the same display at any time. The interface for the tablet displays contained a display window showing image or video data and a control window for selecting the required image or video. Three pen interactions were supported:

- Touching a listed video or image source caused that source to be displayed on all four tablets simultaneously
- Holding the pen over the display window put a live cursor point located below the pen on all four tablets
- Touching then drawing the pen on the tablet surface drew a coloured line which appeared on all four tablets.

Each tablet was coded for a different drawing colour so that different people's drawings could be identified with them. A fade control was provided so that the drawn gestures could either be ephemeral or could be left in place on the screen for longer time-frames of discussion.

Any image or video from any source in the system could be chosen for display, including the display from external computers. Figure 9.2 shows two people (one in each room) discussing a web page loaded in a browser on a hospital computer (the computer's monitor can be seen on the right). The surgeons had password-protected access to the hospital system and were able to show the patient's X-rays and other radiological data on the tablet displays. They then use the electronic pen and tablet display to annotate the X-ray with pointing and drawing gestures as they explained matters to the patient and family.

Diagnostic cameras in the patient's room

The following diagnostic video cameras were available in the patient's room:

- Hand-held camera for close viewing, including intra-oral and extra-oral views of the patient
- A pair of arm-mounted cameras which could be placed at any position around the patient. Simultaneous views from the two cameras could be displayed to the surgeon on a special-purpose 3D stereo display system, either as live video in 640x480 pixel resolution or as high-resolution digital photographs.
- A single camera mounted 40cm above the floor on a tripod and pointing horizontally gave the surgeon a view of young patients in standing or walking poses (the "walking camera")
- A pole-mounted camera with pan, zoom and tilt controlled by the surgeon gave a head-and shoulders view of seated patients and the equivalent of a standing view of patients lying on the examination bed.

The camera of the examination close-up subsystem was also used to observe the patient. Its field of view included patients sitting on the examination bed and older patients sitting in a chair. A high-resolution document reader with front lighting was located on the desk in each room. These allowed both family and surgeon to show each other documents such as photographs, referral forms and health clinic charts.

Figure 9.3 shows the author sitting in the examination wing of the clinic room close to several of these cameras. The "walking camera" is off-screen to the bottom right. The examination bed is along the fourth wall of the room to the right-hand side of the photographer and can be seen in Figure 9.4. This figure also shows the correspondence between the two close-up displays and the room overview display.

Figure 9.3: Patient's room. The pole camera is above the person sitting on the right, the arm-mounted cameras are by his head, the hand-held camera is on a flexible cable behind him and the examination close-up camera is in front of him. The document scanner is on the desk.

Figure 9.4: Patient's room showing the correspondence of the two close-up displays and the room overview display from the surgeon's room.

The surgeon's room

Figure 9.4 shows the surgeon's room. The surgeon sits inside the curve of the desk, allowing him or her to turn easily to pay attention to the examination close-up display, the room overview display or the consultation close-up display.

Figure 9.4: Surgeon's room. From left to right: 3D display, examination close-up subsystem, document scanner (below) and patient's room overview (above), consultation close-up subsystem and hospital computer monitor (Photo courtesy Royal Children's Hospital)

9.3 Summary

This telehealth system was designed to support remote outpatient consultations for paediatric surgery. The design used a whole-of-room approach with three sets of fixed video cameras linked by high-quality digital connections, and parallel audio connections. These are supplemented by a networked electronic pen and tablet display sub-system to support interactive shared access to visual data, and by a range of video cameras to capture diagnostic views of the patient.

The design allowed the surgeon to manage the consultation. It provided:

- High-quality video and audio teleconferencing with the patient and family
- Remote guidance capability, to direct and observe the examination of the patient
- Shared access to patient data, to explain the clinical interpretation of the examination and the proposed treatment or management plan for the subsequent time interval.

The network over which this telehealth system operated had sufficient capacity, and there was sufficiently little competing network traffic, that it behaved in the manner of a broadband network for this system's requirements.

10 Case study: Training and process change

10.1 Purpose

The purpose of this study was to observe how the twelve clinicians who were scheduled to use our telehealth system during the pilot trial approached learning to use that system. This was important because the training situation is likely to be typical of future such trials and these observations can provide a baseline on which to plan future training sessions. Eleven of the twelve clinicians had not seen any information about the telehealth system prior to the training sessions. They all had heavily committed work schedules and, to support a four-week pilot trial, they were able to invest only one hour of their time in the week prior to the trial for training. This study observed what they did during their training sessions and looked for common threads across those sessions.

The material in this chapter was first published as a full conference paper at OZCHI 2008 in Cairns (Stevenson 2008).

Previous chapters have addressed the development and review process. Subsequent chapters address evaluation of a pilot trial. This chapter looks at the clinicians preparing themselves to conduct the trial.

The time frame for developing a broadband telehealth system is likely to be quite long – this system took 21 months. During that time much can happen in a major teaching hospital. For example, in this project two surgeons left to work overseas during the system's development and several staff who had acted as clinic assistants in the trial moved on to other hospitals during the nine months following the trial. This level of staff mobility means that we can not count on continuity of understanding among the clinical partners in such a development and we must be prepared to deal with near-horizon training and preparation of the clinical staff.

The time-scale of the pilot trial is also important. By their nature pilot trials are short-term, running long enough to gather enough data but short enough to minimise workplace intrusion. In terms of evaluating such a pilot trial we need to recognise the nature of the preparation that the clinical staff members have undergone and to see the early parts of the trial as extensions of this training process.

10.2 Method

Six one-hour training sessions were held in the hospital during the week prior to the trial, using the telehealth system set up as it was intended to be used for the trial. The hospital clinicians were scheduled for the training sessions by the Department of Surgery based on their other hospital commitments. Each staff member was only available for one hour during that training time. Table 10.1 shows the allocation of clinicians to the training sessions. Ideally, a training session had a surgeon and the staff member scheduled to work with that surgeon as the clinic assistant but this was not always possible and some surgeons and assistants were trained on their own. Some clinics had more than one clinic assistant (to bring in complementary skills) and some surgeons worked with different assistants as the study progressed.

Session.	Clinicians
1	Surgeon + 2 assistants
2	Surgeon + 2 assistants
3	Surgeon + 1 assistant
4	Assistant
5	Surgeon + 1 assistant
6	Surgeon

Table 10.1: Allocation of clinicians to the training sessions

A CSIRO colleague and I conducted the training sessions. We took an active role in these sessions, explaining and demonstrating the components and, together with the clinicians, role-playing the patient, parent or clinic assistant as we explored scenario components of clinical consultation. When issues of system limitations arose we worked with the clinicians to resolve them. For the purposes of the pilot trial both the surgeon's room and the patient's room were located on the same floor of the hospital and during the training sessions we were able to move freely between these two rooms.

Video recordings of the training sessions were the primary data for this study, supplemented by field notes made at the time and personal memories of conducting the sessions. The video recordings show the actions, gestures and speech of all the participants in the training sessions. Notes were prepared from viewing these recordings and these notes contain descriptions of the sequences of actions observed and transcriptions of key sequences of dialogue between the clinicians and between clinician and researchers. These notes were then coded in the style of Corbin and Strauss and observations were drawn from across the six sets of notes and codes (Corbin and Strauss 2008). My analysis of these observations focussed on understanding the perspectives of the clinicians.

The time codes from the video recordings provided information about the proportions of time when the researchers were explaining and presenting the system and time when the clinicians were exploring the system for their own specialties. This data is shown in Table 10.2.

Eleven of the twelve clinicians had not seen the telehealth system before the training session nor had they been involved in its design and development. The research team, therefore, felt the need to cover all the aspects of the system and of the forthcoming trial during this one hour and had prepared a training plan based on prior experience of presenting the system. There were four basic aspects to be covered:

- Use of the fixed cameras and screens to connect the two rooms, and specifically directing attention to people in different parts of the other room
- Functionality of each of the special-purpose cameras in the clinic room
- Shared use of the pen and tablet displays to support dialogue about image and video data
- Protocol for the trial.

During the training sessions we presented and demonstrated the components and the clinicians explored the system themselves. There was continuous dialogue amongst the clinicians and between the clinicians and researchers throughout the training sessions.

The researchers adapted their preconceptions of how the training sessions would proceed to the directions set by the surgeons. They covered the four basic technical aspects of the training but did so differently for each case. Often the researchers became involved directly with the clinicians' training, acting as patient, parent or assistant as needed to help the clinicians explore the possibilities of the system.

10.3 Results

All the training sessions were recorded on videotape, with the camera positioned so that it captured all the action in the surgeon's room as well as the large-format screen display of the action in the patient's room (see Figure 10.1). It also captured the audio from both rooms. This meant that the researchers could be deeply involved in the training sessions without needing to make running field notes.

Figure 10.1: Frame from video showing field-of-view of the camera located in the surgeon's room. We see four people talking in the patient's room.

The surgeons approached the training sessions with a focused mindset, targeting the practicalities of conducting their particular style of clinic. The training sessions, therefore, did not follow the training plan that we had devised nor did they match any of our previous presentations of the system. The surgeons were specifically interested in:

- How would they work with their clinical partner to conduct the consultations – who would do what, where?
- Which camera views would they use for examining their particular patients, and how would those cameras be managed?
- How would they adapt their practice to use the system?
- How could they adapt the system to better fit their practice?

The clinic assistants were hospital staff – registrars, a nurse, a physiotherapist, surgical fellows – who worked closely with, and under the direction of, the surgeons and they actively followed their surgeon's approach. Table 10.2 shows the way each training session progressed. The times are rounded to the nearest minute

Session number	Time of initial block of presentation (min)	Total time of presentation (min)	Total time of clinicians' exploration (min)	Interruption due to technical issues (min)	Total time of session (min)
1	15	17	24	8	49
2	14	18	25	-	43
3	2	10	39	-	49
4	8	17	33	-	50
5	8	18	24	-	42
6	7	10	39	-	49

Table 10.2: Distribution of time during the training sessions (in minutes)

Relatively early during the training session the clinicians took control of the flow of the session. They asked specific questions about how the system would support their particular needs. They initiated hands-on use of the components and co-opted their assistants and the researchers to work with them. Some of them had put considerable thought into how they might use the system and into the issues that they needed to resolve. The assistant who attended a training session on his own asked explicitly "What am I going to do?" and then used a discussion of the study protocol to establish how he would work with the system.

The protocol for the trial called for a member of the research team to be present in each room (surgeon's room and patient's room) for each consultation to provide technical support. This enabled the surgeons to think in terms of their clinical application rather than in terms of technical management of the telehealth system. The following subsections give specific examples of the way the clinicians took part in the training sessions.

10.3.1 Working with clinical partners

Examining a patient

At an early stage in the training the five surgeons began role-playing examining patients, using whoever was available in the clinic room to act as the patient - a clinic assistant, a child-sized manikin or one of the research team. They directed the examination to look for things that were important to them.

> Surgeon: [Viewing scene from above with wide angle setting on camera lens] I want to look more vertically at the patient from above. Tilt the patient more … that's about where I want it, but clear the hair back with your hand.

Surgeon: [Zooms camera lens for close-up view of patient] That's a nice view. Can you guys see that? [addressing both assistants] That's the sort of view we will be wanting to get.

In the training session with only a clinic assistant, the assistant saw immediately the role he would play in examining a patient by drawing the analogy with presenting a surgical case to a panel of consultants, a task he has to do regularly as part of his registrar training. He understood the importance of making sure the consultant had a good view of the patient and of the dynamics of the examination, and that the skills of presenting to a number of consultants translated directly to presenting to a number of cameras.

Planning use of the clinic space

The surgeons and clinic assistants spent considerable time during the training establishing how they would use the space in the clinic room, especially the separation of the room into the seated discussion space for the patient and family and the examination space. This examination space included an examination couch, walking track and examination chair. All five surgeons rehearsed aspects of the patient examination with their clinic assistant, or in one case with a researcher.
They also explored visibility between the patient's clinic and the surgeon's office. In one case the assistant moved about the room looking for an ideal place for a patient to demonstrate standing poses:

Assistant: [walks to one corner and waves hand] Can you see this?
Surgeon: Yeah, I think the corner that A is in is good for standing poses
Assistant: [moves away to consider then moves back to the corner]
Surgeon: Perfect, but I think in terms of walking ... [talks about other options for the patient to walk]

10.3.2 Adapting clinical practice to the telehealth system

Hands-on involvement with the patients

The most obvious change in the surgeons' clinical practice was that they no longer had hands-on contact with their patients, and that they would have to rely on what they could see and hear with the telehealth system and on what their clinic assistant could show and tell them. Much of their role-playing use of the examination cameras involved learning to adapt to this situation.

Surgeon: [Speaking to assistant in the other room] Now turning the patient front on. That's good. It's a very clear picture, isn't it?
Researcher: Do you think you can diagnose with that?
Surgeon: Well, yeah.

This issue reappeared in the first clinic conducted for the trial. In their exit interview the two surgeons who conducted it talk about the importance of hands-on interaction with their surgical patients, and about how frustrating it is for them to have to delegate this aspect to their clinic assistant.

X-rays

All four surgical specialties rely heavily on X-ray data to track the progress of their patients and to discuss future treatment with the patients and families. Their current practice uses mouse-based software on the hospital's computer to display comparative X-rays. They then use hand gestures or mouse pointer movements to highlight features under discussion. This involves turning their computer screen around to show the patient/family or using a wall-mounted screen, both of which limit everyone's ability to see and understand the display.

The surgeons explored using the electronic pen and tablet displays to present and discuss the X-ray data, annotating the display with the telehealth system's electronic pen in freehand mode rather than using the mouse-based drawing tool provided by the hospital's software. They rejected the original plan, which was to have a hospital computer in both rooms logged in to the same patient data, in favour of the surgeon logging in to one hospital computer and using the tablet displays to share the view of the X-rays. They talked about how they would use this technology to explain things to the patient and family:

> Surgeon: So I could show the parents the sutures, and the line here is all filled in. You guys can see that clearly? [addressed to the two assistants in the clinic room]
> Surgeon: [proceeds to draw over the line in the X-ray using the electronic pen]

In his normal practice, one surgeon frequently had new patients arrive with hard-copy X-rays from the referring doctor. He talked with his assistant about how they would handle this situation with the telehealth system, and he resolved to bring a hard-copy X-ray to assess using the document-reader and tablet-display combination.

Patient's medical records

For the hospital-based trial there was only one copy of the patient's medical records, and that was in paper rather than in electronic form. One surgeon explicitly raised the question of where that copy would be located, with the patient or with the surgeon, and another surgeon talked about needing time between patients to write up his notes with the implicit assumption that the notes would be with him. The issue was not resolved during the training sessions but the surgeons decided after the first week of actual clinics to place the notes with the surgeons themselves. They then adapted their normal practice to allow time for the surgeon to brief the clinic assistant on the next case before the patient and family was called into the patient's room.

Planning ahead for each patient

One surgeon had a very good understanding of the additional logistical burden the telehealth system would add to the normal conduct of a consultation with a patient. He proposed organising beforehand to plan specifically for each patient because "in orthopaedics we have a lot more moving around than in plastics. For example, if we have a knee [there will be a different use of space than if we have a different part of the body]". He was also aware of the complexity of working with moveable cameras and commented to the researchers:

> Surgeon: I am also mindful of the time, you can't spend time during the consultation fiddling, trying to get the camera angles …

He observed that he needed to consider the practicality of working with two parents, one patient and a clinic assistant in the relatively small space of the room that we were using for the patient.

10.3.3 Adapting the telehealth system

All the surgeons adapted the telehealth system to their own practice. They were very specific about which camera views were appropriate for their patients and about how those camera views would be managed. They were also very specific about how they would use the space in the patient's room.

Three of the five surgeons had patients who needed to demonstrate standing postures and walking gaits. This created two important requirements – camera views that showed the standing and walking patient to the surgeon free of perspective or angle-of-view distortion and sufficient room for the patients to walk a number of steps in a straight line. All three surgeons spent considerable time on this issue, getting the assistant or one of the researchers to stand in various locations in the clinic room and to walk to and fro while the surgeon explored all the available camera views. The research team resolved this issue by developing an additional camera system drawing on the flexibility designed into the system software and using spare components purchased for just such an eventuality. This new camera system was configured to give the exact view needed by the surgeons and was used in three-quarters of the clinics conducted during the trial.

The telehealth system included a 3D camera rig in the patient's room, with two cameras mounted on a moveable arm and separated by approximately the between-eyes separation of an adult. These provided a stereo pair of high quality images for viewing in passive stereo mode by the surgeon. The Hand Plastics surgeon saw huge potential for this tool in his clinics but he insisted several times that it would be even better if it provided a 3D video view of the moving hand and fingers rather than just a still stereo image. This idea had been in the team's mind for some time and the appropriate software framework had been put in place, so by the time the Hand Plastics clinic was conducted the 3D video feature was implemented and the surgeon used it extensively.

10.3.4 Observations during the trial

By the time the clinicians had conducted three or four outpatient clinics they were able to use the interpersonal components of the consultation with confidence and knew exactly which camera systems to use for examining their patients. In particular, the orthopaedic surgeons who had requested the "walking view" camera made extensive use of it. After his first two clinics one surgeon commented:

> Surgeon: I was, I was really worried on Friday when we saw what we had and I think you guys have just been brilliant bringing that camera in, 'cause you saw with each one we were able to get far more information just by getting them to walk and even stand and even do part of the clinical examination without having to go to the handheld camera. Only once did we have to get the handheld camera in up and close and again that was just because we wanted to look at his foot.

The surgeon who predicted that 3D video would be very useful confirmed that prediction in his clinic and used the 3D video facility extensively to examine all his patients.

The registrar who had seen the parallel between presenting a case to a panel of consultants and presenting a physical examination of a patient to a set of cameras observed that he had learned to anticipate what his surgeon would want to see and how that surgeon would want to see it. He attributed the smooth functioning of the third clinic in large part to this learned collaboration between himself and the surgeon.

Some of the surgeons reported changes in the way they were conducting their clinics. All of them embraced using the pen and tablet displays as a tool for communicating with the patient and family about the patient's condition and future treatment. One saw the issue of the hands-off involvement with the patient in a new light, writing up his patient notes in detail while the assistant conducted the actual examination and reducing the elapsed time for the consultation.

10.4 Discussion

In this chapter I make the distinction between the **training provided to** the clinicians so that they could understand and use the telehealth system and the **process change identified by** the clinicians during the training sessions that prepared them to use the telehealth system.

The training that the research team provided covered the mechanics of using the telehealth system – use of the room space, fixed camera/screen subsystems, examination cameras and the interactive pen and tablet display subsystem. The system and its components had been designed for the purpose of outpatient surgical consultations, and had been tested in our laboratory for interface and collaborative usability, so we were pleased that the clinicians very quickly understood the system and the mechanics of using it. They demonstrated this understanding by their actions – brief conversations over the video subsystems, looking at objects with the examination cameras, annotating X-Rays with the pen and tablet subsystem – and confirmed their understanding in conversation with the researchers. They also understood the range of options offered by the system and chose to concentrate on those that were relevant to themselves.

I note here that we were not training the clinicians in their clinical tasks. We were offering the training in using the telehealth system based on our generalised knowledge of the clinical problem gained from our observations and clinical input. The clinicians were using the knowledge of their own clinical context to give this training concrete meaning.

The issue of process change surfaced very quickly during the training sessions and the clinicians saw it as an issue of high importance. Even though the system had been designed to reduce the difference between a tele-consultation and a face-to-face consultation by, for example, supporting simultaneous interactive access to image and video data for all participants, the physical nature of the consultations and the depth of personal interactions meant that there would necessarily be changes to process. Each of the clinicians, and the five surgeons in particular, spent their time during the training sessions focusing on how they were going to conduct their outpatient clinics during the trial. The patterns that emerged over the six training sessions can be grouped into three categories: dealing with real-time collaboration between surgeon and clinic assistant, making changes to their clinical practice to accommodate the telehealth setting and identifying changes that they required of the telehealth system for it to accommodate to their practice.

The important point is that these issues of process change were raised by the clinicians and addressed by the clinicians individually by reference to their actual clinical practice. In particular, each surgeon had a specific personal approach to his practice that the researchers would not have been able to anticipate. What the surgeons did, however, was to involve the researchers in their (the surgeons') investigations about using the telehealth system. They frequently broke the flow of the training plan to practise using a particular component with their own or simulated patient data, role-playing or rehearsing what they would do with actual patients. From this they were able to identify the process changes that would be required of them in order to conduct their clinics as part of the telehealth pilot trial.

We saw in this study that there were three broad areas of change that the clinicians identified and dealt with during the training sessions. In the broader picture we might use these three areas as a way of managing this change.

- Firstly, we can expect that there will be an assistant located with the patient and we can expect the clinician and assistant to establish how they will work together. Even if they have an existing working relationship, it is likely that they will have to modify how they work together in a telehealth mode.
- Secondly, we can expect that there will be changes to the process of conducting their clinical practice and even changes to the practice itself to adapt to a telehealth mode.
- Thirdly, we can expect changes to be required of the telehealth system to meet the needs of particular clinicians. We saw that each of the five senior surgeons had a different way of matching his surgical practice with the telehealth system. In this study we had a large multifunctional system to match the complex needs of the healthcare situation. We might expect such a large complex system to be made available to a range of senior clinicians, not all of whom would have been involved in the requirements gathering process. We should therefore be prepared to adapt the telehealth system as new requirements arise.

We have been looking at the next generation of telehealth system, functioning in a tertiary healthcare environment and used by experts in their clinical fields. We have seen that the time allocated for training these experts can also have a role in letting those experts confront and deal with the process changes involved in making the transition from face-to-face to telehealth clinical practice. We also saw, in our case study, that it was the experts (our surgeons) who drove the exploration of this process change, each in their own way. This study can, therefore, act as a highlight for researchers and developers in this field, inviting them to focus attention on both the training and process change aspects as they introduce their system to its prospective users.

10.5 Conclusion

This case study deals with the observations of twelve clinicians during their training sessions with a research prototype of a broadband telehealth system. The clinicians quickly understood the resources of the telehealth system and they focused their attention on the process changes required for them to use the system in their own clinical practice. In particular, there were three areas of concern:

- How the clinicians would collaborate with their remotely located clinical partner in using the telehealth system;
- How the clinicians would adapt their practice to match the practicalities and resources of the telehealth system; and
- How the clinicians would adapt the telehealth system at points where it did not meet their needs.

In this study we saw the clinicians using the telehealth system for the first time. They were able to understand the spatial arrangements in each of the rooms and to use this information to make decisions about how they would conduct their clinics. They were readily able to use the pen and tablet interface for pointing and drawing gestures both relating to the physical space in the patient’s room and relating to the information space of displayed video and still images. They were also able to use these pointing and drawing gestures to work together to decide how best to employ the technology in their clinics. These observations, supported by direct dialogue between the clinicians, indicate that the design conclusions reached from the three laboratory studies were valid when the clinicians came to use the telehealth system.

The results from this study highlight the distinction between training provided to the clinicians and the process changes identified by those clinicians as they prepared to use the telehealth system. This distinction and the three areas of process change observed during the case study can form a basis for other researchers and developers working on broadband telehealth systems in a complex hospital environment.

A summary of the major results of this thesis is given in Section 1.6, pages 8-9, and this case study supports result R2: The surgeons, who were in charge of these outpatient consultations, spent most of the allocated training time mapping their own particular way of conducting the outpatient consultations onto the resources of the telehealth system. This involved establishing how they would work with their clinic assistant, how they would need to adapt their practice to use the telehealth system and, in some cases, identifying changes that they would require of the system before they could use it.

This phase was not limited to the training sessions. Some patients presented with conditions which required ways of using the telehealth system that had not been resolved during the training sessions, thereby extending the adaption phase into the early weeks of the trial.

11 Case study: Pilot trial - interviews and questionnaires

11.1 Purpose

The pilot trial of the telehealth system was conducted and evaluated to determine whether the design of the system could adequately support post-operative outpatient consultations for the Departments of Orthopaedics and Maxillo-facial surgery at the Royal Children's Hospital in Melbourne, Australia. This class of outpatient consultation was chosen because it represents a significant part of the hospital's work and because the burden of distance falls heavily on the patients and families during this phase of the treatment. These two departments were chosen by the hospital's Chief of Surgery as having suitable clinical relevance for this trial.

In this study I present the data gathered immediately after each telehealth session and after each block of sessions. The data from these interviews and questionnaires represent what the participants <u>said</u> about their experiences and feelings <u>after</u> the telehealth sessions.

The purpose of this study was to analyse the responses that the participants gave during exit interviews which were conducted with the patients and family after each consultation and with the clinicians after each block of consultations. This analysis addressed three broad issues:

- Whether delivery of telehealth consultations with this system would be acceptable to the patients and their families
- Whether the mode of clinical contact would be acceptable to the surgeons
- Whether the support provided for managing the patients and presenting clinical examination and findings to the surgeon would be acceptable to the staff performing the role of assistant

This study is a human-centred evaluation of the pilot trial of a broadband telehealth system placed in a tertiary hospital. This evaluation was conducted from the points of view of the participants in the trial and it demonstrates an approach to evaluating such pilot trials by tailoring the exit interviews for each class of participants to best draw on their context, history and knowledge. Each participant has a different point of view of the success of a particular clinical consultation. By drawing on all three points of view we are able, over the period of the study, to evaluate the telehealth system as a whole.

11.2 Method

Pilot trial and data gathering

Two meeting rooms on the eighth floor of the hospital were used for the trial, one as the surgeon's room and one as the patient's room. The patients reported to a waiting room on the same floor. At the scheduled time a member of the research team fetched the patient and family from the waiting room, checked that the consent process was complete and took the patient to the telehealth room. The assistant ushered the patient and family in and directed them to their seats. The surgeon, already in place in the surgeon's room, greeted them and commenced the telehealth phase of the consultation. The researcher remained with the patient and family for the entire time. After the telehealth phase of the consultation, the surgeon stepped out of his office, walked to the patient's room and conducted the face-to-face phase.

At the end of the whole consultation the researcher took the patient and family to a separate room and conducted an exit interview with them. This exit interview, which was audio-recorded and later transcribed, consisted of six Likert-Scale items and a number of semi-structured questions as shown in Appendix A. While this exit interview was taking place a second researcher got the surgeon and assistant to complete a brief questionnaire about their impressions of that particular consultation.

At the end of each clinic (a half-day block of patients) the researchers conducted an exit interview with the surgeon and separately with the assistant. These interviews also consisted of a number of Likert-Scale items followed by semi-structured questions (Appendix A), which were audio-recorded and later transcribed.

Pattern of the clinics

The trial consisted of three half-day clinics per week for four weeks. Due to prior commitments on the part of the surgeons there was not an exact match of clinics week by week. Two surgeons, however, each attended four clinics and another attended three. Two other surgeons attended a single clinic each. The pattern of the clinics is shown in Table 11.1

Week	Clinics	Numbers of patients
1	Orthopaedics (1,2) Limb reconstruction (2) Craniofacial plastics (3)	4 3 2
2	Orthopaedics (1) Hand plastics (4) Craniofacial plastics (3)	4 3 4
3	Orthopaedics (1) Limb reconstruction (2) Orthopaedics (5)	6 3 4
4	Orthopaedics (1) Limb reconstruction (2) Craniofacial plastics (3)	4 2 5
Total		44

Table 11.1. Pattern of clinics during the study, showing the surgeons (coded 1-5) who conducted the clinics.

The three main surgeons, therefore, had an opportunity to refine their use of the telehealth system during the four-week trial.

Question structure

Each group of participants was asked to respond to items or questions which their situation or prior experience qualified them to answer. For example, the patients and families were asked about their personal response to the just-concluded consultation and the surgeons were asked about their professional response. Three broad types of items or questions were presented:

- Items about personal response, such as the statement "I felt that the [subsequent] face-to-face appointment was necessary"
- Items concerning what they were able to do, such as the statements "I could get the doctor to understand and respond to my concerns during the telehealth appointment" and "I was able to direct the assistant"
- Hypothetical items, drawing on both the participant's experience and expectations, such as the question "Would you have been satisfied to let the patient leave after the telehealth appointment?"

All Likert-Scale items were presented as first-person ("I") statements with a choice of five response categories: Strongly agree, Agree, Neither agree nor disagree, Disagree and Strongly Disagree. The response options were listed vertically, with "Strongly agree" at the top.

Where possible, the statements were phrased so that a positive sentiment matched the category "Strongly agree". This might appear to contradict accepted wisdom, in which some questions are phrased in the negative to prevent a "donkey vote" of mechanical ticks to a large number of items by relatively uninvolved respondents. Our situation, however, was different. We had only six "tick the box" items. We had keen participants. For example, one parent commented that the hospital had been so good to her and her family over the course of treating her child that she was pleased to be able to give something back by taking part in this trial. In the first week of the trial we did have one item on the families' questionnaire that required parsing a double negative to interpret. We found that the families were so occupied by the reality of the day spent at the hospital that they did not have the mental energy to interpret the question. For the remaining three weeks we re-printed that page of the questionnaire with the double negative removed.

Data analysis

The Likert-Scale items contained five levels of response with "Neither Agree nor Disagree" at the centre. From our observations of the patients/families completing the questionnaires we often saw cases where the sentiment was clear but there were differing thoughts on whether the response should be, for example, Agree or Strongly Agree. Since we have no separate measure of the interpretation of this level of sentiment between differing families, nor between differing surgeons or assistants, I have taken the approach, described by Gardner and Martin, and clumped the responses into three categories – Agree; Neither agree nor disagree; and Disagree (Gardner and Martin 2007) for all three groups of respondents. Some items in the semi-structured interview led to a Yes/Neutral/No interpretation. Note that some data points are missing. Some families did not complete the exit interview, often for simple reasons such as that their parking ticket was about to expire, or they simply did not answer a question in the semi-structured part of the interview. One family did not complete the exit interview.

11.3 Results

11.3.1 Demographic data

Table 11.2 shows the distribution of the patients' home locations in terms of distance from the hospital. It also shows the way those families responded to the hypothetical question as to whether or not they would have used such a telehealth service for this consultation if it had been available locally.

Patients' home location	Yes	No
Distant (4hr travel or more)	4	0
Country Victoria (1.5hr to 3.5 hr travel)	5	0
Regional to Melbourne (1hr to 1.5hr travel)	5	1
Outer Melbourne suburbs	7	2
Melbourne suburbs	14	4
Total responses	83% (35)	17% (7)

Table 11.2: Patients'/families' home locations and responses to whether they would have used this system if it had been available locally

11.3.2 Patients and families

Likert-Scale questions

Table 11.3 summarises the responses from the patients and families to the six Likert-Scale questions in the exit questionnaire.

Likert-Scale questions	Agree	Neutral	Disagree
1. During the tele-health appointment I was able to see the specialist clearly	43	0	0
2. During the tele-health appointment I was able to hear what was said clearly	43	0	0
3. I felt comfortable having this appointment using the tele-health system	40	3	0
4. I could get the doctor to understand and respond to my concerns during the tele-health appointment	42	1	0
5. During the tele-health appointment I was worried that others might be listening	0	1	42
6. I felt that the face-to-face appointment was necessary	13	7	23

Table 11.3: Responses from the patients and families to the six Likert-Scale questions

Questions 1 & 2 concerned technical aspects of the video and audio link. All 43 respondents agreed that they were able to see and hear the surgeon during the telehealth phase. This implies both that the technical link was adequate and also that the surgeons were able to maintain their on-camera presence during the course of the consultations.

Questions 3 and 4 reflected comfort with the telehealth phase and with the ability to communicate with the surgeon during it. Forty of the 43 respondents felt comfortable and the remaining three were neutral on this question. Forty-two were able to get the surgeon to understand and respond to their concerns and the remaining respondent was neutral.

Question 5 dealt with privacy issues. Forty-two of 43 respondents disagreed with the assertion that they were worried that others might be listening to their consultation with the surgeon, with the other respondent neutral. When asked about their response during the interview one family said that they trusted the environment and the people inside the hospital to respect their privacy. Another parent commented:

> Parent: No, I didn't even think about it

Question 6 dealt with the patients' and parents' perceptions of the face-to-face phase. Thirteen respondents agreed that the face-to-face phase was necessary, seven were neutral and 23 disagreed. We used the interview transcriptions to look for reasons why those 13 respondents felt that the face-to-face phase was necessary.

Patient 1

> This family had travelled for an hour to get to the hospital. They were very positive about their experience and responded positively to the hypothetical question about having this appointment via telehealth. Question 6 was the question with an implied double negative [corrected for the remaining 3 weeks of the trial] and their response may just be due to misinterpreting the question.

Patient 2

> This family had driven for 2.5 hours from country Victoria for this appointment. They were strongly positive about their telehealth experience. Responding to the hypothetical question about having this appointment via telehealth they replied:
>
> Parent: Um yes, yes for this one, yeah definitely. For this one now it would've been really handy to have it closer to home.
>
> Their response to the question about the face-to-face phase being necessary, however, they said:
>
> Parent: Just today, well we got more out of the face-to-face because he could feel, so strongly agree
>
> Parent: [later in the interview] Though I felt like that actual doctor when he touched him was able to feel the difference between the right and left whereas I don't think that was quite as clear cut
>
> They later commented on the next appointment that day to see the hospital physiotherapist, showing that the issue of acceptability is wider than just this particular outpatient consultation
>
> Parent: The only think I would've said is we're off now to see a physio and I would much prefer to see the Royal Children's physio than a physio at <their country town>

Patient 3

> Both parents and also the patient responded to this question. One parent was neutral but the other parent and the patient both felt that the hands-on contact was important
>
> Parent: I like the consultant who's prodding and poking rather than …

Patient 4

> Both parent and grandparent were strongly positive in their responses about the telehealth experience, but the parent felt strongly that the face to face phase was necessary:
>
> Parent: Yeah I did actually, yeah I did yeah so I strongly agree on that
> Parent: … he likes him a lot
> Parent: Yeah, yeah I've been seeing him since we've started all this and he is very comfortable with him
>
> What the mother is saying is that, after two years of treatment, her young son has grown to like the surgeon a lot and would have been disappointed if he had not seen the surgeon in person.

Patient 5

> No reason given for the response

Patient 6

Parent: Probably because that's the way I'm used to it, doctors looking [in person]

Patient 7

Personal closure is important to this parent:

Parent: It, it just made it – that sort of added that closure to it and it sort of made it a little bit more, you know, personal, sort of thing, when he came in

Patient 8

This patient presented with a new problem in addition to the problem being treated and this required the face-to-face phase to properly resolve.

Patient 9

Both parents were strongly positive about the telehealth experience, but both emphasised the importance of the face-to-face phase this time

Parent: Yeah, face-to-face, that's really important

Patient 10

This family had driven from interstate to attend this appointment. Although they were strongly positive about the telehealth experience and said that they would have been happy to have had this appointment locally via a telehealth system they still felt that, in this situation, the face-to-face phase was necessary

Parent: Yep, yep, yeah it was good to just see him [the surgeon] at the end

Patient 11

This patient also presented with a new problem which required the face-to-face phase to properly resolve

Patient 12

This case fell outside the strict scope of the trial but was included to see how well the system supported it, on the understanding that the face-to-face phase would deal with any unresolved issues.

Patient 13

This family had also travelled from interstate and, although they were very positive about the concept and (hypothetically) would have used it in preference to spending three days travelling, they felt that the face-to-face phase was important at the end of this consultation.

Semi-structured questions

The responses to **semi-structured questions 3 and 5** are considered here, and Table 11.4 summarises these responses. These semi-structured questions were answered orally and some families did not give explicit answers to all the questions.

Semi-structured questions	Yes	Neutral	No
3. If you could have had an appointment closer to your home using the tele-health system instead of travelling to this hospital, would you?	35	-	7
5. Did you feel that the doctor was able to make an accurate examination of your child using the tele-health system?	31	2	4

Table 11.4: Responses from the patients and families to semi-structured questions 3 and 5

Thirty-five of 42 respondents would have used such a system at a local hospital rather than travelling to RCH, including the nine respondents who lived more than 1.5 hours travel from the hospital. One family explained the "No" response to the hypothetical question about using the system at a local hospital, saying that their child needed to see multiple clinicians at the hospital that day and that some of those appointments required hands-on treatment that could not be delivered in a telehealth mode.

Thirty-one of 37 respondents felt that the surgeon was able to make an accurate examination of their child, two were neutral and four did not. One parent offered this explanation for her high rating of the surgeon's examination of her child:

> Parent: Yeah I think he can still make an accurate assessment over that video linkup because gosh it was a very clear picture and when I was looking at the two legs I thought well I can see where the curve is, I can see him walking, I can see all of those things so obviously the doctor can too …

Other comments from the patients and families

During the interview the families were asked what they thought of the role played by the assistant. One parent responded:

> Parent: The assistant was there to answer any questions that I might have.

Another commented on the communication role played by the assistant:

> Parent: … he was able to converse quite well with him [the surgeon] really and get all the language across just right. Half of it I couldn't understand … but he explained some of it to me, so that's good

Other parents understood the assistants' role in terms of completion of the examination, seeing things that perhaps the surgeon had not seen over the video system.

11.3.3 Surgeons

The surgeons completed an exit interview and questionnaire after each clinic. Those surgeons who conducted multiple clinics completed the same questionnaire each time because the questionnaire dealt with their experience of that particular clinic and those particular patients. The questions mirror in part the questions asked of the patients and parents.

Likert-Scale questions

Question 1 dealt with their level of comfort in greeting the patient and then conducting the consultation using the telehealth system. All 12 responses agreed that they felt comfortable doing so.

Questions 2 & 3 covered understanding and addressing the patients' and parents' concerns. All 12 responses agreed that they could understand the concerns; 11 agreed that they were able to address those concerns and the remaining response was neutral.

Responding to **Question 4**, all 12 agreed that they were able to explain future treatment plans and expected outcomes during the telehealth phase.

At **Question 5** all 12 agreed that they were able to direct the assistant. At **Question 6**, 11 responses agreed that they were able to understand what the assistant was seeing, touching and doing and the remaining response was neutral.

For each patient the surgeons completed a two-item questionnaire. To the assertion that the telehealth appointment alone was satisfactory the responses were 39 "Agree", 3 "Neither" and 2 "Disagree" covering all 44 patients. Asked whether they would have been satisfied to let the patient leave after the telehealth appointment the responses were 41 "Yes" and 3 "No", again covering all 44 patients.

Of the two patients for whom the surgeons did not think the telehealth phase alone was satisfactory one family did not speak English and needed an interpreter and the other presented with a new problem in addition to the problem being tackled.

One of the three patients which the surgeons would not have wanted to leave after only the telehealth phase had the interpreter. For the second case the surgeon wanted to offer face-to-face reassurance about the conservative treatment plan he was proposing. The third was a new case (technically out of scope for this trial) for which the telehealth phase adequately created a plan for diagnostic investigations but was not adequate in terms of establishing the basis for a long-term doctor-patient relationship.

Interview data

During their interviews after the clinics the surgeons talked extensively about their experience and impressions of using the telehealth system. Two surgeons who each conducted four clinics worked together on the very first clinic and the exit interview was essentially a discussion between them about the situation.

In this first clinic we saw them being uncertain about how well they addressed the patients' concerns and reflecting on not actually being with the patient:

> Surgeon2: I'd be interested to see what they fill in on the questionnaire for that. I'm not sure you can [address their concerns] as being remote as much as if you were there. Maybe we like to think that as doctors that the presence or the touch has some value. I'd put neither agree nor disagree myself.
>
> Surgeon1: I would absolutely concur 'cause that's the one thing that we feel – it's an alien nature to be detached. It's, it's absolutely intrinsic to be involved, you know to be hands on and we almost feel jealous of <assistant> being in there and doing it.
>
> They conclude, even at this early stage in the pilot, that it is possible to conduct these outpatient clinics using this system:
>
> Surgeon2: You become more the expert witness rather than the actual operator, which is sad for us because we like being the operator. Um, but it works, it certainly works.

We also saw them reflecting on the learning process ahead of them.

> Surgeon1: I don't think anything went badly, I mean I think we'll improve as the month goes by … I know that I will try and work out a comfortable way for me to address those concerns about not being physically involved and not being able to get hands-on information which is what I depend on all the time.
>
> [This surgeon mentioned an early field trip of ours when one of the researchers had charted his movements all around the clinic room and then compared that to sitting in the surgeon's chair in the telehealth suite]

We saw them discussing the limits of such a telehealth approach. They discussed the difficulty of seeing new patients and discharging old patients with this system.

> Surgeon2: I think the ones that are most difficult are the ones that you probably want to get rid of, you want to discharge. Like the boy, the fractures. He for me was the most difficult because you almost want that hands on to reassure you that you can just say right okay we've done all we can, goodbye.
>
> Surgeon1: We've not yet explored what it would be like to see a new patient. I don't think I'm brave enough to do that yet because there would be so much uncertainties things, the tension's already quite high when they come and see us

Later in the trial, however, we saw these surgeons comfortably discharging patients in the telehealth phase, and even successfully dealing with a new patient with multiple complex conditions.

They discussed the issue of the patients' paper-based medical records which had been placed in with the assistant for that clinic. They resolved to place the medical records with the surgeon so that he could brief the assistant prior to the patient entering the room. They also discussed planning the consultation with the assistant, using shared access to the X-rays, and placing a clock in the surgeon's room so that they might aim for a standard 15 minutes for the telehealth phase.

The following day Surgeon2 conducted the next clinic:

> Surgeon2: It's amazing what a difference a day makes. … the learning curve is very fast … you sort of adapt your technique.

> He commented on the procedural change of reading the notes/briefing the assistant before the patient enters:

> Surgeon2: It worked better if you sit down and read the notes a little bit so there's not a large pause and I think in a clinic the pauses don't seem so awkward but on this they seem a little bit more awkward.

Surgeon1 made a similar comment after his second clinic at the start of week 2:

> Surgeon1: I'm getting quite confident with this now, and I'm able to direct things in a way that will allow me to get through it far more efficiently

He also commented on their new way of using the patients' medical records:

> Surgeon1: I think it worked very well for me, 'cause it crystallised my thoughts, got me much better prepared to kind of get things running in the conversation with the parents and the kids themselves and allowed <assistant> to clarify in his mind how he would like the consultation and examination to go …that's why we were able to keep well to time, which is critical to making this work.

In discussing the criterion for success for this type of telehealth consultation he said:

> Surgeon1: … routine reviews where success is not having to change the plan, the examination remains consistent and repeatable. Where it gets to things that are slightly off or where there are concerns that require specific intervention or investigations it may work as a preamble but better face to face

This surgeon concluded the exit interview with:

> Surgeon1: … overall I think by the end of the month I'll be quite happy to do this, this kind of consultation … so if this were to be a long term plan I'd be quite comfortable doing it

After the third clinic of that first week Surgeon3 commented on the quality of the video subsystems:

> Surgeon3: You feel like you could make eye contact with the patient, so it was good, yeah.

> Later, commenting again on the support for personal communication

> Surgeon3: It was pretty much, pretty similar to a face to face really. Had a sort of close to and face to face feel about it.

The fourth surgeon only conducted one clinic. He commented on the way the system worked and on the skill level of the assistant:

> Surgeon4: Ah, no, I don't think there were any issues at all. I think in fact it works, the system seems to work the way it's set up it works very well

> Surgeon4: I was, yeah but I think you'll need an experienced person at the other end 'cause I could then just ask them to do things, I didn't have to direct him on how to do what I wanted to see.

After his second clinic Surgeon3 commented:

> Surgeon3: I thought well they were all pretty much like normal appointments to me, I don't see any shortfalls so far ah except for the macro issue for close ups [he had tried to use the arm-mounted camera pair to look for millimetre-height texture on the patient's face and this went beyond the capability of the camera lens]

For his third clinic Surgeon1 doubled the number of patients to see if the system could cope with approximately normal patient scheduling. The surgeon was confident in his use of the telehealth system:

> Surgeon1: I'm quite used to it now and I know what I want to do and how to achieve it

The surgeon noted two changes in the role the assistant is playing [he has worked with this same assistant for all three clinics]. The assistant is able to anticipate how the patient examination should proceed and is presenting the surgeon with the results:

> Surgeon1: He makes sure that I can see what he wants me to note … we vocalise everything, verbalise everything so that it gets said, it registers.

The surgeon noted that he was communicating less about the physical findings with the patient because the assistant was doing this. Communication between the assistant and patient occurred in lay language; communication between the assistant and the surgeon occurred in clinical language. He also commented that he is able to take advantage of not having to manage the patient and the details of the examination to write up his clinical notes:

> Surgeon1: It makes sure that all the important things are written down without the chance of forgetting to write the sort of document down, 'cause note-keeping is so critical as being a record of what happened. For me that's an indirect benefit of this which I never expected at all.

At Surgeon2's third clinic he observed that this system really worked for long-term cases – patients that they see repeatedly:

> Surgeon2: Where you just want a little bit of what's happening now. Rather than making big decisions, rather than planning out operations and corrections – where, "Are we actually on track like I think we should be?"

He also reflected on changes:

> Surgeon2: I think we adapted some of our stuff that we do, but not in a huge way. I think we just got more comfortable with it. … I suppose I'm getting used to the fact that I can't go and touch them.

Surgeon5 also conducted only one clinic. He commented on using the telehealth system:

> Surgeon5: Yeah, it works fine, yeah you could establish a rapport with family and get where you need to get, yeah.

He also commented on learning to use the system:

> Surgeon5: Actually I started to warm up and be able to work out which camera I wanted and how to direct it so … I was learning on the job.
>
> Surgeon5: [commenting on using the cameras to examine the patient] … you only need to do it once and you realise where it will work and where it won't

In this last week of the trial Surgeon1 summarised the overall outcome of the trial for him, after having an unexpectedly difficult case in his last clinic:

> Surgeon1: I think ah we overall challenge ourselves in different ways and I'm glad we did because it would've been a false sense of achievement if we had got very simple cases and then say oh yeah this we can do and oh yeah this is no problem at all to be faced with real difficulties when you try to reproduce that in the real world. This one [i.e. this pilot trial] has allowed us to say can we do interpreters, can we do kids with complex disabilities, can we do kids who have more than one problem.

In his final exit interview Surgeon2 explored the boundaries of where this telehealth concept would work for his speciality (orthopaedics):

> Surgeon2: The whole thing's concept works extremely well, the whole thing can run really smoothly, but I think it works best for the patients that you know well

He then cited the example of that last clinic to show how touch is important:

> Surgeon2: When I went into the room to see her … you appreciate why she's got knee pain 'cause <list of clinical first-hand observations> and when you see her in the flesh you can appreciate that. … How do you assess knee pain if you can't touch the patient?

11.3.4 Assistants

Question 1 dealt with their level of comfort in managing the greeting stage of the telehealth phase. In all 12 clinics the assistant agreed that they felt comfortable with this.

Questions 2 to 5 dealt with the assistant's ability to perform their role during the telehealth phase. **Question 2** addressed the issue broadly and in each of the 12 clinics the assistant agreed that they were able to take an appropriate part in the consultation. **Questions 3 & 4** dealt with understanding and acting on the surgeon's directions. In each of the 12 clinics the assistant agreed that they were able to understand and act on the surgeon's directions.

For **Question 5**, all 12 respondents agreed that they were able to communicate to the surgeon what they were seeing, feeling and doing.

For each patient the assistants completed a one-item questionnaire. To the assertion that "overall the tele-health appointment went satisfactorily" there were 40 "Agree", 2 "Neutral" one "Disagree" responses and one missing response, covering the 44 patients.

Interview data

After the first clinic of the trial the assistant talked about the difficulty of being part of a 3-way conversation where the primary dialogue was between surgeon and patient, and how it was hard to know whether to interrupt or wait when he had something to say. In his usual clinics as a surgical registrar he would see the patient by himself then later present the case to the consultant if required rather than facilitate the flow of information between surgeon and patient.

> Assistant1: So this is an extra role, this is a completely different thing

He noted, however, that the task of presenting an examination of a patient to a group of specialists is something he often did and he likened this to conducting the patient examination during the telehealth phase. He described the problem that, when there were specialists present he knew where they were looking and could properly present the case. In the telehealth suite he described the problem as "not knowing which cameras are looking where" and therefore not being sure if he was presenting the case at a correct angle to the camera or even if he was blocking the view of the camera. [He was showing the limiting angles of movement of the patient's joints, which the surgeon needed to see square-on to the camera] In response to prompting about the arm-mounted monitor showing what the surgeon was seeing he said:

> Assistant1: I wasn't looking, I was – because you're so busy concentrating on the angles it's – you're not really looking at the monitor

He might have moved the examination couch away from the wall and examined the patient from the other side (going against convention of examining from the right-hand side) but there was limited space in the room.

The style in the second clinic was different because the two assistants (Assistant2 and Assistant3) work together with Surgeon2 in their normal clinics. They observed that the communication felt more formal than it would have been in a face-to-face setting.

> Assistant2: I felt like I had to be aware of when I could say things … I sort of felt like, like I, um, had to wait my turn almost

She mostly sat at the examination chair during discussions and noted that the directional cues that we built into the layout of the two subsystems helped

> Assistant2: This system is better than using the video conferencing when, because you – like how it's set up, when the person turns and looks at you that's much better than … rather than not having that visual face to sort of talk to

Assistant3 had the task of recruiting patients for this clinic and she tried to choose patients whose situation was just being reviewed. For one patient the surgeon had changed his intention and wanted to plan the next lot of surgery. She observed:

> Assistant3: So you need to have a good idea probably of what's going to happen in the consultation. The others I knew were just reviewed.

Assistant4 observed that the quality of sound and image is very good, but talked about the difference in using the video/audio mode compared with normal face-to-face:

> Assistant4: It's not the same as if you were present … I don't know exactly what makes the difference, but I feel – I feel that it's different. But I can communicate, it's not a problem. It might be – I might be feeling that now because we are starting.

After his second clinic Assistant1 commented:

> Assistant1: It was reassuring to see that the parents, you know, walk out with their questions answered and happy with things, so that's like – I think that's a good indication of how things went.

He also noticed that the surgeon was getting used to using the telehealth system:

> Assistant1: I think he – he was more familiar with the equipment and knew, ah, you know, how to change the monitors and the angles and things

He reiterated that presenting the examination of the patient to camera was like presenting to a group of consultants and noted that he had done exactly that earlier in the day at a conference session. He also reiterated that in order to get out of the way of the cameras he needed to examine the patient in a non-standard manner (i.e. not from the patient's right-hand side).

He specifically commented on how well the surgeon was able to display and annotate the patient's X-rays on the tablet system, located right in front of the patient and family, and on how well the families responded to this. He contrasted this with the situation in the normal clinics, where it was very difficult to use displayed X-rays to explain matters to the patient and family:

> Assistant1: … at out outpatient clinics we have one computer, one monitor … there's a big thing on the wall [a second display screen] but it hardly ever works, but having the monitor in front of us and then you've got to spin it around and then you've got to use the mouse and try and swivel it around …

In his first clinic Assistant5 observed some difference in the way the surgeon and family interacted between telehealth and face-to-face phases:

> Assistant5: … the only thing that I did notice was that the rapport was probably slightly better when Surgeon4 actually came into the room than you get over the videos. … You know I think it's just having direct contact does make a tiny bit of difference … I just felt mum and kid relaxed a bit more when he was actually there and he was always, it was all quite formal over the cameras whereas everyone seemed to relax a little bit when he actually walked into the room

Assistant6 observed that he needed to use both hands to properly examine one of the patients and he was unable to adequately use the hand-held camera to show what he was seeing to the surgeon. Neither could he use the other arm-mounted camera because this would have required re-positioning the patient which was not a suitable option. He also mentioned the tendency to verbalise observations:

> Assistant6: [In response to a question about whether he used ways of communicating that he might not normally use] Oh, no because we tend to describe a lot to the bosses anyway, like on the telephone, so we're used to describing things on the telephone so that's fine.

After his third clinic, Assistant1 made two observations. He talked about reaching a point in his learning where he knew where the cameras were, what they could see and how he should position himself so as not to obscure the view yet still present the case. He had also learnt to observe the local tablet display so that, if something that he thought the surgeon should see was not in view, he could direct the surgeon's view to it.

He also talked about the experience necessary to fulfil this role as assistant, and even his own limitations:

> Assistant1: … with me being orthopaedic trained I know what um tests and things to look for, do for and having been in orthopaedics for a few years and I'm still not familiar or happy with some of the tests.

He commented on the difficulty of directing an untrained assistant:

> Assistant1: The assistants on the other side if, you know it'd be tricky to try and demonstrate some of those tests and those examinations

He commented on the specialisation of physiotherapists:

> Assistant1: Even physios. Physios [in this hospital] are [completely orthopaedically trained] because we need certain physios that just deal with the orthopaedic … they are good at that but in other hospitals physios are not necessarily you know pre-groomed at demonstrating the signs for [specific tests].

Assistant2, at her second clinic, commented on the problems of seeing subtle angles and curves with the video cameras:

> Assistant2: I completely understood what he asked me to do … but I still couldn't show him what he wanted to see … I don't think he could see exactly what I could see.

Assistant7 observed that, at the start of a consultation the patients and family were having trouble picking up on the conversational cues, waiting for the other person to stop talking before they started, but later in the consultation the conversation became more fluid:

> Assistant7: [initially] they weren't too sure when they could chip in and say their bit, but as the interview went on people carried it on more like a conversation

In commenting on the assistants' role he said:

> Assistant7: … from an assistant side of thing I think the most important thing is that an examination's being done by kind of protocol, if there's specific things they want to look at those instructions need to be pretty clear

In the last week of the trial Surgeon1 chose to work with a different assistant (Assistant7) to broaden his experience of using the system. Assistant7 commented on the way Surgeon1 was using the system:

> Assistant7: I thought Surgeon1 was very clear, I mean he's obviously done quite a few of these and he's very clear on his directions

About his own learning curve he said:

> Assistant7: I felt more comfortable in just putting the patient where I knew the cameras were and knowing which cameras are going to get the best view than I did the first time.

Assistant7 commented on the way the system supported him in presenting a difficult case:

> Assistant7: I was pretty pleased with how I could show the deformities on the camera and the <clinical terminology> deficits on the camera

11.4 Discussion

Summary statistics

These statistics were collected from the data of the exit interviews. In some places the data items are missing. One patient and family were unable to complete the exit interview due to language difficulties and time pressures. Some families addressed the semi-structured questions in an indirect manner and clear responses to certain items were not available from the transcripts. One clinic assistant was also not able to complete the exit interview due to work commitments elsewhere in the hospital.

These summary statistics need to be interpreted in the context of this pilot trial. The patients were selected on the basis that their situation matched the selection criteria for the trial, which in turn were constructed to meet the design intentions of the telehealth system. The patients themselves were not an homogenous group. They covered four surgical specialties and, even within those specialties their situations differed from each other. Broadly positive responses indicate an aspect of the trial that appeared to work well. Outliers indicate aspects that might need attention or aspects where the boundaries of the pilot trial were not broad enough to satisfy the situation. In one case the split in responses was so marked that I have shown details for each apparently adverse response as a way of showing an interpretation of such data.

The summary statistics from the exit questionnaires show the level of success of the pilot trial. In 40 of the 44 cases the surgeons felt that the telehealth phase alone was satisfactory and they would have been satisfied to let the patient leave after that phase. The responses from the assistants support this, agreeing in 40 of the 44 cases that “overall the telehealth appointment went satisfactorily”. In contrast, 13 patient/family responses (out of 43) felt that the subsequent face-to-face phase was necessary; seven were neutral and only 23 respondents felt that the face-to-face phase was not necessary.

Of the 43 patient/family responses, 42 said they were able to communicate their concerns to the surgeon and have him address them. All 12 surgeon responses agreed that they could understand those concerns and 11 of the 12 responses agreed that they could address them.

In all 12 clinics the surgeons agreed that they were able to direct the assistant, and in 11 cases agreed that they were able to understand the assistant’s examination of the patient. In all 12 clinics the assistants agreed that they were able to understand and act on the surgeon’s instructions and that they were able to communicate the patient examination to the surgeon. The patient/family responses largely support this, with 31 of 37 respondents feeling that the surgeon was able to make an accurate examination of their child.

Thirty-five of 42 patient/family responses said, hypothetically, that they would have used such a system for this consultation if it had been available locally. This group included all those families who had made a major travel commitment to attend the consultation.

These juxtapositions of statistics illustrate the importance of taking the points of view of the different groups of participants, and in particular of the patient and family, into account. At times they reinforce each other, giving stronger weight to a piece of evidence about the performance of the system during the trial. At other times they appear to conflict, indicating that a deeper investigation of the situation is required.

In this example we had differing points of view on the necessity of the face-to-face phase of the consultation and to investigate this issue we looked for a deeper level of information from each of those 13 patient/family groups. For some cases the patient fell outside the intended boundaries of the trial and both surgeon and family agreed that the face-to-face phase was necessary. In some cases the families' expectations from prior experience were too strong and they still required the personal presence and hands-on touch of the surgeon for closure, most notably where the young patient had wanted to express a friendship bond with him. Others had made a major travel investment to attend this consultation and, for them, it would be unthinkable to not see the surgeon in person at some stage during the consultation.

There is an apparent contradiction in that many of these 13 families had given hypothetical agreement that they would have used such a system for this consultation. This might flag that the families were stepping in and out of their role as participants in a telehealth trial as they answer these questions, one moment envisaging themselves in a telehealth situation and the next moment dealing with the reality of being present in the actual hospital. It serves as a reminder that trials such as these are an approximation to the reality of normal clinical practice and need to be understood as such.

Criteria for success

Two criteria for success have emerged in this evaluation data. The surgeons' criterion relates to repeatability of the patient examination and continuity of the treatment plan. This criterion is closely linked to the scope of the trial, where the patients were chosen on the basis of review consultations. The examination, then, would not show anything unexpected (based on the prior history of the patient) and the proposed treatment plan would be a continuation of the previously established plan. Specifically, success in terms of this particular trial is in terms of not having to change the treatment plan (that was determined and agreed on in the telehealth phase) as a result of the face-to-face phase.

A success criterion for the patient and family, articulated by one assistant, was that the patient and family walk out "with their questions answered and happy with things". A different assistant described a condition for success rather than a criterion, saying that the most important thing was that there needed to be a structure, or protocol, in place for each patient examination [in contrast, say, to an unstructured series of requests for actions from the surgeon to the assistant], implying that the assistants needed to be skilled in those protocols and that success occurs when they are able to follow those protocols well.

These criteria all relate to context, prior history and experience. Context requires that the patient already have a treatment trajectory, analogous to that described by Corbin (Corbin 1998), so that the surgeons have a store of previously face-to-face-acquired patient data to work with. Prior history on the part of the family, in terms of a sequence of prior consultations punctuating the treatment trajectory, gives the family the questions they need to ask and the judgement to know whether those questions have been addressed. The prior experience on the part of the assistants enabled the examination of the patients in a manner which satisfies the surgeons and therefore was the essential facilitation element of these consultations. Both the surgeons and the assistants themselves comment extensively on the importance of this prior experience and on how specific that experience may need to be.

We saw, therefore, that having a successful outcome of the trial was not just a property of the telehealth system alone. It depended on the choice of patient to match the capabilities of the system. It depended on the patient and family raising issues that mattered to them and being able to judge whether those issues were addressed. It depended on the assistant having the appropriate skills. It also depended on the successful human interactions between surgeon and family (to communicate and agree on the treatment plan); between surgeon, assistant and patient (to present the clinical examination) and between assistant and surgeon-family as he or she mediated and facilitated the consultation. Understanding and evaluating the success or otherwise of the trial, therefore, depended on understanding the human interactions that were contained in the context and actions of the trial.

Use of the fixed video and audio links

The surgeons, assistants and patients/families used the fixed video/audio links to support interactions with each other and with the patient's data. One of the distinguishing features of this telehealth system is the way it uses these technologies to support the flow of communication between the two ends of the telehealth link, in contrast with conventional telehealth systems that use traditional videoconferencing arrangements. It is therefore important to know how these links were used and how well they worked.

The patients and families all reported that they could see and hear the surgeon during the consultation, and they reported that they could use the video/audio systems to raise concerns and have them addressed, although one surgeon initially expressed personal concerns about how well he was addressing them. A surgeon who conducted three clinics said that it was very similar to face-to-face, that he felt he could make eye contact and that it had a "face-to-face feel about it". Another surgeon noted that the practice of verbalising all observations during an examination was well suited to communications between surgeon and assistant because the surgeon received both a visual and an auditory account of the examination. During his only clinic, one surgeon noted that he was able to establish a rapport with the family and then use this rapport to get the information he needed. One assistant, whose role required her to move around the room a lot, noted that the use of body and head direction on the part of the surgeon to indicate his direction of attention made it much easier for her to take part in the conversations.

By drawing on the responses and reported actions and impressions from each of the participants we get a composite reinforcing impression, sometimes referred to as "triangulation", of the effectiveness of this particular aspect of the system.

Learning about the telehealth system

There are three types of learning about the telehealth system to be found in the exit interviews. Firstly, the patients and families had a very short learning phase lasting about as long as it took them to enter the room, sit down and respond to the greeting from the surgeon. Some commented that they were initially in awe of the system with the large number of screens and displays but they noted that they settled in quickly. Other than this the patients and families did not comment on the process of learning to use the telehealth system. Once the surgeon had their attention he led them into the pattern of the consultation and, because they had attended such consultations before in the normal setting, they knew what to do. The time-frame of the trial, four weeks, was shorter than the accessible repeat cycle for any patient so no patient got to experience the system twice.

The surgeons commented explicitly on the learning curve for the telehealth system. They noted that after one clinic, or even by the end of their first clinic, they were getting to know the system, and one concluded that by the end of the month they would be very happy with using this system. He, in particular, probed the system to discover its usability issues. He doubled the number of patients for his third clinic, and worked with a different assistant for his fourth. He took advantage of the small number of patients who were outside the strict scope of the trial to analyse and reflect on the characteristics of patients who were best suited to it.

The assistants also observed their own learning. From being too busy managing the system to pay attention to the feedback monitor in his first clinic one assistant was using the feedback monitor fluently by the third week. His surgeon noted the changes in his skill with the system, mentioning the way in which he was taking more responsibility for examining the patient and communicating the results in lay terms to the patient and family.

We note from their comments that they were learning to work with each other, learning how each other used the system and what each other wanted. Again, what the surgeons wanted varied from surgeon to surgeon. For example some were happy with angles of limiting movement being reported by the assistant whereas others wanted to see the movement square-on to the camera and estimate the angles for themselves. This emergence of collaborative working behaviour is consistent with the observations of their training sessions reported in an earlier chapter and is one of the important issues revealed in our study of human interactions in this trial.

By looking at the human interactions as reported and observed by each group of participants we see beyond the summary statistics of clinical success to uncover the learning processes occurring during the trial. We see processes analogous to those observed during the scheduled training sessions but now with actual patients.

Types of patients

As the trial progressed, the clinicians payed a lot of attention to the types of patients and clinical situations which this telehealth approach would suit. They observed that it was important to have both an existing patient trajectory within the hospital system and also an existing relationship with the patient and family. Further, they felt that the best situation would be to have “review” appointments where no major changes were expected and no big clinical decisions were to be taken. Early in the trial the surgeons explicitly expressed concern about seeing new patients or discharging old patients using a telehealth consultation, though they did successfully manage at least one of each of these later in the trial. Some surgeons also experienced situations where they were covering for other surgeons and, while they did have the patient’s clinical notes they did not have an existing personal relationship with the patient and family. In these situations they found it difficult to maintain the level of personal contact that they would have wanted.

Assistants, their roles and skills

For the patients and families the assistant was seen as a communicator, discussing the case with the surgeon in technical terms and explaining it to them in lay terms, and we saw this expressed in the very first clinic. The assistants were conscious of this role and by the third week the surgeons also observed this aspect of the assistants’ role, with one commenting that the assistant was taking some of the patient management load from the surgeon thereby freeing the surgeon to focus on the clinical issues.

Initially, however, the surgeons concentrated their comments on the technical skills of the assistant in terms of examining the patient. They repeatedly made the point that they wanted to give examination directions to the assistant at a very high level and to have the assistant observe subtle details and report them back in the language of their particular specialty. The assistants' comments supported this position. One assistant observed that someone with generalist training, such as a physiotherapist, might have difficulty examining a patient who was rehabilitating from specialist orthopaedic reconstruction surgery. He cited his own situation that, after three years of orthopaedics training there were still some tests about which he was uncertain.

Privacy

The telehealth system had been designed to maximise the awareness on the part of all the participants of who was present in both rooms and where each participant was directing his or her attention. The doors of each room were in full view and could be seen and heard if they were opened or closed so that people entering or leaving were obvious to all. Forty-two of the 43 families were not concerned that anyone might be listening to the consultation. The true privacy situation, however, might be masked by the location of the trial. Several families were surprised to be asked the question, saying that they trusted the hospital on this matter. One parent said explicitly that she was sure the hospital wouldn't have anyone listening who was not supposed to hear. This implicit and explicit trust placed in a major hospital might not be available in subsequent long-distance trials to regional centres.

One assistant raised the issue of personal privacy, saying that she was reluctant to ask patients to expose their arms and legs in front of so many people. We can interpret this observation as an indicator that the trial did not properly handle issues of scale. We already know from earlier field studies that these consultations can involve multiple clinicians but the telehealth situation added further clinicians and included members of the research team, thereby changing the sense of exposure felt by the patient. There are techniques for handling the situation – separate changing rooms, drapes, having more conservative items of clothing to replacing light summer clothing – some of which were indeed used during this trial. By paying attention to the assistant's observations we identify an important design issue for subsequent system iterations.

11.5 Conclusion

All three groups of participants responded in ways that gave clear answers to their levels of acceptance of the relevant aspects of the telehealth consultations. In addition, each group was able to explain those levels of acceptance. The surgeons were able to identify points on the health trajectory for which patients might be suitable for telehealth consultations and they were able to identify the characteristics of the clinic assistant necessary for them to effectively conduct the examination of the patient. The clinic assistants were able to learn how to use the system with their particular surgeons over the four-week trial period so that they could adequately present the patient examination in a collaborative manner. The patients and family were able to make judgements on the acceptability of the telehealth consultation based on their existing relationships with the clinicians and on their prior experience of this type of consultation. Where the patients/family appeared to give contradictory answers to different questions the contradiction could be resolved by seeing the consultation in its wider context, both its social context in terms of patient-hospital staff relationships and in its wider context of the complexity of the hospital's treatment of the patient.

This study illustrates an evaluation based on the expressed positions of the participants involved in this class of broadband telehealth. We see the multiple perspectives converging on some issues, such as the effectiveness of the video and audio communication subsystems. We see them diverge, such as on the criteria for success of an individual consultation in telehealth mode. We see different understandings of time and process – the patients and family seeing the event as a point on their treatment trajectory and the clinicians seeing the sum of events as a learning process. We uncover interpretations, such as the privacy qualities belonging to the hospital rather than to the telehealth system.

Finally we see deep reflective thinking on the part of the clinicians. This covered the types of patients for which this system would best work and the attributes required of the clinic assistants. It also covered issues of learning to use the telehealth system and learning to work with their clinical partners to conduct the consultations in a telehealth mode.

We uncovered apparent inconsistencies in the responses of the participants to our interview questions and we can relate these in part to the situation of the trial, where we were approximating the experience of a telehealth consultation but in reality we were located firmly within the major hospital. An expressed hypothetical willingness by the families to use such a system for this consultation seemed to clash with a strongly expressed feeling for the necessity of the subsequent face-to-face phase, but was in fact an expression of the reality of the patient's and family's situation. An agreed treatment plan at the end of the telehealth phase appeared to clash with the surgeons' reluctance or ambivalence to rate the face-to-face phase as not necessary. Matters outside the scope of the consultation but firmly anchored in the context of the hospital were involved, emphasising the importance of understanding the bounded scope of the trial.

The evidence presented in this chapter directly supports the itemised results shown in Section 1.6, pages 8-9:

- R2: The surgeons and the assistants explicitly observed the learning process - using the system, learning to judge the suitability of patients for the telehealth phase of the consultation and learning to work collaboratively over the system.
- R3.1 and R3.2: The human-centred exit interviews elicited responses from the participants and explanations of those responses. Quantitative responses from the participants, as Likert-Scale responses or Yes/No answers, established the levels of acceptability of the telehealth experience in the trial and qualitative responses linked those levels of acceptability to the wider contexts
- R3.3 and R3.4: The responses from the participants to the exit interviews showed the competence of their responses and the range of viewpoints.
- R3.5 and R3.6: We saw in the outliers and anomalies in the participants' responses the impact of the wider contexts in generating these responses and the need to interpret these outliers and anomalies in terms of the participants' view of those contexts.

12 Case study: Pilot trial: video and audio recordings

12.1 Purpose

This chapter presents an analysis of the video/audio recordings of the telehealth sessions and deals with what the participants did and said during the telehealth sessions of the pilot trial at the Royal Children's Hospital. The purpose of this study was to use observations of the participants' actions and speech to make inferences about their responses to the telehealth system in the context of the application scenario and in the context of the pilot trial.

The context of the application scenario is that of a genuine outpatient consultation with the intentions on the part of the clinicians to follow the normal pattern of their consultations. The intentions of the clinicians, and in particular of the five surgeons, were inferred from their approach to the training sessions, described earlier, in which they focused not on the details of the telehealth system but on how they would conduct their own clinics using it. These intentions are also inferred from the way they allocated their time between the telehealth and face-to-face phases. They conducted the telehealth phase until they had achieved their required outcome in 40 of the 44 cases then used the face-to-face phase for confirmation and closure. This intention was confirmed in a discussion between the two surgeons who conducted the very first clinic (recorded during the exit interview):

> Surgeon1: What do you think <name>? Do you think it will work?
> Surgeon2: It will certainly work, there's no doubt about it. It will certainly work with patients like <patientname>.

The context of the pilot trial included both the presence of the trial at the hospital and the artificial situation by which both rooms were on the same floor of the hospital and a face-to-face follow-up was prescribed in the trial's protocol.

This chapter illustrates the high level of interaction between the participants, and between participants and data, in this type of telehealth scenario, which reinforces the argument for a human-centred approach to the design and evaluation of broadband telehealth systems. It also demonstrates the importance of trialling a well-bounded pilot system in the actual workplace setting. As we saw from the training sessions conducted for the clinicians, and from their early interview feedback, whether or not the clinicians could successfully conduct this type of outpatient clinic was an open question at the start of the trial. We saw the participants' understanding of what was in or out of scope in this pilot study and we saw them behaving as in real life during the consultations.

One of the scope requirements was that the patients and family already have experience in this type of outpatient consultation. In the same way that we saw them competently answering questions about their experience in the previous chapter, we see them here competently engaging with the telehealth system and with the clinicians during the consultation.

12.2 Method

Video and audio data

Two tripod-mounted video cameras, one in each room, recorded the video and audio for each of the 44 outpatient consultations. Figures 12.1 and 12.2 show still frames from the tripod-mounted video cameras.

Figure 12.1: View of surgeon's room from the tripod-mounted video camera

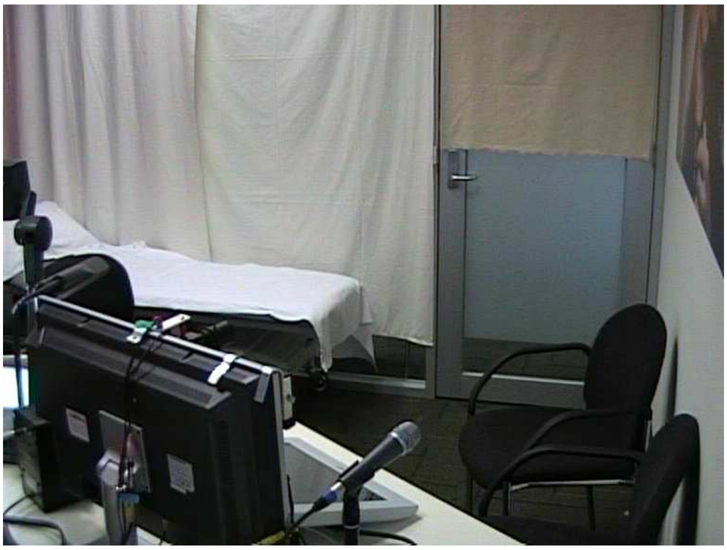

Figure 12.2: View of patient's room from the tripod-mounted video camera

The view of the surgeon's room shows the display on the tablet and the room overview of the patient's room where hospital staff have gathered prior to the start of a clinic. The viewpoint in the patient's room shows the patient/family as they sit talking to the surgeon, and shows the examination couch. For cases where the patient was seated to be examined the camera was manually panned to the left. Where actions occupied the whole of the patient's room they could be seen from the room overview display in the surgeon's room and watched again on the second video recording to be sure of the parents' responses

Each camera recorded the audio of the major conversations, both between rooms and between individuals in each room and this audio track could be used to match events between the two video recordings. Some conversations were conducted *sotto voce* and were not intended to be heard in the other room; these conversations are only heard in the audio track of that room's camera.

Data analysis

The video recordings were coded in the manner of the Grounded Theory approach described by Corbin and Strauss (Corbin and Strauss 2008). For each recording a text file was constructed, taking the role of field notes. Specific events, such as greeting, patient examination, use of the two close-up video subsystems, use of gesture, use of the pen/tablet subsystems, asking difficult questions and so forth were noted, along with video time codes where appropriate. A comment about the significance of the event was written and in some cases instances of dialogue were transcribed to illustrate the event.

The video recordings were viewed in pairs – first from the patient-room camera then from the surgeon-room camera – with the second recording often showing additional information about particular events in that consultation. During the clinics I and another colleague sat in with the patients in turns so I was actually present during about half of these consultations. Although I viewed these video recordings several months after the trial I had a strong memory of the pattern that the consultations took and was easily able to identify the key events in the consultations.

Five surgeons conducted clinics for this trial and I viewed the video recordings grouped by surgeon, starting from the earliest consultations and working forward to the latest. For each surgeon I took these field notes and wrote coding notes in the margin; these coding notes served to formalise the nature of the events that I had observed in the video recordings. From these field notes I constructed memo outlines, one set for each surgeon, grouping together common codings across that surgeon's consultations and including quoted dialogue. These memo outlines form the data base for the results and analysis below.

12.3 Results

12.3.1 Structure of the telehealth consultation

All five surgeons used a common pattern for the telehealth consultations and this pattern matched the consultations that we had observed during our field visits to Royal Children's and Royal Hobart Hospitals.

Greetings

As the patient and family entered the patient's room the surgeon captured their attention with a clear, directly voiced and personalised greeting. One surgeon greeted the patient and parent(s) by first name, and made a point of including other family members:

> Surgeon: Who's that in the background?
> Parent: That's my mum [i.e. patient's grandmother]

They sometimes made a brief reference to the telehealth system, such as:

> Surgeon: This is good, isn't it? Can you hear me OK?

Questions/discussion about the patient's progress since the previous consultation

They immediately followed the greeting with a context-based question, such as:

> Surgeon: It has been a year now [since we saw this patient] how has it been?
> Surgeon: The issues last time in March were …

This led directly into discussion about the patient's progress and where the patient was old enough to speak for himself or herself it actively included the patient in the discussion. It was clear from the open manner with which the patients and families spoke with the surgeons that they were familiar with this situation and with this pattern of consultation.

Examination

The examination typically began with the surgeon telling the patient and family that he would ask the assistant to examine the patient. The assistant then performed an examination under the observation and direction of the surgeon.

Discussion between surgeon and patient/family

The patient and family gathered around the family pen-and-tablet display while the surgeon summarised the patient's situation and the examination, often displaying X-ray or CT scan images on the tablet display and annotating them as part of the discussion.

The Plan

The surgeon then presented the treatment plan for the time-period until the next consultation, or in a few cases explained that no further treatment was necessary and discharged the patient.

Closure

Finally, the surgeon closed the consultation, usually by asking

> Surgeon: Do you have any further questions for me?

The surgeon then stepped out of telehealth role and asked the patient and family to wait a moment while he came in to see them in person.

Expectations

In addition to the implied expectation on the part of the surgeon that the telehealth consultation would be successful there were occasions when the surgeon had specific outcomes in mind.

Example

> The surgeon spent considerable time and effort convincing the patient and parents to leave the frame [which holds the leg bones in place] on the leg for another month. In the exit interview after that clinic he commented:
>
> Surgeon: From my point of view all I was interested in was showing them that X-ray and saying to <patient's> mum and dad "another month".

12.3.2 Structure of the face-to-face consultation

The surgeons all treated the telehealth consultation as the primary interaction with the patient, so that by the end of the telehealth consultation they had arrived at a treatment plan for the patient and there were no further questions from the patient or family. They treated the face-to-face consultation as a social interaction, as an opportunity to confirm the patient's/family's agreement with the treatment plan and in some cases as an opportunity to confirm their understanding of the examination of the patient.

The face-to-face consultations, therefore, had a much looser structure, beginning with further greetings such as physical handshaking. The ensuing discussions were relatively short and involved confirming topics previously discussed during the telehealth consultation. In some cases sub-conversations started up – the surgeon talking quietly with a parent while the assistant repeated explanations of rehabilitation exercises with the patient, for example. Closure was a matter of the surgeon saying goodbye and walking out of the room.

The surgeons' differing surgical specialties and personal approaches influenced how they used this face-to-face time with their patients. One surgeon, whose patients had long-term treatment for hip, leg and foot correction used the face-to-face consultation to offer personal contact and reassurance.

Examples:

> One patient, who wore a leg splint and needed to protect the leg from injury, was feeling teased and uncomfortable at school. The surgeon offered to write a letter to the school explaining the patient's needs, discussed with the patient how to deal with harassment at school and offered positive encouragement to the patient's mother.
>
> The surgeon examined another patient first-hand
>
> Surgeon: I wanted to see your splint close-up
> He discussed again the stability of the patient's limb and repeated his recommendation for not doing any surgery on the patient.
>
> On entering the patient's room the surgeon crouched down to eye-level with the three-year-old patient:
>
> Surgeon: Hello, how are you? I am so happy to see you [expressing the close relationship that forms between the surgeons and their patients]
> He then discussed the ongoing management of the patient with the mother and offered the mother further reassurances.

The face-to-face consultation was also used to deal with items that were out of scope of the pilot trial, writing and signing referrals for follow-up services such as X-rays and making subsequent appointments. The surgeon or assistant went back and forth between the two rooms to complete forms and attach patient-specific bar-coded stickers from the patient's medical file.

The surgeons, however, still treated this face-to-face consultation with attention and respect. One surgeon had conducted a detailed conversation about the adjustment regime on the patient's leg frame during the telehealth consultation (referring to his instructions at the previous consultation), and continued the discussion with hands on demonstration in the face-to-face meeting. At this point he realised that the patient's family had misinterpreted the adjustment instructions that he had given them at the previous consultation two weeks previously and he corrected the instructions.

12.3.3 Timing and frequency of the consultations

Appendix B shows the elapsed times for the telehealth and face-to-face phases of the consultations, grouped by surgeon (Table B.1). We can make the following observations from this data set:

- The surgeons spent longer on the telehealth phase of their consultations than they did on the face-to-face phases. This supports the observation noted in the previous section that the surgeons treated the telehealth phase as their primary interaction with the patient.
- The times taken for the telehealth phase vary widely, even within the data for individual surgeons. This indicates that the patients and their clinical situations varied widely and that the surgeons responded to this individuality in the way they conducted their consultations.

Appendix B also shows, for each patient, the time-period to the next consultation and Table B.2 aggregates this time-period data. The time-period to the next consultation generally matched the time since the previous consultation, except for the five patients who were discharged during this appointment with their surgeon. We can see that the bulk of the patients (31 out of 44) had a consultation period of between 2 and 12 months. This indicates that their clinical situation was relatively stable and that the patient and family had taken responsibility for managing the patient's condition during that time. This observation is consistent with the observed importance of the initial part of the consultation, where the surgeon, patient and family discussed in detail the patient's progress since the previous consultation.

12.3.4 Use of the fixed video/audio subsystems

The design intention behind the three fixed video/audio subsystems was that the room-overview subsystem would provide continuous visual context and the two close-up subsystems would provide links between the surgeon-and-parents and surgeon-and-assistant respectively, with the patient appearing in one or other of the visual fields depending on the progress of the consultation. It was expected that by facing the appropriate subsystem camera/screen the surgeon would be able to signal his or her conversational attention to the people at the corresponding subsystem in the patient's room.

Direction of attention

The surgeons used this direction of attention in almost all the consultations, typically when the family were seated at their subsystem and the patient was on the examination couch or examination chair [and therefore in front of the examination subsystem]. This situation arose both during the examination or in summing-up discussions where the patient had chosen to stay seated in the examination area.

Example:

[The patient is seated in the examination chair]

Surgeon: [Facing the family subsystem] The important thing [turns to face assistant's subsystem] 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.

[Further in the conversation]

Surgeon: [Facing towards the parents] The correction can be achieved in 6-12 months so we don't need to rush in and do it now, OK?

Parents: Yes

Surgeon: But the thing to watch out for [turns to examination subsystem and waves his hand at the patient] Oi, wake, up, don't fall asleep [turns back to family] is weight.

The people in the patient's room also understood the directionality of the surgeon's attention.

Examples

A young patient was sitting on the examination bed putting her shoes on and her father moved to sit in the examination chair to assist her. She had been looking at the surgeon through the examination subsystem 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 subsystem to her and that her father was now blocking this line of sight]

At the beginning of a consultation, with the patient and family sitting in their seats in front of the family subsystem and the assistant sitting at the examination subsystem:

Surgeon: You know me [gesturing to himself using the family subsystem to show the gesture], and that's <assistant-name> [pointing to his view of the assistant over the examination subsystem] who's [assisting in this] clinic with me.

Example of the expectations among the people in the patient's room that the surgeon would be directing his gaze as he spoke

Surgeon: Are you guys happy with what we are planning to do [glances to examination subsystem, family subsystem then back to examination subsystem]

Assistant: Are you talking to <the other assistant> and me or to them? [i.e. to the patient and family]

Here the surgeon has created confusion by appearing to direct a reasonably focused question to everyone in the room.

Use of gestures

The surgeons often used gestures about their own body to illustrate what they were saying and presented those gestures to whichever camera subsystem they were using.

The hand reconstructive surgeon used his own hand to demonstrate over the examination subsystem the actions of fingers and fist forming that he wanted the patients to imitate.

The surgeon explains that the patient's limitations in walking will ultimately depend on her mind/attitude rather than on her feet:

Surgeon: Generally that depends not on her feet [spoken emphasis] but on this [points to his own head].

The surgeon discusses a plan to reduce the patient's use of an external splint with the verbal and gestural phrase

Surgeon: … less and less and less [hand makes a downward motion with each spoken "less"]

When changing his view to use the pole mounted camera to see the patient the surgeon used a hand gesture to the parent to indicate the high viewing angle of the camera as part of his explanation of what he was about to do.

12.3.5 Spatial awareness

The clinicians were aware of the relative spatial relationships of people and objects in the patient's room.

Surgeon :[speaking to assistant] Look behind you and tell me whether the AFOs are hinged [the direction of "behind the assistant" was skew to each of the fixed cameras]

Assistant: [picking up the AFO] Where are you? [asking which camera the surgeon was using]

The assistant was directing the patient to demonstrate a particular movement.

Surgeon: Get him to do it facing me [i.e. facing the camera that the surgeon was using at the time to watch the patient.]

12.3.6 Privacy

The interview responses from the patients and families, presented in Section 11.3.2, indicated that these participants generally had no concerns with personal privacy during the trial. What they did not comment on, and what is not addressed in the CSCW literature on privacy, is the issue of scale. A patient might feel comfortable exposing himself or herself in front of one or two people but uncomfortable doing so in front of a group of people. This is relevant in our outpatient telehealth scenario because the telehealth configuration, which included the research staff, had noticeably more people collectively present than would be present in a normal outpatient clinic. We met this situation with one patient during our pilot trial. The patient reported unexpected new symptoms (the same condition but in another part of her body) part-way during the consultation and the video recording shows some awkwardness on the part of the clinicians and patient in examining these new symptoms. The nurse, who took the role of assistant, reported during the exit interview that she had been reluctant to ask the patient to undress further in front of so many people. She and the surgeon stepped out of the scope of the trial to schedule a second appointment for later that day in a more private setting, and with additional X-ray data.

12.3.7 Use of the pen and tablet subsystem

While the original design intention behind the pen and tablet subsystem was to support the surgeon in guiding the assistant through an examination of the patient the major use that was observed was for the surgeon to communicate with the family. The three orthopaedic surgeons relied heavily on X-rays to supplement the patient examinations and they used displays of these X-rays on the tablet subsystem to explain the patient's situation and future treatment to the patient and family. To do this they used our electronic pen to point to features and to make freehand gestures over the displayed X-rays as they spoke. These displays were captured from the screens of the hospital computers using special hardware which meant that the hospital software for precise drawing over X-rays was also available. The surgeons sometimes used this hospital software, for example to show lines of force between joints in the leg, but these displays were static and took some time to set up. Overwhelmingly the surgeons used our electronic pens for dynamic real-time sketching over the X-rays as they spoke, using positional words like "here" and "there" and directional phrases like "this way" synchronised with their sketching.

While the patients and family took an active part in these discussions they generally did not use their electronic pen to contribute pointing or gestures. One exception was a young teenager who supported his question about rehabilitation by colouring over the relevant part of the bone shown on the X-ray.

In two cases where there were no X-rays available the surgeon conducted the discussion of the patient's situation over live video of the patient.

> The surgeon asked for a video view of the patient's foot and used pen gestures over the video display to explain to the family the dynamics of the foot's behaviour during walking.
>
> With a second patient the surgeon used pointing and drawing gestures over a video of the patient's foot to discuss the case with the assistant.
> In some cases the pointing and gesturing with the pen reflected dynamic actions in the real world, such as the case of recent surgery to correct a leg deformity. The screws in the frame around the leg were to be adjusted in small amounts daily by the patient's family and the point/gesture based explanation conveyed to them the reasoning behind the adjustment regime.

In an exit interview, one surgeon commented:

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

12.3.8 Use of the cameras

The telehealth system supported several component cameras which could be used to assist with the progress of the consultations. The patient's room contained a horizontally pointing camera 40cm from the floor (walking camera), a hand-held close-focus camera on a flexible cable, a pair of cameras mounted on an articulated arm, a desktop document camera and a pole-mounted pan/tilt/zoom camera. The surgeon's room contained a pan/tilt/zoom camera placed on the desk. Each camera subsystem could produce either video or still images, depending on how the user controlled it.

The telehealth system used for this pilot was designed as a research prototype and intended for a short-term deployment with a range of surgical specialties. A consequence of this design is that it contained the above-listed range of camera components, all of which were available for use. The surgeons were free to select whichever cameras they felt most appropriate at the time, and in this subsection I note their patterns of use of the camera subsystems.

Walking camera

All three orthopaedic surgeons used the walking camera extensively. They were responsible for its placement in the system (as a result of the training sessions they attended) and they used it to observe walking gait and standing posture.

Hand-held camera

This camera was primarily intended for close-up views of the face (extra-oral) and inside the mouth (intra-oral) and the cranio-facial surgeon used it with each of his patients.

Stereo-pair (3D) of cameras

The pair of cameras mounted on the arm was intended to provide a 3D view of the patient, either as high-resolution still or as 640x480 video views. One surgeon (hand plastic surgery) used this camera for all of his patients in the one clinic that he conducted and he spent this time viewing the 3D motion of their hands and fingers. Two other surgeons tried this camera as an adjunct to their last clinics of this trial.

Examples

> [The stereo cameras were arranged to inspect the patient's foot]
>
> Surgeon: Oh, … I've got a 3D view of those feet. Awesome. That looks really nice.
> [Assistant adjusts the position of the cameras]
>
> Surgeon: Good, and the big toe seems to have stayed back. What range of movement?
> Surgeon [talking to the researcher while he watches the examination of the foot and ankle movement]: This 3D camera works really well.
>
> A second surgeon identified the need for depth perception at a millimetre scale, to distinguish between a surface mark and a raised mark on the patient's face. He tried using the stereo video camera but concluded that they needed a macro lens capability to get the close-up resolution he wanted.

Document camera

The document cameras were only occasionally used. In a few cases the family had documents, such as the growth chart from the local Health Centre. One assistant used the document camera to show completed referral forms to the surgeon though the actual handling of these forms was out of scope of the trial. One surgeon used the document camera to show the family example photographs of another patient's hand to illustrate the outcome of the procedure that they were discussing.

Pole camera

The pole camera was specifically designed for viewing seated patients' heads and the craniofacial surgeon used the pole camera for all of his patients. For the other clinics the pole camera was adjusted to cover the examination couch located on the far wall. Its field of view intersected with the field of view from the examination video subsystem and the surgeons in these other clinics used the two video systems relatively interchangeably.

In all cases the video output of the special cameras was directed to the pen and tablet subsystem and the surgeons managed the examination of the patient from this interface. One surgeon in particular used pointing over live video from the pole camera to support his discussion with the patient and parents.

12.3.9 Use of the laser drawing/pointing tool

The laser drawing and pointing tool was only used twice during the four weeks of the trial. The drawing tool itself was designed for use with the pole-mounted camera and was intended for pointing at or drawing on the patient's head/neck/shoulder region. This specific use was designed to support the maxillo-facial surgeons who typically sat their patients in a chair or on a parent's lap to examine them. For the first patient of the first such clinic the surgeon drew a line across the patient's forehead and asked the assistant to examine the region for a ridge of bone that was causing concern. There was a moment of confusion so the surgeon repeated the request just using words and the assistant carried out the request. Thereafter the surgeon just used verbal instructions to direct the assistant in examining the patient.

A second surgeon was discussing growth anomalies on the patient's body and asked the researcher for help to point the laser at one of these.

> Surgeon [to assistant]: Right there is one [of the anomalies]

The conversation between surgeon and assistant continued over further examination of the patient.

12.3.10 The treatment plan

The clinical outcome from each of these telehealth consultations was a treatment plan. This covered the time-period until the next appointment and what the patient and family should do in the meantime. The surgeons spent considerable time and communication effort explaining the plan and making sure the patients and families understood and agreed to their part of the plan. The plans ranged from detailed daily adjustments of the screws in the orthopaedic frame that was correcting a leg deformity through long-term daily stretching exercises to staged resumption of the patient's sporting activities. With the younger patients one surgeon explicitly discussed the plan with the patient first, getting their agreement, then repeated the discussion with the parents.

The plan often involved a very conservative approach to treatment and called on the patient and family to be prepared to wait.

Examples:

Surgeon: The honest truth is that I can not commit myself to a diagnosis. It seems to be getting better on its own. Keep an eye on it. [He scheduled a 3 month review appointment before embarking on invasive clinical tests]

Surgeon: That's a difficult one to judge. I would be hesitant to rush into an operation.

Surgeon: Success would be NOT operating on him. Having to do something would be admitting having failed to correct it [with non-surgical approaches]

The surgeons' way of expressing the success of the telehealth consultation was that the treatment plan remained unchanged as a result of the interactions during the subsequent face-to-face consultation. In this study 42 of the 44 treatment plans remained unchanged.

12.3.11 Good news, bad news and difficult questions

The surgeons were able to use the telehealth system to deliver both good news and bad news, and to ask and answer difficult questions.

Examples of good news:

Surgeon: <Patient-name>, I think you have done very well by yourself and that you don't need to keep coming back here any more.

Surgeon: <Parent-name>, she walks really well with the AFOs [external splints] … really encouraging … all happening in the right sequence

Surgeon: The good things I have seen today are relating to the long view that we took …

Examples of bad news:

The surgeon discussed in detail why he wants to leave the surgical retaining frame on the patient's leg for another month, using pointing and drawing gestures on the tablet display of the patient's X-ray. This is an important and personal discussion with patient and family because the retaining frame is uncomfortable and inconvenient for them. Finally the surgeon asks the patient:

Surgeon: Are you OK with this?
Patient: [in a quiet voice] Okay.

Examples of difficult questions

Surgeon: Do you honestly think he is any better [as a result of the surgery six months previously]?
Parent: No, worse off.

In response to the closing comment from the surgeon (Do you have any more questions?) one parent asked the surgeon whether the younger child might contract the disease with which the older brother was presenting.

Difficult questions were also spread over a sequence of dialogue:

Mother: [after hesitating] What's the chances in the long term [that she will need a] walking frame?
Surgeon: [after pause] Let me see if I have understood your question [he reflects back his understanding of her question then elaborates]
The mother then asks one final brief question about the future

Surgeon: we will face that all together. If things become difficult we will face them together; if things are successful we will celebrate together. OK?
Mother: OK

There were instances, however, when surgeon and patient held back on difficult questions until the face-to-face meeting.

Examples of questions and issues raised in the subsequent face-to-face meeting

> A parent raised an issue about the patient's foot pain and walking gait, and produced an X-ray hardcopy taken at their local hospital just before this consultation.
>
> While the assistant helped the patient to get dressed the surgeon stepped to one side and spoke quietly with the parent, asking how the parent was managing.
>
> The patient asked the surgeon whether his younger brother, who was already taller than him, would remain taller [the medical condition had limited his growth and therefore challenged his status as the elder brother]
>
> The surgeon, in a low voice meant for just the patient's mother, gave her positive feedback about her direct attitude to the situation.

12.3.12 Collaboration between surgeon and assistant

The clinic assistants for these consultations were registrars, surgical fellows, a nurse and a physiotherapist. They normally worked closely with the surgeon who was leading the consultations so the instructions from the surgeon were at a relatively high level.

> Surgeon: I need you to tell me if he has any pain in the <technical-name> joints
> Surgeon: While he is on his tummy can you see if he has any extension?
> Assistant: Do you want me to do a Thomas test?

The surgeons recognised the skills of the junior surgeons working as their assistants:

> Surgeon: Was there anything else you felt we needed to do?
>
> [After a long examination of the patient and discussion with the parents]
> Surgeon: So, what are your thoughts, <assistant-name>?

The surgeons also recognised the skills of the non-surgical assistants. After one clinic a surgeon commented that he knew that particular physiotherapist and was able to assess what she was showing him during the examination of the patient. He observed that if it had been a physiotherapist whom he did not know then it would have been much harder to assess what he or she was showing.

In the exit interview, one surgeon corroborated this broad observation:

> Surgeon: I had an excellent assistant. A less experienced examiner would add time and complexity. I was able to communicate with <assistant-name> at a high level. Not everyone could follow those directions so quickly and understand what I was asking for.

The same surgeon, talking to a family who had driven from New South Wales for their appointment, explained his confidence in using this approach:

> Surgeon: I saw everything, and we have doctors up at Albury [the main hospital nearest to where this patient lives] who aren't confident in dealing with a condition like this, but they would happily [act as the assistant in a telehealth consultation] where we don't feel comfortable doing this just off the X-ray.

In spite of the assistants' skills there were times when the surgeon gave very specific instructions, or cautioned the assistant to be particularly careful.

Examples:

> Surgeon: Just go gingerly with that, <assistant-name>, because you don't know how much he can get up to. Let him do it himself [raising his knee while lying on the examination couch]

In one examination the surgeon gave very technical instructions for evaluating a particular muscle.

The assistants showed a strong awareness of how the surgeon was seeing the patient and how he was observing the examination of the patient. In an exit interview, one assistant, a surgical registrar, drew the parallel between presenting the patient examination to the bank of cameras and presenting the same patient to a board of senior surgeons as part of his own surgical training. Another assistant, a physiotherapist, wanted to show the patient's limits of stretching to the surgeon and wanted to find the appropriate place in the clinic room:

Assistant: Whereabouts? Can you guys see if we do it over here? [She took the patient to the wall next to the door] Where's the best place for <surgeon-name> to see?

Another assistant monitored what she was showing the surgeon by looking at the arm-mounted tablet display which showed an exact copy of what the surgeon was seeing:

Assistant: It doesn't look as red on that picture as it does in real life

12.3.13 Patients' and families' prior experience

We see evidence that the patient and family had prior experience of outpatient consultations. All but two of them had at least one previous appointment and this was typically mentioned in the surgeon's greeting and opening question:

Surgeon: Hello <patientname or parentname>, how has it been since last time?

In each case the responses were immediate, clear and to the point. They knew what sort of things to mention as increments on the patient's situation since the previous appointment.

The families also showed an awareness of the radiology data, typically X-rays, as this sequence of dialogue, from the very first patient of the trial, illustrates:

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?
[The surgeon explains the bone formation by pointing to the X-rays]

Mother: So, what sort of time are we looking at [for] bone forming?

12.4 Discussion

12.4.1 Bounded trial in the application setting

These results show the importance of conducting such a trial and evaluation in an actual application setting. The trial was designed to have items that were in scope and to exclude or manage separately items that were out of scope. As described previously, features that were in scope included:

- There would be both a telehealth phase and an immediately following face-to-face phase to each consultation.
- The patients were selected on the basis that they already had a scheduled outpatient appointment for timeslot of the clinic and they fitted the target profile for the design of the telehealth system – post-operative with indications of normal clinical progress or pre-operative with indications that the intended surgery would be straightforward.

- The surgeon and clinic assistant(s) for any particular clinic already had an existing working relationship and the assistants were familiar with the type of surgery involved in the cases.

Features that were out of scope included:

- Actual or simulated matching of patient/surgeon schedules across two hospitals
- Coordination of patient clinical records across two hospitals
- Coordination of paperwork for clinical referrals (for example arranging X-rays or photography for subsequent appointments)

Telehealth phase

For all of the patients the surgeons followed their normal pattern of consultation from initial greetings through to agreed outcomes. This is consistent with the surgeons' approach to the training sessions that we conducted prior to the trial. During those sessions they focused on how they would conduct their clinics using this system and they left the sessions having addressed the major components of talking with the patient/family, examining the patient and accessing radiological data. We saw the patients and family engaging with the telehealth phase in the same manner that we observed during our preliminary field observations at the two hospitals. We saw them able to report on progress, observe and comment on the examination of their child, ask probing questions and agree on a treatment plan.

Face-to-face phase

The face-to-face phase was part of the scope of the trial, included to ensure the quality of care for the patients given that the ability of telehealth phase to adequately support the consultations was not known prior to the trial. We saw from their actions that the surgeons were largely satisfied with the telehealth phase and so they appropriated the face-to-face phase for a mixture of extended closure of the consultation and selective confirmation of points that they had observed in the telehealth phase.

Screening of patients for the trial

From the video recordings we saw that all of the consultations followed the standard pattern during the telehealth phase, and reached an agreed outcome. This indicates that there was a good match between the clinicians' understanding of the design criteria for this stage of the telehealth system and the actual implementation, and that the pilot study was able to proceed without putting the patients and families to the inconvenience of repeating the whole consultation in face-to-face mode.

Relationship between surgeon and assistant

The existing relationships between surgeon and assistant, supported by the prior training session, allowed the trial to begin smoothly without needing to build that relationship in the presence of the patients. Further, we saw that the close match between the skills of the assistants and the particular cases they were managing meant that the instructions from the surgeon and the interactions between surgeon and assistant were conducted at a very high clinical level. Even then, the experience of the surgeon was seen at the times where he needed to caution or provide detailed instructions to the assistant. This created some discussion about how this bounded trial might be extended to a hospital-to-hospital trial and raised the need to pay attention to both the relationship between surgeon and assistant and to refining the skills of the assistant.

Out of scope features

Apart from patient selection the out-of-scope features largely dealt with issues external to the core of the consultation, such as appointment scheduling and follow-up paperwork. We saw that the clinicians and patients/family were happy to step out of the telehealth role to complete paperwork for subsequent referrals and they generally used the face-to-face phase for these tasks.

Two important issues regarding scope and patient clinical data were resolved early in the trial. Shared access to radiology data (X-rays and CT scans) was crucial to the success of the consultations and prior to the trial we were expecting difficulties coordinating surgeon's and patient's access to this data via the two hospital computers (one in each room). The clinicians found, however, that the minor degradation of X-ray image caused by our hardware implementation of screen capture was not an impediment and they used our tablet display system to share the display from the hospital computer located with the surgeon. This gave them simultaneous shared access to and interactive annotation over the X-ray images and they used this feature extensively. The clinicians experimented with access to the patient's paper-based clinical records and they developed a new procedure whereby the surgeon briefed the assistant over the telehealth link prior to the patient entering the room.

12.4.2 Prior experience of the participants

An important feature of focusing this evaluation on the participants is that it shows how the prior experience of the participants influenced the conduct of the consultations. This aspect appeared in the exit interviews described in the previous chapter and is reinforced here. The surgeons' prior experience goes beyond their direct clinical competence to show itself in the way in which they conducted themselves in this non-standard situation. There was not a hint of hesitation or awkwardness in the way they greeted the patient and settled down to the consultation.

The hospital staff-members who took the role of assistant, too, had considerable clinical experience. They also had experience conducting outpatient consultations, under the guidance of the consultant surgeons. They were therefore able to do their main task (examining the patient for the benefit of the surgeon) with a very high level of direction from the surgeon and in terms of the flow of the consultation they took their lead seamlessly from the surgeon.

Forty-two of the forty-four patients and families had already attended several outpatient consultations. We saw them express curiosity, surprise and interest as they walked into the patient's room where they were confronted by multiple screens and arrays of equipment but they each responded immediately to the surgeon's greeting and then followed his lead into the structure of the consultation. They responded appropriately at each stage with information, questions and personal engagement.

From the video recordings, therefore, it was clear that the surgeon was in charge and that a standard clinical hierarchy of senior surgeon, junior surgeon, patient and family was present at the consultation and that the leadership of the surgeon and familiarity with the situation on the parts of the other participants provided the structure for successful outpatient tele-consultations.

12.4.3 Design of the trial

The surgeons' main concern, voiced during the training sessions prior to the trial, was to establish how they would actually conduct their outpatient clinics using this telehealth system. Unlike a more formal trial structure, such as a traditional controlled trial (Friedman and Wyatt 1997), they placed their emphasis on being able to successfully complete the consultations during the telehealth phase. They made no attempt to replicate the full consultation during the face-to-face phase.

A simplistic approach to an experimental design might have called for full completion of both phases, perhaps randomising the order (telehealth then face-to-face or vice versa). From the depth of the discussion during the telehealth phase and from the demeanour of the patients and family it is clear that it would have been artificial to have repeated the examination and discussion in the face-to-face phase. The patient's and family's experience leading up to the consultation (travelling, preliminary X-ray appointment, managing tired patients and siblings) and the emotional experience of the consultation itself were exhausting and it would have been unreasonable to impose a full second consultation.

12.4.4 Participants' use of the connected space

A major aspect of the design of the telehealth system concerned the way the participants might use the connected space comprising the surgeon's room and the patient's room. The connection was supported by three high-quality bi-directional video and audio streams configured in a way that was intended to support broad awareness of the whole of each room and specific awareness of the people sitting at each of the family and examination video subsystems, as explained in a previous chapter. It was intended that participants could use the attitude of the head of the person they were facing using one or other of these subsystems to infer their gaze direction, and to direct their spoken attention to that person or to understand whether or not they were the person being addressed.

From the many examples of participants using these directional cues, we saw that they were able to incorporate this feature seamlessly into their conversations. We saw an instance where the gaze direction was ambiguous (the surgeon was looking at the overview screen rather than at one or other video subsystems) and the recipients of his question were uncertain as to which one of them was being addressed. We also saw participants using pointing and gesture in their own personal space to convey information to people in the other room.

We saw the participants using the room space, particularly in the patient's room, with either the expectation or confirmed understanding that people in the other room could make sense of what they were doing. We saw people successfully making relative positional references with respect to people or objects in the other room and being understood. These observations of people's actions in the application environment bear out our expectations from the results of our media spaces laboratory study conducted in the early stages of building the telehealth system and described in a previous chapter.

12.4.5 Participants' use of the technology

Pen and tablet subsystem

This subsystem provided real-time shared access to and interaction with any of the video or image data items present in the telehealth system. It was originally intended as a guidance tool for the surgeon to guide the assistant but this role was filled largely with verbal instructions using the language of the clinical application. Instead we saw the surgeons use this subsystem extensively to view the examination of the patient and to communicate diagnosis and treatment plan with the patient and family using real-time pen-based annotation of video and X-ray data.

Video cameras

The surgeons and assistants made fluid use of the different video cameras provided for examining the patient. They remembered the functionality of each camera and had no trouble selecting or asking for its use. They co-opted the examination subsystem camera because it was pointing at the examination couch at a range suitable for seeing a child patient.

3D camera/display

The 3D camera and display subsystem was included in the telehealth system as speculative technology. Two of the surgeons experimented with its use towards the end of the trial but a third surgeon identified it as an important tool for him and he used it for all of his patients.

Laser drawing and pointing tool

During demonstrations of the telehealth system the concept of the surgeon being able to point and draw directly into the patient's space and onto the patient drew a lot of interest. In the actual clinic, however, the ability to point at and draw over the patient did not seem to easily fit into the established work patterns of the surgeons and assistants. There were also technical issues in using the laser tool, relating to calibration and parallax mismatch between the pole camera and the laser projector, and these created a level of awkwardness that possibly discouraged use of the tool.

We noticed, however, that the pole camera on its own was used extensively by the three orthopaedic surgeons who used the pan/zoom/tilt controls to look at patients sitting on or lying on the examination couch.

12.5 Conclusion

These results demonstrate the role that observation of the participants plays in evaluating a broadband telehealth system. We observed how they focused their scarce time on the telehealth phase of the consultation rather than explicitly postponing issues to the face-to-face phase that they knew would come directly afterwards. The surgeons modelled the telehealth phase very closely on their normal outpatient clinic and the patient and family followed this lead. Together with the assistant, the surgeon examined the patient, discussed the patient's situation with the patient and family and presented a treatment plan. The patient and family raised concerns and the surgeon or assistant addressed them. In all, we saw how the participants behaved in order to achieve an essentially successful outcome; they behaved in manner very similar to their behaviour in normal consultations. This information can act as detailed positive feedback for designers as they move from pilot to production versions of such systems.

We also saw elements of ambivalence. Both surgeons and patients/parents occasionally deferred or revisited issues in the face-to-face phase, sometimes deliberately and sometimes apparently opportunistically. This could reflect the novelty of the telehealth experience and it could also indicate limitations of the way the telehealth concept was expressed and implemented. These points of ambivalence may act as beacons for system designers to look at what the issues actually were in order to address them in future.

In terms of the participants relating to the space in each of the rooms and using this to maintain strong interpersonal dialogue with voice, gesture and movement we have observations that they were able to do this. The multiple fixed video and audio links were designed and placed to support communications between the surgeons, who would essentially stay in the same position and use direction to manage their dialogue, and the occupants of the patient's room who would use their position in the room to manage their dialogue. Repeatedly, we saw the participants successfully following this personal communication pattern.

The interactive tablet display sub-system was designed as the backbone for display and interaction with patient data including images and video from the various special cameras. Again, we repeatedly saw the surgeon using this facility to observe the patient examination and to support dialogue with the assistant. We also saw the patient's family intently observing the examination on their tablet display, sometimes alternating glances at the assistant and the patient with glances at what the surgeon was seeing on the tablet display.

What we were not expecting was the focus with which these two features were often combined during the explanation and discussion of the proposed treatment plan. This discussion often occurred in the context of interactive shared display of the patient's X-ray data, with both surgeon and patient/family pointing and gesturing over the X-rays as they discussed sometimes very sensitive matters of prognosis and treatment. Good news and bad news were given and difficult questions asked and addressed.

This case study showed the importance of including observational data in evaluating the use of telehealth systems at this broadband tertiary level of telehealth. With this data we are able to see how our design intentions played out in actual use. Aspects that were successful, such as our layout of the three fixed video and audio streams, might be taken for granted by the participants and not specially mentioned in exit interviews. Other aspects, which might cause hesitation on the part of the participants, again might not be mentioned in exit interviews because they had too personal a content or the memory was masked by broader issues. As we saw in this case study, where several people were involved in the telehealth event there were sometimes multiple simultaneous conversation fragments, some intended for public hearing and some more private. These unstructured situations, which might not occur in the smaller scale of conventional telehealth, gave rise to important clues about the success or otherwise of aspects of our pilot trial. Even larger-scale issues, such as the approach of completing the telehealth phase and relegating the face-to-face phase for other purposes, might not be seen by the participants as important in a structured exit interview.

The evidence presented in this chapter directly supports the itemised results shown in Section 1.6, pages 8-9:

- R3.1 and R3.2: The observational data presented in this chapter shows aspects of the trial which were not apparent when the exit interview was formulated prior to the trial, and which were not specifically noted by the participants in the semi-structured responses to items in that interview. These data, however, play an important part in understanding the involvement of the participants in this trial.
- R3.5 and R3.6: From the observations of what the participants said and did during the trial we get a sense of the participants' understanding of the wider clinical and hospital contexts.

13 Reflections

13.1 Human-centred evaluation

Observations from the case studies

In this section I draw on the experience of the case studies in Chapters 4, 6, 7, 8, 10, 11 and 12 to explore the use of a human-centred approach to evaluating telehealth applications for tertiary outpatient consultations. As an emerging field, this area of telehealth has the potential to assist in many areas of specialist care for people who live outside the major cities. There will be many pilots and early trials of such systems as the various specialties tackle their own situations. We saw a diversity of approaches within specialties. We can expect even greater diversity between specialties. In Australia there will eventually be longer-term trials where the evaluation focus moves from the human issues of novel technologies to the more impersonal issues associated with integrated deployment of mature technologies in the wider healthcare systems.

These case studies have given us vignettes of volunteers taking part in novel situations, demonstrating involvement, excitement and, in many cases, passion and commitment as they progressed through the scenarios of the preliminary and laboratory studies, mapped their clinical practice to the telehealth system and took part in actual telehealth outpatient consultations. These volunteers also gave us (the researchers) permission to observe them in action and to ask them about their experiences afterwards, and they were open and thoughtful in their responses to those exit interviews.

The tasks that these volunteers undertook were complex applications involving humans interacting with telehealth technologies, and involving humans interacting with other humans via these technologies. The tasks and the use of the technologies were intermingled. The progress of the scenarios was in the hands of the participants, as was the end-point. Each participant had a valid perspective on the success or otherwise of the task.

In each case, there was something novel about what the participants were doing. It was this novel aspect that the participants thought about, worked with and reported on during their exit interviews. In the laboratory studies the novelty lay in using technology that they had not seen or used before. In the hospital studies, and in the preliminary study, the novelty lay in doing something that they had done many times before but doing it in a new way (i.e., in a telehealth mode).

From the observations of these case studies I have identified features of a human-centred approach to evaluating our broadband telehealth system for tertiary outpatient consultations:

- The participants took an active part in the studies (in contrast to a double-blinded medication trial, for example).
- There was a novel element in the studies and the participants used this element as a focus for their reflections and comments.
- The participants showed commitment to their involvement in the case studies.

- The participants interacted with each other, in addition to interacting with the telehealth system.
- The evaluation process asked the participants to report on their actions and experiences.
- The researchers had permission to observe the events, and were able to observe what the participants did, and hear what they said, during the studies.
- The participants had their own perspectives on the situation and events during the studies, formed by their own roles and prior experiences, and they were competent to provide evaluation answers and comments.
- The researchers and the participants had potentially different understandings of the context of the hospital trial. The researchers saw the activities and locations of the trial itself, and the exit interview questions focused on these. The participants, especially the patients and families, saw the wider context of the hospital and their presence in it, and they sometimes responded with this wider context in mind. The researchers needed to see this wider context through the participants' eyes in order to adequately interpret their interview responses.

Each of these features contributed to the overall ability to understand and make evaluations, or judgements, about the conduct of these case studies.

13.2 Laboratory studies during system development

Pilot trials of a telehealth system are likely to have been preceded by development of that system. The three laboratory studies presented in this thesis show how a human-centred evaluation approach can be used to assess laboratory studies in this development situation. From our hospital observations of outpatient clinics during the early phases of developing our telehealth system we saw that outpatient consultations at this tertiary level of healthcare have a high degree of human activity and personal interaction. While we (my CSIRO colleagues and I) were able to unit test the functionality of the technology that we were developing, we needed scenario-based testing with actual people to test whether the telehealth system would support the kinds of human activity and interaction that we were expecting when we came to trial the system with actual patients.

In the Media Spaces literature, the reported experiments explored basic issues of space, place, public accessibility of actions and objects, privacy, continuity between multiple video streams, and continuity of actions from one part of the media space through the video and audio connections to another part of that space. While we received valuable guidance from the questions raised in these papers we did not find evaluation examples for real-world applications. The literature on remote guidance contained a series of studies which used video-based approaches to assist an expert to guide a novice through some form of spatial task, and ideally a task with which the novice was not familiar. These studies typically used performance measures in their evaluations, and their conclusions took the form of comparative assessments of one technique against another.

Our situation differed from these. We envisaged the specialist surgeon guiding and interacting with a trained clinician to examine and assess a patient, a task with which the trained clinician would have broad familiarity. This process would be a collaborative one, with our guidance components supporting dialogue and instruction between the two clinicians. The measures of success would be that the participants were able to work together on the problem and come to an agreed conclusion. We therefore chose a human-centred evaluation approach, rather than a performance-based evaluation approach for our laboratory studies, and we designed our studies with this evaluation approach in mind.

An important part of the design of our laboratory studies was that the participants were in control of what they were doing. They were given relatively high-level instructions. It was then up to them to decide how they would use the resources of the components that we were scenario-testing to complete the tasks. It was also up to them to determine when they had completed those tasks. As a result of handing this autonomy to the participants they were able to respond to the flows of the study tasks in a meaningful way.

The study tasks were abstractions of the human-centred activities that we had observed in normal outpatient consultations during the early phases of our project. Because we were unable to use clinicians from the hospital to take part in these laboratory studies, as explained in earlier chapters, we needed the study tasks to be free of clinical content. The purpose of the tasks was to create human activities analogous to those that we had observed in actual consultations. We were using generic volunteer participants so these abstract tasks needed to have no medical or clinical content.

A consequence of this approach of using abstract tasks, and of using a consensus-based approach amongst the participants to determine the task completion, is that they require a human-centred evaluation approach. Because there is no absolute match between study task and the real world, and because the outpatient consultations did not have performance-based components, we can conclude that a performance-based approach to evaluating these laboratory studies is not appropriate.

13.3 Pilot and early-stage trials

The purpose of the pilot trial was to determine whether our telehealth implementation of outpatient consultations for the Department of Surgery at that hospital could be used to deliver those consultations.

Attitude of the clinicians

The clinicians approached this trial from the point of view of the welfare of their patients and they did this in five ways:

- They selected patients according to suitability criteria defined in the research protocol for this pilot trial.
- They paid great attention to ensuring that they would be able to map their clinical practice onto the resources of the telehealth system during the training session.
- They treated the telehealth phase of each consultation with full seriousness, taking as much time as they needed in order to reach a satisfactory conclusion.
- They avoided burdening the patients and family with the artificiality of a repeated face-to-face consultation.
- When aspects of the consultation moved out of the strict scope of the trial, as they did several times, the clinicians took the obvious and direct actions needed for the situation without concerning themselves with any rigid trial protocol.

This attitude contributed strongly to the success of the trial, in which the surgeons agreed that in 39 of the 44 cases the telehealth phase was satisfactory in its own right. A consequence of this positive response and of several other largely positive quantitative responses to the exit questionnaires is that the researchers needed to pay close attention to the qualitative responses in the exit interviews with the clinicians, and to the observational data, in order to identify problem areas with the trial.

Attitude of the patients and their families

The patients were invited to take part in this trial based on the assessment of the their treatment progress by the surgeon, using criteria, specified in our proposal to the hospital's Human Research Ethics Committee, that would protect the patients' and their families' interests. Further, the patients at this hospital had generally formed a strong positive relationship with the hospital and its clinicians. The Royal Children's Hospital has had iconic status for quality children's care in Victoria for more than half a century. The patients and their families were generally very positive about being involved in this trial. One parent commented specifically that she was pleased to be able to repay the care that the hospital had shown to her and child by taking part in this trial.

The responses of the patients and families to the quantitative items in the exit interviews were also largely positive. For example, 35 out of 42 respondents answered "Yes" to the hypothetical question on whether they would have used such a system at a local healthcare facility for this consultation. Again, a consequence of this situation is that the researchers needed to pay close attention to the small number of negative responses and to explore the qualitative responses in the exit interview to uncover any criticisms of the trial.

Learning curves

A feature that I was not expecting was the learning curve that the clinicians traversed as they progressed through the pilot trial. In conventional telehealth I have not found reference to the need for the clinicians involved in trials to learn to use their telehealth systems, and this may be due to the less complex nature of the healthcare and the simpler nature of those telehealth systems. In our trial we observed, and we heard the clinicians themselves reflect on, the process that they went through to learn to use a telehealth approach to their work.

There were several aspects to this learning process:

- The surgeons, who were the senior clinicians in our trial, spent most of their training session mapping their existing outpatient approach onto the features supported by the telehealth system. This was relatively straightforward because we had designed the telehealth system to support what we had observed in several outpatient clinics. Even so, each surgeon at this level of specialisation had his own particular approach to his work, and each surgeon wanted to conduct his clinic differently to his colleagues.
- The clinic assistants, who themselves were highly skilled in their own specialty, had to learn a new role, which was to manage the interaction between surgeon and patient/family, and to conduct any examination of the patient in a way that the surgeon could fully appreciate.
- The surgeons and clinic assistants needed to develop a new professional relationship with each other in terms of working together to conduct these

outpatient clinics. These particular relationships are not present in the normal course of their work – the senior surgeon might review the results of a consultation taken by the registrar, but they do not normally conduct outpatient consultations together.

- The surgeons were initially uncertain about the types of consultations that they could perform with this system. In the exit interview after their first clinic, two surgeons agreed that they would not be comfortable seeing a new patient or discharging an existing patient with a telehealth consultation. Four weeks into the trial, however, we saw them doing both of these and reaching an agreed endpoint in each consultation.
- For these particular surgeons, the range of health conditions for the patients was wide. Even towards the end of the trial the patients were presenting with clinical situations which were new for this trial. These cases typically required the surgeon and assistant to continue their learning process for the telehealth system.

During the course of the four-week trial the surgeons and assistants repeatedly observed in their exit interviews that they were steadily learning to use the telehealth system, and in particular they were learning how to effectively work with their clinical partner (surgeon or assistant). This is an important point for future researchers in tertiary outpatient telehealth. Even though the specialists are highly competent in their own specialty, the complexity of conducting outpatient consultations in a telehealth mode requires them to learn how to do so, and the evaluation responses in the first few weeks of a trial are likely to reflect this learning process.

Role of laboratory studies

Pilot, or early stage trials are likely to follow a period of development for the telehealth system. The case studies in this thesis show that there can be a role for laboratory studies in this period of development. There will, of course, be technical unit testing that verifies the correct functioning of the various hardware and software components, but this will not be sufficient to ensure that the system supports the required user behaviour. User behaviour for this level of telehealth needs to be explored in the context of scenarios that match in some way the expected behaviour in the actual trials.

The tension in this situation is that, while it is very important that the telehealth system support the required user behaviour at the very start of a trial with actual patients, the clinicians at this level of healthcare are likely to be too busy to take part in pre-trial evaluation studies. The three laboratory studies which are presented in this thesis illustrate an approach to resolving this tension. We can think of this approach in the style of a Pattern Language (Alexander, Ishikawa et al. 1977), where these studies identify the (design) problem, namely that it is impractical and inappropriate to ask highly trained clinicians to take part in studies of relatively low-level components of the developing system. These studies then illustrate a pattern for addressing this problem, which is to abstract sufficient elements of the actual scenarios to exercise the system's support for the user behaviour, and to also abstract from the actual scenarios the criteria for evaluating the abstracted scenarios.

Pilot trials in the hospital setting

The pilot trial showed that it is very important to conduct early trials of telehealth systems for tertiary outpatient consultations in an actual hospital setting. To attempt a trial in a laboratory setting with actors playing the roles of the participants would not capture anything of the high-level clinical skill that we observed during the trial, and any evaluation would only reflect the quality of the initial briefing for the actors. To attempt a trial with actual patients in any place other than the hospital would also be very difficult. We observed many dependencies from within our trial on the wider hospital setting, including radiology, patient management, medical records and close proximity for the clinicians to their normal working locations. In our case we had both the surgeon's and the patient's rooms within the same hospital but, even if the trial were to span two healthcare facilities (a tertiary hospital and a regional healthcare facility, for example) this same wider context would need to be provided.

Emergence of previously hidden requirements

Even though we had one and a half years' of interaction with the hospital during our development phase, when we arrived to install the telehealth system and train the clinicians we found that eleven of the twelve clinicians had only recently been involved in our project and had no familiarity with our telehealth system. During the four weeks of our trial two of our surgeons had prior commitments, and two other surgeons substituted their own outpatient clinics on these occasions. Nine months after the trial, two of the main assistants in the trial had resigned from the hospital and the other assistants had moved to different hospitals as part of their long-term training.

This meant that for five of the six training sessions, and for five of the twelve clinics, we were working with clinicians in a "first time" role. In each case the clinicians identified additional requirements for the telehealth system, even though we were at a late stage of fine-tuning the development. Some of these requirements were preferences to which the clinicians could adapt, but some were mandatory for the success of their clinics.

At this level of healthcare, the specialists are likely to each have their own particular way of doing things. With the volatility of staff availability that we observed, it is likely that researchers on future pilot or early-stage trials will meet similar situations. We dealt with our situation in two ways:

- As an implementation approach, we designed a level of generality, redundancy and flexibility into our system so that we could make adjustments to its functionality during the trial. We used this flexibility on two occasions, implementing an additional video camera to observe standing/walking patients and configuring the output of the hospital's computer to show X-Ray data on the display tablets for both surgeon's and patient's rooms.

- As an evaluation approach, we treated these uncovered requirements as out-of-scope events which we noted as valuable input for any subsequent version of our telehealth system.

13.4 Evaluating tertiary-level outpatient telehealth

Pilot or early-stage trials

Pilot, or early-stage trials typically explore whether or not a concept can be taken from the laboratory into an application setting. In our hospital trial we explored whether the surgeons could conduct their outpatient consultations with our telehealth system, and whether the resulting clinical interactions would be acceptable to the participants. A human-centred approach suited our particular pilot trial very well, because it captured elements of discovery, elements of comparison and elements of measuring success.

- **Elements of discovery** appeared in the participants' responses to the semi-structured questions of our exit interviews, and in the audio recordings of their discussions amongst themselves as they completed the Likert-Scale items. They also appeared in the video and audio recordings of the actual consultations, where we saw participants respond, in the moment, to the progress and events of the consultations.

  Because we were working within a formal Ethics Approval framework we were constrained in what we were able to ask the participants during the exit interviews. This constraint, which Corbin notes in the most recent edition of her book on qualitative analysis (Corbin and Strauss 2008), derives from a more formal evaluation approach within the healthcare community. This approach is geared towards the traditional randomised controlled trial, where all the variables except the intervention are fixed. The particular constraint in our trial was that we could only ask questions that had been established prior to the trial and approved by the Ethics Committee. There were also elements of a conservative approach to protecting the interests of the patients, in terms of protecting them from unexpected, inappropriate or confronting questions. As a result, we could only ask questions about issues of which we were already aware.

  We included some relatively open questions in the exit interview, together with a closing question inviting them to say anything else that they felt was relevant. This produced some important insights but it was limited to aspects that the participants themselves had noticed and were prepared to speak about.

  The video and audio recordings, therefore, were an important source of discovery. An example is the question of what the participants actually did during the face-to-face phase of the consultation. None of them commented on this aspect, yet it clearly played an important part in the trial. Even though we researchers were present for half of these consultations (each consultation ran in parallel to the exit interview with the previous patient) we were too busy with the moment to be able to take extensive notes.

- **Elements of comparison** appeared and were embedded in the participants' exit interview responses. The patients and families generally knew what to expect of these consultations, having attended several previously, and used this as the basis for statements or responses to the questions. A few explicitly noted that certain features, such as talking over the close-up video system, were just like talking to their surgeon in the same room. Some features were rated as better than in a normal consultation, for example being able to see the examination details of their child on the tablet displays.

The surgeons made two types of comparisons:

- Comparing the telehealth consultation for a particular patient with their extensive prior experience of that patient's condition and situation. They do this normally with every patient and it enabled them to give a clear answer about the success or otherwise of each consultation.
- Comparing that particular telehealth consultation with telehealth consultations conducted earlier in the pilot trial. Here they were explicitly observing either their own learning curve with the telehealth system, or the relative appropriateness of the patients for a telehealth mode of consultation.

The assistants typically made comparisons with previous consultations and focused on their own learning curve. When asked to judge the success of each consultation they were able to draw on their own clinical experience and on their observations of the attitudes of the surgeon and of the patient and family.

- **Elements of measuring success** were drawn from the Likert-Scale items in the exit questionnaires. The responses from the surgeons and from the assistants were very clear and professional, and they focused on the purpose of each of the consultations. For example, one surgeon noted, in the long exit interview after one clinic, that his sole objective in the consultation with patient X had been to persuade the patient and family to leave the brace (which supported the healing bone) on for another month, and he succeeded in this objective.

  The responses from the patients and families were often given with a wider context in mind. Using a rigid framework like the Likert-Scale questions sometimes produced superficially contradictory responses which needed an understanding of this wider context to interpret.

These results suggest that evaluating short-term trials for delivering remote tertiary-level outpatient consultation is likely to involve answering known questions and also discovering new aspects. The case studies in this thesis have shown how a human-centred evaluation approach can address both of these points.

Longer-term trials

Longer-term trials will typically be intended to produce traditional comparative evaluations. They will have identified appropriate population sampling, suitable metrics and ways of comparing between the new intervention (telehealth) and the previous approach (face-to-face in the hospital) for outpatient consultations. The case studies in this thesis have identified many issues which will impact on longer-term trials.

- It would be challenging to construct a matched trial design, with one patient receiving a telehealth consultation and the other a face-to-face consultation. Patients at this level of healthcare have long and complex treatment trajectories and their specialists will need to judge whether a particular patient, at a particular stage of treatment, is suitable for a telehealth consultation. Finding an appropriate matching patient for a normal consultation may take considerable elapsed time, thus lengthening the time footprint of the overall trial.

- Similarly, it would be difficult to conduct a trial where the patient receives both a full telehealth consultation and a full face-to-face consultation. Such a trial design is likely to produce unreliable data. Knowledge about the first consultation would influence the progress of the second consultation. Stressful events, such as asking or answering difficult questions or delivering bad news, are likely to colour the tone and mood of the subsequent consultation and lead to unreliable participant responses. Similarly, the process of presenting, persuading and reaching agreement on a further treatment plan would have been completed in the first consultation and would be missing from the second.

  I emphasise this point here because it is not obvious to people who design experiments in the abstract and who are not familiar with the clinical implications of carrying them out. We saw the surgeons instinctively avoid this model, concentrating on the telehealth phase and using the face-to-face phase for completion or complementary activities. In responding to a submitted conference paper on our work, one anonymous reviewer praised our experimental design, which he or she interpreted as giving each patient two full consultations, and suggested that we might reverse the order for half of the patients.

- It is not easy to make comparisons between telehealth and face-to-face outpatient consultations at this level of healthcare. Within the one specialty the patients present with a range of problems and comparable patients are likely to be at different stages of their treatment. This makes it difficult to control for similar patients across the two healthcare delivery modes. Even with two comparable patients, the task of comparing a telehealth and a face-to-face consultation is itself difficult. For specialties that require physical examination of the patient, the telehealth consultation may have the added complexity of the specialist directing a remote assistant and interpreting their findings, thus involving additional parties and creating relationship dynamics and flow for the consultation that are not present in the face-to-face equivalent. As our pilot trial showed, at this level of healthcare the clinical outcomes from the consultation can be influenced by the communications overlays of the telehealth implementation, making it difficult to isolate measureable attributes.

- The telehealth participants are not blinded to their involvement in the trial. The patients will know whether they are conducting their clinical engagement in a telehealth mode. They will either be actually located remotely from the tertiary hospital or they will be in a telehealth suite within the hospital, depending on the design of the trial. The patients taking part in the trial will, for ethical reasons, be volunteers and they are, therefore, likely to come with a constructive attitude. The clinicians will be doing their best to make the clinical event a success, from a mixture of personal consideration, consideration for their patients and in order not to waste valuable hospital resources. At this level of healthcare each patient is different and it is difficult (and perhaps undesirable from a patient-care point of view) to require clinicians, especially those located with the patient, to adhere to a rigid trial protocol. Where a tool, data set or action is required for proper care of the patient, the clinicians will use it, regardless of whether or not it is in scope for the trial.

- A telehealth system, by its very nature, involves participants and equipment located at different physical places. An aspect that is crucial to the success of a telehealth system, and which is not present in the face-to-face equivalent, is the way in which the telehealth system supports mutual understanding amongst the participants. In broadband telehealth the system should

- Allow the participants to see what each other is doing
- Support shared access to objects and data for all participants
- Support mutual understanding of voice and gesture, so that when someone speaks or gestures, the other participants know whom they are addressing and what meaning they are conveying.

This aspect is missing in a face-to-face consultation but it is highly important for the success of a telehealth consultation, and a meaningful evaluation will need to address it.

During our pilot trial we, the research team, discussed the possibilities of a subsequent trial with a longer time-frame and a more clinical focus. It became obvious that many other factors would be relevant, ranging from organisational and professional relationships between the Royal Children's Hospital and its remote counterpart through to high-level government policy for telehealth programs within Victoria. We can see that, at this level of healthcare, a formulaic approach to designing longer-term telehealth trials would not be adequate.

Resource implications

In terms of designing a longer-term trial, future research teams should pay attention to the resourcing implications of maintaining an evaluation program. This analysis of the resource implications of a human-centred evaluation approach draws on the case studies from the hospital trial case, reported in Chapters 11 and 12, and it supports the result R4 as listed in the summary of results in Section 1.6. These studies showed that a human-centred evaluation approach for this class of telehealth is very demanding on resources.

- There are likely to be multiple participants, and gathering an exit response from each of them will require the presence of members of the research team. While it is certainly valuable to gather simple quantitative data with Likert-Scale response items, our case study has shown that the responses of the participants in clinical situations such as these are likely to be more complex than can be captured on a single response scale. We supplemented our Likert-Scale items with semi-structured questions to gather qualitative and expansive responses, and these responses were very valuable in explaining anomalies or apparent contradictions from the participants. We audio-recorded the patients and families as they discussed their responses to the Likert-Scale items and these recordings also helped in explaining the responses.
- We video-recorded all of the consultations. Analysis of these video recordings was very time-consuming but, as the final case study shows, it provided a rich source of information about the participation of all three groups in the consultations. This information was generally complementary to the exit interview findings. Note that the exit interviews were constrained to use questions that had been prepared in advance and approved by the hospitals Ethics Committee and, therefore, only addressed aspects that we expected to occur. The video data gave us the opportunity to note aspects that we had not anticipated.

The resource implications are that a longer-term trial may not be able to sustain the level of human-centred evaluation that we used in our pilot trial. Researchers undertaking longer-term trials of this class of telehealth may need to adopt a compromise or hybrid solution to their evaluation. Such a compromise may take a form like the following:

- The researchers will need to establish their long-term evaluation objectives for the trial, and they may need to embed these in some form of process-centred or outcome-centred evaluation approach.
- The researchers will want to know whether there are any serious faults with their trial's structure or implementation and they may conduct an initial short-term human-centred evaluation to investigate this point.
- The researchers will also want to know when a stable state (i.e., the clinicians learning to use the system) has been reached and, again, they can use a short-term human-centred evaluation to establish this.
- Finally, they may want to monitor the progress of the trial to identify any anomalous events, such as a change in clinical staff, and re-start their human-centred evaluation approach to investigate these.

In our discussions with senior staff at the Royal Children's Hospital about a possible longer-term trial to a regional hospital their first estimate was that it could take three months to reach a stable state and that they would expect the trial to last at least a year to capture sufficient data to make a case for this type of telehealth to become a standard service at the hospital. These time-frames imply serious resource commitments to the process of mounting a longer-term tertiary telehealth trial for outpatient consultations.

13.5 Multiple perspectives

The three groups of participants in our trial (surgeons, assistants, patients and families) brought different perspectives to the conduct and evaluation of the outpatient consultations conducted during the trial:

- They had differing expectations for the consultations and differing criteria for the success of those consultations.
    - The surgeons expected that they would be able to conduct the consultations in a similar manner to conventional consultations. Their criterion for success was that the examination of the patient, together with the recent radiology images, would be consistent with previous consultations for that patient and that they would reach agreement with the patient and family on a plan for treatment or management of the patient until the next consultation.
    - The assistants' criteria for success were that they would be able to adequately support the interactions between the surgeon and the patient and family, and that they would be able to present an examination of the patient to the satisfaction of the surgeon.
    - The patients' and families' criteria for success were that they would be able to communicate their concerns to the surgeon and have them addressed, that the surgeon would make an adequate examination of the patient and that they would be satisfied that the outcome of the consultation led to proper treatment for the patient.

- They brought different but extensive prior experience to the trial and were able to make valid evaluations of the trial from their perspective.
    - The surgeons each had long experience in their specialty and were able to use this experience to judge the success or otherwise of any particular consultation. They were also very familiar with the clinical situation of most of the patients that they saw and were able to use this patient-specific knowledge to guide their evaluation of the clinical outcomes.
    - The assistants were competent in their clinical field and understood the needs of the patients and families. They were therefore able to make informed judgements about the success of the consultation from the points of view of the people located in the patient's room. Through their interaction with the surgeon they were also able to tell whether they had adequately presented what they had seen about the patient to the surgeon.
    - The patients and families were generally into the long rehabilitation phase of their surgery, and had already attended many outpatient consultations at the hospital. This prior experience meant that they were able to give meaningful evaluation responses to the research team.

These different prior experiences meant that all three groups of participants were able to give informed responses to the evaluation of the pilot trial. This gave the researchers the opportunity to compare the different responses, with points of agreement reinforcing aspects of the evaluation, and points of disagreement flagging issues that needed closer investigation.

This is not necessarily the case in current telehealth literature. Evaluation data is not always collected from each group of participants. In many cases data is collected from the patients or their families but little use of it is reported. In other cases the healthcare scenarios involve the patients' first contact with the health system for their particular condition where they do not have the personal experience to usefully comment.

The important point for future researchers is that, in trials of tertiary-level outpatient telehealth, the participants are likely to have the experience to present a valid perspective on the events in which they take part and that the researchers need to solicit their evaluation responses and to give these responses adequate weight.

13.6 Context, scope and priorities

The observations from our case studies show that it would be very difficult to conduct this type of telehealth outpatient consultation in settings other than at the tertiary hospital for the specialist and at a suitably equipped healthcare facility for the patient. In this section I explore the implications of context for tertiary outpatient telehealth.

Contexts

I observed two levels of context being implicitly referred to during the consultations of our pilot trial:

- The broader hospital context. The patients were keenly aware of this context and it shaped their demeanour and behaviour. The building and its procedures were familiar to them and were invested with a level of trust by the patients and their families. This context contained other services, such as radiology, physiotherapy and other allied healthcare services, and in cases where more complex treatment was needed it contained other specialists. This context created pressures on the patient and family: getting to the next appointment within the hospital, dealing with tired children (especially younger siblings of the patient), even rushing to catch an expiring parking meter.

- The patient's clinical context. This context resided in the treatment history of the patient, their relationship with their surgeon, their medical records, and the memories of previous inpatient and outpatient events during their treatment.

These contexts influenced the evaluation responses from the parents and patients, and created potentially confusing or contradictory responses for the researchers to analyse. Two examples illustrate this point:

- One family responded that they would (hypothetically) have been happy to have had this outpatient consultation using a telehealth mode at a location more convenient to their home. Further into the exit interview they stated that it was important to them that the face-to-face phase of the consultation occurred. Their responses to the more open questions in the interview showed that they had other appointments at the hospital that day and, for that particular day, it was important for them to have come into the hospital.
- A second family gave the same pair of responses, but their explanation was that their young child had formed a strong friendship with the surgeon and would have been disappointed if he had not seen the surgeon in person.

For the researchers to adequately understand and interpret the Likert Scale and yes/no responses from the participants they need to be aware of these wider contexts.

Scope of the pilot trial and priorities for the clinicians

Our pilot trial was located entirely within the hospital, with the patients' and surgeon's rooms set up in two meeting rooms on the same floor of one wing of the hospital. The activities of the pilot trial concerned a very specific component of the overall treatment of the patients who had volunteered to take part in the trial. The scope of the pilot trial covered some, but not all, of the activities that were required for the consultations that were scheduled for the trial and this concept of "scope" is important in understanding and interpreting the trial.

Examples of items which were in scope:

- Voice and gesture communication, shared access to video and image data on the tablet displays, the surgeon directing the assistant to examine the patient
- The standard consultation structure: greetings, discussion of the recent past, raising and addressing issues, examining the patient, reviewing radiology data, proposing and agreeing on a plan for the immediate future, closure
- Patients presenting for review appointments after surgery

Examples of items which were out of scope:

- Patients presenting with new symptoms
- Shared access to the patient's medical records between the surgeon's and patient's rooms
- The surgeon writing follow-up referrals (X-ray, physiotherapy and other allied health treatments) for the patient

- A surgeon needing a viewpoint which was not supported by the existing video cameras

When something occurred which was out of scope the evaluation process needed to deal with it. A more mechanistic evaluation process, for example recording success or failure, might have flagged these out-of-scope events as failures, thus masking the underlying causes. A human-centred approach of the style used in these case studies would be aware of the boundaries of the trial and would note the out-of-scope event as a valuable piece of feedback for the next iteration of development of the system under trial.

The flow of events, and in particular those events driven by the clinicians' priorities in looking after the interests of their patients, sometimes masked the presence of these out-of-scope events. This point is illustrated by some examples:

- One patient presented with new symptoms of the same underlying condition but in different limbs, and so there was no X-ray data of those limbs. There was also some difficulty showing the surgeon an external view of the extent of the problem. The surgeon stepped out of the role of the trial by sending her back to Radiology for additional X-rays and scheduling a second appointment later that day. From the clinicians' and patient's points of view this was an acceptable outcome.

  From a mechanistic evaluation approach the "tick the box" response to the question "would you have been satisfied to let the patient go home after just the telehealth phase" would have been "No". From a human-centred evaluation approach it highlighted that people matching patients to opportunities for a telehealth appointment might not be 100% correct because they may not have the most up-to-date information.

- The medical records at this hospital exist in paper form and could not be meaningfully shared between the surgeon and the assistant. The surgeons dealt with this by modifying their normal procedures after the first week and briefing the assistant on the case in the few minutes before the patient arrived.

- The surgeons chose to offer but not to write actual referrals during the telehealth phase. Instead, they wrote them during the face-to-face phase, retrieving the patient's bar-coded labels from their medical records as necessary.

Future researchers might try to design a trial protocol to handle these events but my observations suggest that the clinical complexity of this tertiary level of healthcare creates flows of the consultations that are all subtly different. Out-of-scope events are likely to occur and the protocol may not be able to deal with them.

14 Conclusion and future work

14.1 Overview

My conclusion takes the form of a set of major results concerning human-centred evaluation approaches for the development and trialling of broadband telehealth systems to support tertiary outpatient consultations. These results are summarised in Section 1.6, and in each of my case studies I indicate which of those major results the conclusions from that case study support. In this concluding chapter I repeat the list of major results and interleave that list with summaries of how the evidence from my case studies, together with my reflections on those case studies, supports those results. I finish this chapter with an exploration of possible future work in this area.

14.2 Major results

The four major results, labelled R1, R2, R3 and R4, are stated below, and they are accompanied by summaries of the evidence, from the case studies, that supports them.

R1 *Development of broadband telehealth systems for tertiary outpatient care must account for the high level of human interaction involved. Scenario testing of these interactions will require reference to the actual clinical context of the intended application even though access to clinicians, patients and patient data may be very restricted during the development phase.*

Observations during hospital outpatient clinics in the early stages of our project (Chapter 5) and during the outpatient consultations of our pilot trial (Chapter 12) showed that outpatient consultations at this level of healthcare can involve extensive human action and interaction, and that the flow and interactions within any particular consultation will depend on the specific circumstances.

We also observed how scarce the hospital clinicians' time was, and concluded early in our project that it would be difficult and wasteful to ask them to take part in scenario-based evaluations in our laboratory. The three laboratory case studies (Chapters 6, 7 and 8) demonstrate an approach to abstracting both tasks and evaluation criteria from observations of actual consultations and to use these in laboratory-based evaluations with generic volunteer participants.

R2 *Deployment of broadband telehealth systems for tertiary outpatient care contains pronounced transient phases which have not been noted previously in the literature.*

The case study in Chapter 10 presents the way that the surgeons and clinic assistants mapped their particular consultation practice onto the resources of the telehealth system. This involved adapting their practice to take advantage of particular features of the system, extending their professional relationship to encompass working together in a telehealth mode, and identifying desirable or mandatory changes to the telehealth system itself. This process of adaptation continued into the trial, where certain patients presented with conditions that caused the surgeons to extend their list of desirable changes to the system (Chapter 11). We note that organisational issues within this major tertiary hospital prevented the development team from gathering requirements from the surgeons prior to the trial, and that some requirements were only voiced when particular patients triggered the need for a missing system feature.

During the trial, the clinicians observed and reflected strongly on the way in which they were learning to use the telehealth system to conduct their outpatient clinics (Chapter 11). For the surgeons, this included becoming fluent in using the telehealth system, learning to judge which patients would be suitable for telehealth consultations and learning to work with their assistants in a telehealth mode. For the assistants, this involved learning to anticipate how their surgeon preferred to use the system and learning to collaboratively present an examination of the patients to the surgeon. The surgeons who took part in this study are at the top of their profession, yet they took three to four weeks before they noted that they were comfortable using the telehealth system.

R3 *Effective evaluation of these telehealth systems in their early phases is complex and requires:*

- *R3.1* *A human-centred evaluation approach conducted in realistic settings*
- *R3.2* *Both quantitative and qualitative responses from the participants, complemented by observational data*
- *R3.3* *Data from all participants, with recognition of the competence of those participants to provide such data*
- *R3.4* *Recognition of multiple, and possibly differing, points of view amongst the participants*
- *R3.5* *Recognition of the wider clinical and hospital contexts in designing and evaluating the trials*
- *R3.6* *Recognition of the participants' views of these contexts in interpreting their evaluation responses*

The preliminary study (Chapter 4) highlighted the importance of conducting tertiary-level evaluations of telehealth systems in a realistic setting (R3.1), of having participants who are competent to make judgements about their experience with the telehealth system (R3.3) and the importance of complementing exit interview data with observational data (R3.2).

The study presented in Chapter 11, which was based on exit interviews with all the participants, showed the importance of gathering both quantitative and qualitative response data from the participants, where the quantitative data presented the broad trends in the trial's results and the qualitative data explained the outliers and apparent contradictions which appeared on analysis of the quantitative data (R3.2). This study showed that the different groups of participants had different perspectives on the progress and outcomes of the consultations and differing criteria for success (R3.4). The data from this study showed that the participants at this level of health care had the experience to competently respond to the exit interviews, and that the patients and families had sufficient experience on their particular healthcare trajectory to meaningfully respond to questions of opinion and hypothetical questions relating telehealth modes of care to their own situations (R3.3). From the qualitative responses, and in particular those relating to outliers in the quantitative data, this study shows the importance of recognising the wider clinical and hospital contexts, and of understanding the participants' views of these contexts (R3.5, R3.6).

The study presented in Chapter 12, which was based on observational data of the outpatient consultations, showed the complexity of the clinical work conducted during those consultations and the dependencies on the wider hospital system, reinforcing the need to conduct these early-stage trials in a realistic setting (R3.1, R3.5). This study emphasised the role of observational data in showing the reality of conducting outpatient consultations using this telehealth system (R3.2) and the importance of the wider clinical context in the actual conduct of the consultations (R3.5).

R4 *In longer-term trials of more mature broadband telehealth systems for tertiary outpatient consultations, a hybrid evaluation approach is appropriate, with a human-centred approach employed during the transient phases and a more mechanical performance or outcome-based approach for steady-state operation of the telehealth system.*

As my reflections on the resourcing implications of longer-term trials show (Section 13.4), the human-centred approach which was use to evaluate the pilot trial (Chapters 11 and 12) was very resource-intensive. It is unlikely that this approach would be sustainable over the long term. A longer-term trial, however, would only be undertaken with a specific purpose in mind, with the issues that I raise in my reflections on long-term trials addressed (Section 13.4), enabling a performance or outcome-based evaluation approach to be employed.

Based on observations of the clinicians, and in particularly the surgeons, during training (Chapter 10) and during the early weeks of the trial (Chapter 11) we can expect that there will still be pronounced transient phases at the start of a long-term trial. The evidence for the existence of these transient phases was gathered using a human-centred evaluation approach, and it is reasonable, therefore, to propose that a human-centred evaluation approach be used to identify and track the transient phases of any long-term trial. Data from such a human-centred approach would allow the evaluation team to identify when a suitable steady-state of operation of the telehealth system had been reached, at which point it would be appropriate to begin to use the performance or outcome-based evaluation data.

14.3 Future work

Broadening the base for tertiary telehealth

The project which provided the case studies for this thesis addressed a single area of telehealth within the tertiary healthcare system (paediatric surgical outpatient consultations). There are more areas to be investigated, each with different requirements for a telehealth mode of delivery and each with different catchments of patients:

- Consultations which involve real-time instrumented examination of the patient, such as the use of ultrasound. The challenges include creating screen-based representations of the activities surrounding the patient and shareable interactive representations of the outputs of the instruments.
- Consultations involving a third party, for example a specialist giving a second opinion or a specialist from a complementary specialty. Third-party involvement may involve different levels of communications technologies that require heterogeneous technical support and novel representational metaphors for the parties taking part.
- Consultations which reach down to the primary care level, for example at a general practice, a local health centre or into the patient's home. These could open up very interesting areas of work-practice change and requirements elicitation, together with challenging technical and human-computer interaction issues around *ad hoc* installation and use of remote telehealth nodes.

Once completed, these projects would provide a basis on which to design a more general-purpose telehealth facility for a tertiary-level hospital, and also to design some more general-purpose evaluation approaches and metrics for this level of telehealth.

Research is also needed to explore potential high-value remote locations for tertiary-level telehealth nodes. Examples include delivering health services to the prison population and to other remote groups who are constrained by location. In Australia these could include field stations in Antarctica and remote quarantine locations. The high value of this type of specialist healthcare was emphasised in discussions with staff at St Vincent's Hospital, Melbourne, which has the contract to provide prison health services for the Victorian Government. The experience of being transported under guards and shackles across the state and into the hospital can be so unpleasant and degrading that the prisoners often refuse medical treatment (Dr Foti Blaher, pers. comm.). Approaches to designing and conducting pilot trials of such systems could usefully draw on the experience presented in this thesis.

Extending the reach for tertiary telehealth

A major step forward would be to extend the reach of this telehealth delivery beyond Australia. The Royal Children's Hospital has already begun to work in this area. It has an international arm with outreach programs into countries in Asia, including a bilateral program with the National Hospital of Pediatrics in Hanoi, Vietnam (www.benhviennhitu.org.vn/intro_en.asp). Just prior to our hospital trial a high-quality videoconferencing link was established between the two hospitals using research internet bandwidth provided by the Trans Eurasia Information Network (www.tein2.net). At its inaugural conference, a surgeon at RCH in Melbourne conducted a post-operative review with a Vietnamese child on whom he had operated the previous month in Hanoi.

The opportunities and good-will are present to take the research, which is presented in this thesis, to places outside our country's borders. The applied research challenges lie in the whole range of activities from establishing requirements for multi-cultural telehealth through development and deployment to designing and conducting appropriate evaluations.

Glossary of terms and abbreviations

AARNet	The Australian Academic and Research Network which provides Internet connectivity to academic and research institutions in Australia
ACM	The Association for Computing Machinery, an organisation dedicated to advancing computing as a science and profession. It supports a wide range of conferences and journals in the computing field
AFO	Ankle-Foot Orthosis: An external splint for stabilising a patient's ankle or foot
ANU	Australian National University
AUIC	The Australian User Interface Conference, one of the conference streams hosted as part of the Australian Computer Science Week set of conferences
CeNTIE	Centre for Networking Technologies for the Information Economy, a research program led from within the CSIRO ICT Centre and supported by funding from the Australian Department of Communications, Information Technology and the Arts
CHI	Computer-Human Interaction (sometimes referred to as Human-Computer Interaction). Also the acronym for the ACM annual conference on human factors in computing systems.
CSCW	Computer-Supported Cooperative Work. Also the acronym for a biennial ACM conference and a journal published by Springer.
CSIRO	Commonwealth Scientific and Industrial Research Organisation – the Australian Government's premier science and industry research organisation, established as a statuary authority reporting to the Australian parliament
CSIRO ICT Centre	One of the research divisions of CSIRO focusing on Information and Communication Technologies
DVTS	Digital Video Transport System, an open-source software system for encoding and decoding video signals for transmission over the Internet
ECSCW	Acronym for the biennial European conference on Computer-Supported Cooperative Work
HCI	Human-Computer Interaction (sometimes referred to as Computer-Human Interaction)
HREC	Human Research Ethics Committee, the term used in Australia to refer to the committees which vet research proposals involving research on human subjects
ICT	Information and Communication Technologies
MDTM	MultiDisciplinary medical Team Meeting, a term used by authors Kane and Luz in their paper describing medical team meetings at the hospitals in their study (Kane and Luz 2006)

OZCHI	The annual conference of the Australian Computer-Human Interaction Special Interest Group of the Human Factors and Ergonomic Society of Australia
PACS	Picture Archiving and Communication System – a system used in hospitals for digital storage and transmission of medical images
RCH	Royal Children’s Hospital, Melbourne, Australia. This was the location for the major case study of this thesis. There is also a Royal Children’s Hospital in Brisbane, Australia, and some of the cited papers refer to work done there.
SUMMIT	The Stanford University Medical Media and Information Technologies group

Appendix A: Questionnaires used in the hospital trial

This Appendix contains the five questionnaires used during the Royal Children's Hospital pilot telehealth trial. The questionnaires were:

1. A two-item questionnaire that the surgeon completed after each patient
2. A set of Likert-Scale items and semi-structured questions that the surgeon completed after each clinic (i.e. block of patients)
3. A one-item questionnaire that the assistant completed after each patient
4. A set of Likert-Scale items and semi-structured questions that the assistant completed after each clinic
5. A set of Likert-Scale items and semi-structured questions that the patient and family completed after their consultation.

Surgeon (asked after each patient)

1. The tele-health appointment alone was satisfactory.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

2. Would you have been satisfied to let the patient leave after the tele-health appointment?

- Yes
- No

Surgeon (asked after each clinic)

Likert-Scale Items:

1. I was comfortable greeting the patient and family using the tele-health system.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

2. I was able to understand the patients/carers concerns during the tele-health appointment.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

3. I was able to address these concerns during the tele-health appointment.
- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

4. I was able to explain the future treatment plans and expected outcomes during the tele-health appointment.
- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

5. I was able to direct the assistant.
- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

6. I was able to understand what the assistant was seeing/touching/doing.
- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Semi-structured questions
1. In general how did the consultation aspect of your appointments go during this block of tele-health appointments?

2. Did you experience any difficulties communicating with the participants using the system during this block of tele-health appointment? What were these difficulties? What caused these difficulties?

3. Was there any particular consultation or element of the consultations that you wanted to comment on? What are these?

4. In general during this block of tele-health appointments, how well were you able to communicate to the assistant what you needed him/her to do? What did you use to communicate with the assistant?

5. In general during this block of tele-health appointments, how well were you able to understand what the assistant was seeing, feeling and doing?

6. Where there any aspects of the system which were confusing? What were these?

7. During this block of tele-health appointments, did you change how you conducted the appointment over the system as you became more familiar with the environment? How?

8. During this block of tele-health appointments, did you and the assistant develop any strategies for working together as time went on? What were these?

9. (If this is not the first block). How did you find using the system during this block of appointments compared to your earlier experiences with the system?

10. Any other comments?

Clinic Assistant (asked after each patient)
Likert-scale item
1. Overall the tele-health appointment went satisfactorily.
- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Clinic Assistant (asked after each clinic)

Likert-scale items
1. I was comfortable greeting the patient/family and specialist.
- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

2. I was able to take part in the consultation part of the appointment as appropriate.
- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

3. I was able to understand the specialist's directions.
- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

4. I was able to act on the specialist's directions.
- Strongly agree
- Agree

- Neither agree nor disagree
- Disagree
- Strongly disagree

5. I was able to communicate to the specialist what I was seeing, feeling and doing.
- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Semi-structured questions

1. In general how did the consultation aspect of the appointments go during this block of tele-health appointments?

2. Did you experience any difficulties communicating with the participants during this block of tele-health appointment? What were these difficulties? What caused these difficulties?

3. In general during this block of tele-health appointments, how well were you able to understand what the specialist needed you to do?

4. In general during this block of tele-health appointments, how well were you able to communicate to the specialist what you were seeing, feeling and doing? How did you do this?

5. Where there any aspects of the system which were confusing? What were these?

6. During this block of tele-health appointments, did you change how you used the system as you became more familiar with the environment? How?

7. During this block of tele-health appointments, did you and the specialist develop any strategies for working together as time went on? What were these?

8. (If this is not the first block). How did you find using the system during this block of appointments compared to your earlier experiences with the system?

9. Any other comments?

Patient/family (asked after their consultation)

Likert-scale items

1. During the tele-health appointment I was able to see the specialist clearly
- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

2. During the tele-health appointment I was able to hear what was said clearly

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

3. I felt comfortable having this appointment using the tele-health system

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

4. I could get the doctor to understand and respond to my concerns during the tele-health appointment

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

5. During the tele-health appointment I was worried that others might be listening

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

6. I felt that the face-to-face appointment was necessary

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Semi-structured questions

1. How far did you travel to get to this appointment?

2. How long did it take to get to this appointment?

3. If you could have an appointment closer to your home using the tele-health system instead of travelling to this hospital, would you? What would the trade-offs be for you?

4. How was it different talking to the doctor over the tele-health system?

5. Did you feel that the doctor was able to make an accurate examination of your child using the tele-health system? Why or why not?

6. What did you think about the role that the assistant played?

7. What other comment do you have about your experience during the tele-health appointment?

8. Do you have any other comments?

9. Do you have any questions?

Appendix B: Consultation times – duration and frequency

Table B.1 of this appendix shows the times taken for the telehealth and face-to-face phases of the consultations, and the time periods scheduled for the subsequent consultations. Table B.2 shows the distribution of the time-periods until the next consultation.

Surgeon (code)	Duration Tele (min:sec)	Duration FtF (min:sec)	Next consultation
S1	24:40	7:25	3 months
	20:50	9:50	12 months
	21:20	5:15	2 months
	14:40	2:45	3 months
	25:55	8:55	6 months
	23:10	5:50	6 months
	15:25	1:40	Discharge
	23:10	4:15	3 months
	13:25	0:55	Discharge
	19:20	5:55	6 months
	26:25	1:20	6 months
	22:15	1:25	3 months
	24:40	5:05	6 months
	16:05	1:05	3 months
	20:55	4:30	12 months
	26:50	7:00	3 months
	13:40	3:55	Discharge
	31:50	3:00	Soon
S2	21:10	2:20	1 month
	24:40	5:00	3 months
	20:55	9:40	3 months
	21:35	10:40	Later that day
	12:00	1:00	3 months
	19:45	4:30	2 weeks
	15:30	5:00	3 months
	15:05	6:05	1 week
S3	8:50	n/a	Discharge

	9:30	**1:00**	**3 years**
	10:10	**2:30**	**6 weeks**
	10:40	**2:10**	**12 months**
	8:50	**1:10**	**24 months**
	5:10	**2:30**	**8 months**
	16:45	**4:25**	**5 months**
	9:00	**5:25**	**5 months**
	7:45	**0:55**	**1 month**
	11:05	**1:20**	**6 months**
	6:55	**0:40**	**Discharge**
S4	**13:25**	**3:20**	**2 months**
	9:00	**4:05**	**12 months**
	11:05	**3:20**	**12 months**
S5	**16:45**	**3:00**	**12 months**
	13:05	**2:00**	**4 months**
	24:15	**n/a**	**12 months**
	26:00	**3:30**	**6 months**

Table B.1: Duration of telehealth and face-to-face phases, and time until the next scheduled consultation, grouped by surgeon

Time-period till next appointment	**Number of patients**
One month or less	6
Two to three months	13
Four to six months	10
Seven to twelve months	8
Greater than twelve months	2
Discharged	5

Table B.2: Distribution of time-periods until next appointment

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