A Design Evaluation of Non-Portable Telemedicine Systems for Remote Health Consultation

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ABSTRACT
The need for remote consultations by health professionals is growing in the health industry. Many telemedicine systems are in existence yet there are few, if any, studies exploring them from a human-computer interaction perspective. As such, we conducted an interview and observational study of telemedicine health consultations focused on user behavior and interactions. Here we focus on the ways in which technologies can be better designed, if at all, to support user needs, practices, and social concerns. Our findings show that current telemedicine systems are limited in terms of their design and cause health professionals and patients to miss out on non-verbal body language, gestures, and eye gaze, along with information about the emotional state of the patient. Patients also face privacy issues because of stationary narrow field-of-view cameras. Overall, these findings illustrate the need for wide field-of-view or mobile cameras, the potential for multiple cameras, along with better software features to show improved mirror views of oneself and patient documentation.

Keywords
Telemedicine, health, video communications, telepresence

INTRODUCTION
There is a growing need in the health care community to provide technology to support telemedicine over distance where video conferencing systems are used to connect health professionals and patients in different locations. Such telemedicine setups have the potential to reduce the cost of health care services and provide health consultations to those who are unable to travel to locations containing health professionals [12]. As such, the overarching goal of our project was to explore how health professionals use video conferencing-based telemedicine systems in order to understand how their designs can be improved in the future to better support the needs and workflow of health professionals and patients. In particular, we were interested in exploring how computer hardware configuration and software design affects usage.

To address these questions, we conducted observations of patient consultations with remote specialists along with interviews of health professionals. Here we studied the use of non-portable systems that are already in use in health facilities. Our study goal was to understand health professionals' work practices, the successes they experienced with non-portable telemedicine systems, the challenges they experienced with these same systems, and workarounds that they needed to do in order to conduct their necessary work activities. We also gathered observations about patients' interactions with the technology during consultations. Following this study, we reflected on our findings to suggest future design directions for telemedicine systems that overcome the shortfalls of systems with stationary (non-portable) and narrow field-of-view cameras.

To foreshadow, our research shows that current telemedicine systems provide basic support for remote consultations, yet they cause patients and health providers to miss out on a large amount of non-verbal communication that is critical for person-to-person interactions. Patients also face privacy concerns as a result of cameras that do not adequately show remote locations due to their field-of-view or positioning. These study results suggest that telemedicine systems would benefit from both hardware and software improvements, including better eye contact and eye gaze, better mirror view facilities, and the use of mobile or multiple cameras. Such improvements would help address the current challenges faced by telemedicine systems and create a situation and setting that is much more similar to face-to-face consultations. With these improvements, we feel that telemedicine systems will provide an improved experience for both patients and health professionals and allow them to improve patient-centered outcomes.

Our paper unfolds as follows. First, we describe related research on video communication systems in health, work, and home settings. Second, we present our study methodology. Third, we outline our study results to show how patients and health providers use current telemedicine systems. Fourth, we discuss our findings and include design recommendations for future telemedicine systems.

RELATED WORK

Telemedicine Systems and Studies
There is a growing need in the health care community to provide technology to support telemedicine over distance

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[14]. Telemedicine is defined as the use of technology to support medical assessment and analysis over distance [12,14]. It has been shown to be important for rural areas lacking medical professionals [20] as well as in cases where patients are unable to leave their home (e.g., cases of chronic illness) [14]. Many telemedicine systems focus on the sharing of electronic medical records and diagnostic information between healthcare professionals [14]. This information is often discussed using technologies such as the telephone and text messaging [14].

More recently, we have also seen the incorporation of video conferencing solutions into telemedicine systems [9]. Studies of the satisfaction of patient and healthcare professionals show that both groups value asynchronous as well as synchronous telemedicine systems [22]. Research on video conferencing-based telemedicine systems has shown that people are receptive to such technologies, if available, because they see the value in gaining increased access to health services [7]. Research has also shown that it is possible to develop training programs for video conferencing-based telemedicine systems [9]. Researchers have also developed cost/benefit models to show the economic benefits of such [9].

Together this research provides a basis for understanding the utility of telemedicine systems and user satisfaction with them. Yet it does not provide any empirical investigations of how video conferencing-based telemedicine technologies should be designed to support existing doctor-patient workflows and in what ways varying design attributes may affect these workflows. Thus, it does not explore telemedicine systems from a human-computer interaction perspective, which can yield insight into how the system should be designed to match human needs and practices. Recently, Kahn [12] proposed a series of challenges for telemedicine research. These include investigations of cost effectiveness, legal and regulatory infrastructures, and the unintended consequences of telemedicine. The latter refers to the effects of not seeing a doctor in person and potential issues related to doctor-patient relationships, privacy, and trust. Our study focuses on this challenge to explore both the benefits and limitations of existing telemedicine systems. Our discussion section points to ways to overcome the limitations of such systems through improved telemedicine software and hardware.

Video-Mediated Communication

While not specifically focused on health consultations, there is a large body of research that explores the use of video-mediated communication systems in the workplace and domestic life. This sheds light on the issues that telemedicine systems might face when attempting to support natural human behavior and interaction.

First, video communications research on the workplace has explored how video can be used to support both casual interactions between work colleagues as well as focused meetings. Telepresence systems called *media spaces* supported always-on video links between common rooms (e.g., lunch rooms, meeting rooms) and offices so that distributed coworkers could easily see the comings and goings of each other and naturally move into conversation and interaction over distance [6,8,23]. In these setups, key design concerns focused on where cameras should be placed to adequately capture co-workers' posture, eye gaze, body language and gestures that accompany communication [8,15]. Such acts are critical for video-mediated conversations because they augment speech with necessary contextual cues [8].

Researchers have also documented challenges in designing telepresence systems that adequately preserve user privacy. Telepresence systems often face privacy challenges because users can easily stand out of a camera's view but still be able to see or hear remote users [2,4,5]. Thus, it can be difficult to know who at a remote location can see or hear you, which can easily infringe on one's privacy [2,4,5,17]. We hypothesize that telemedicine systems may face similar challenges to workplace telepresence systems where eye gaze, privacy, body language, and gestures become critical design focal points.

Second, telepresence research in domestic settings (such as the home and while mobile) has illustrated the technical and social challenges in using such systems. Here we see that video conferencing systems are often very difficult for users to setup and it can be difficult to maintain a connection long term [1,13]. The location of cameras and displays become critical as this dictates what can be seen (or not) and how the system supports conversation, awareness of remote parties, and the privacy expectations of users [11,16]. Adequate lighting can also be a major issue in home-based video conferencing [18]. Research has shown that multiple cameras and displays are often needed in order to capture the variety of domestic activities that people are interested in sharing with remote family or friends [16,18,19]. Similarly, we see the need to design for portable displays that can easily be moved between locations or to target different specific activities [10,11,18,19]. Based on this research, we hypothesize that telemedicine systems may similarly benefit from portable displays and cameras that can be easily moved or reconfigured depending on what is being shown to remote users.

In the remainder of the paper, we explore the use of non-portable telemedicine systems to understand how they are used by health professionals to facilitate remote patient consultations. Throughout this exploration, we focus in on the issues and challenges faced by telepresence systems in the workplace and home environments to see how they do or do not surface in health settings. For example, we investigate the impact of camera placement, display location, and the ability to incorporate non-verbal communication mechanisms such as body language and eye gaze.

STUDY METHODOLOGY

We undertook a qualitative research approach where our study was exploratory in nature rather than confirmatory. This is because little is currently known about the usage of video conferencing-based telemedicine systems from a human-computer interaction perspective. We used known requirements gathering and design elicitation techniques from the field of human-computer interaction, described next.

Participants

We recruited eight participants (4 health providers and 4 patients) via Island Health's (IH) Telehealth program coordinator. Five participants were male and three were female. Health providers were contacted through IH's telehealth program manager and booking clerk, and those that agreed to participate contacted their patients were then recruited for the study. Four participants were health providers (general practitioner, dietician, social worker and nurse) and the remaining four were patients. Thus, in total we observed four telehealth consultations (two cardiology and two renal).

All health consultations took place in the province of British Columbia, Canada, on Vancouver Island. The first two teleheath consultations, between two different patients (cardiology) and the same general practitioner, took place between Nanaimo Regional General Hospital and the Oceanside Health Clinic (OHC) in Qualicum Beach. The third teleheath consultation took place between the Nanaimo Kidney Care Clinic (NKCC) and Comox Valley Health Centre, and the fourth consultation took place between NKCC and Campbell River Hospital. Both consultations from NKCC involved a consultation from a dietician, a social worker, and a nurse.

All four health providers and one patient had prior experience using the telehealth system. All participants were briefed on the study procedures and introduced to a consent form prior to arriving to consultation, and at the consultation they gave signed consent after a summary of the consent forms was provided. We also signed a patient confidentiality agreement stating that their consultation and confidentiality will be strictly maintained. Thus, no patient clinical information was collected and all other observed data was anonymized. Ethics approval for the study was obtained from both the Vancouver Island Health Authority and Simon Fraser University's Office of Research Ethics. The study also received Institutional Approval from Island Health.

While the number of participants in our may seem drastically small when compared to clinical trials, in the field of human-computer interaction, this amount of participants is commensurate with qualitative research studies of technology [21]. In these studies, the goal is to deeply explore user interactions with a technology and collect a large amount of qualitative data on a per user basis. Study results then point to the efficacy of a technology rather than any form of statistical data or hypothesis testing. We also focus on understanding what can be improved in the technology to better situate it in existing practices or to design future versions of it. Studies with large volumes of participants (e.g., clinical trials) do not render themselves to the detailed knowledge that we focus on obtaining at a per participant level; thus, they are impractical and less useful for human-computer interaction research.

Method

In total, we conducted four *in situ* observations of consultations between patients and remote healthcare professionals to observe the ways in which they made use of the telemedicine systems. Observations focused on the ways in which the health professionals and patients interact with the telemedicine system. We observed consultations from both the health provider and patient side (OHC consultation were observed from patient side, and NKCC was observed from health provider side). Observations began when the patient entered the telehealth teleconferencing room (i.e. before video conferencing between the health provider and patient began) and ended once the patient had left the teleconferencing room. Thus interactions before and after teleconferencing were also observed so we could see how video calls were initiated and ended. Consultations lasted roughly one hour each.

Following the observations, we performed a semi-structured interview with both patients and health providers. Interviews were conducted individually to maintain privacy and focused on identifying critical incidents in technology usage. These are focal points of usage that stand out as dominant moments when using the technology. Often such critical incidents point to key design successes or challenges. Example interview questions for health professionals included: "What activities do you primarily use the telemedicine system to support?" "Can you describe how you show portions of the patient's body when using the telemedicine system?", and "What would you change in the system if you could change something?" Patients were asked similar interview questions, such as: "Tell me about a situation where the system worked well", "[did] not work well", and "How do you know what data the remote person is talking about when discussing the case?"

Data Collection and Analysis

All data was collected in the form of handwritten notes (i.e. no audio or video recordings of the consultations) and handdrawn sketches of the room layouts (photographs were not taken to preserve the privacy of patients and the clinical setting). We used open, axial, and selective coding [21] to analyze our data for each participant. These are standard qualitative data analysis procedures used in human-computer interaction research. Once the data was classified and grouped according to patterns of usage, we compared experiences and responses across our participants. We did not find any obvious differences.

Next we present our results. First, we describe the environment and interface used for the telemedicine consultations. Second, we describe how patients and health professionals communicated through the telemedicine system. Third, we outline how patient information was shared using the telemedicine system. In each of these sections, we highlight the design factors that affected usage of the telemedicine systems.

ENVIRONMENT AND INTERFACE

This section describes the physical environment of the consultations, what is captured by the Teleconference Unit (TU) and displayed on the Teleconference User Interface (TUI), and how these factors affected usage.

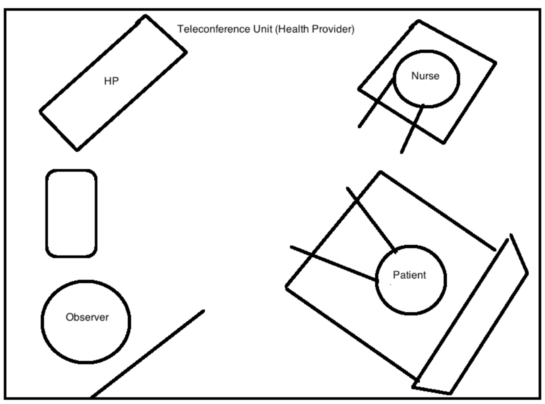

Figure 1: The OHC telehealth room showing the positioning of the patient, a nurse, and the telemedicine system.

Consultation Setting

In all consultations, there was a direct path (i.e. no obstructions) between the participant and the TUI. This made it easy for the telemedicine system's camera to focus on the patient. The consultation rooms were generally the same size and small (~10-15 ft. by 10-15 ft.). Both rooms where the observer was present (OHC and NKCC) were well lit though patients were slightly overexposed in the camera view. In addition, we also noticed that there was a slight glare, particularly on the background wall of the OHC location.The OHC telehealth room contained both the patient and a proxy nurse. Figure 1 shows the layout of this room. The patient sat, with an obstructed path, roughly five feet from the TUI. This was enough distance so that their whole body (sitting down) was captured by the TU camera. The proxy nurse sat outside of the camera view and had shifted her body to face the patient (opening up to patient), though their seat was positioned to face TU camera. This allowed the nurse to directly engage with the patient, yet it meant that she was off-camera for the remote specialist. Such configurations have the potential to create awkward dialogue between health workers, as all parties are not easily seen on camera.

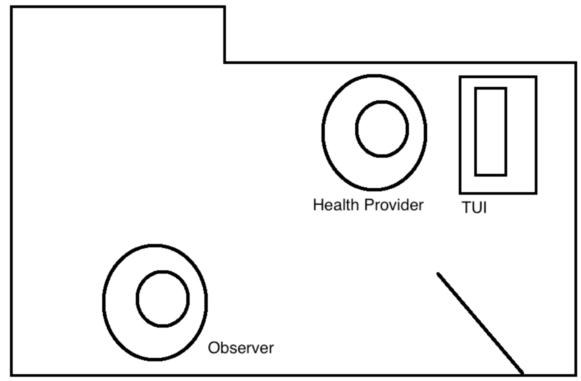

Figure 2: The NKCC telehealth room showing the positioning of the observer and health provider.

Past research has shown the importance of providing users with a mirror view of themselves in a telepresence system [15]. This allows them to see what they look like, how they are positioned in the camera, and if they need to move to better show themselves. Yet the telemedicine systems we studied did not easily support this feature. Instead, the mirror view of a patient was often hidden and replaced with diagnostic information.

This setup created two problems. First, the remote specialist frequently toggled between the two different views as the consultation was performed. During a majority of the consultation (~70%), the view was set to a thoracic graphic, resulting in the patient not having a mirror image of him/herself. Control of the interface was also completely in the hands of the remote specialist, which meant that the patient could not choose to change the view and see how s/he appeared on camera. Second, because the patient and nurse sat far away from the TUI, the thoracic graphic on the TUI display was quite small, and the target even smaller. This made it challenging for the nurse to see the target.

Health Provider side - NKCC

In the NKCC telehealth room, the health provider sat, with a direct path, close to the TUI (~2 ft.). The patient room (observed from the TUI) was much larger, with a lot of space (and two chairs). The remote patient sat at a greater distance (~8 ft). from their TUI such that they only took up small portion of camera view and their whole body was captured on camera. Thus, while the layout of the room made it so their entire body was visible on screen, their distance from the camera meant that it was difficult for them to see their mirror view on the telemedicine system's display.

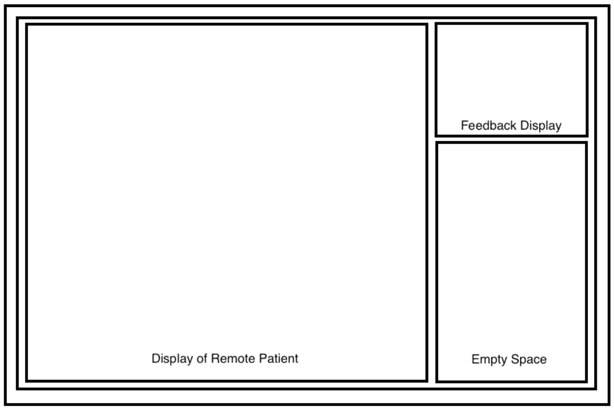

Figure 3: The remote view of the NKCC telehealth room (~15x13 ft.).

The screen real-estate of the TUI (Figure 3) was divided into three sections. First, the left side of the display (Figure 3, left) showed the remote patient who was positioned to occupy only one-quarter of the display. Second, the top-right section (Figure 3, top right) showed a mirror view of the health provider's face along with portions of his chest and neck. Lastly, the lower right section (Figure 3, bottom right) was left black and empty throughout all consultations. Thus, the setup allowed the health provider to see a mirror view of himself, yet the system's camera overly focused on his face and did not easily capture his body, which might include important gestures or body language.

Teleconference Unit Camera

The videoconferencing camera (a Full HD Polycom Eagle-eye III) used in all consultations had 1920x1080p resolution and remotely controlled by the health provider. In some instances the health provider used the camera's zoom feature to examine patients' necks and ankles for swelling and discoloration. While it appeared that the health provider could not see the examination site with much clarity (based on the feedback image), the health provider was generally content with his examination. Here, the health provider gave the patient instructions (e.g. "move your neck up and to the left"; "pull up right pant leg to show right ankle"_ and the patient reacted without complications. Occasionally the patient would ask the health provider questions such as, "can you see my feet?" in order to judge if the right body parts were visible over the video link. In these cases, the health provider gave auditory feedback such as, "OK, yup, no discoloration on the neck" or "OK looks fine," to confirm. Thus, while the camera was adequate enough for the consultation, verbal exchanges were needed between the patient and health provider to negotiate what was shown on camera. This was largely because the patient could not see his or her view on the small mirror display shown on the telehealth system's display given the seating location.

Privacy and Awareness

While the consultation rooms were often small, in all cases the camera could not capture the entire room. This meant that participants did not have a sense of the room layout nor their own privacy. For example, patients did not know if anybody else was in the room, if others were also watching the consultation, or if the examining room doors were open. This privacy issue was best exemplified by P4 who, halfway through his consultation behind closed doors, asked, "Is the room to the door open?"

Patients also lacked awareness of who they were talking to in terms of the health providers' name and position. Camera images were too small to show badge names and health providers did not always tell the patient his or her name. This was especially the case for P4 who was visited by three different health providers in succession. For instance, P4 was asked by the nurse if the dietician had asked him particular questions regarding his health and diet and P4 responded that he was not sure who he had previously spoken too.

COMMUNICATION

This section explores what was captured and communicated through the teleconferencing system.

Body Language and Hand Gesturing

All participants (both health providers and patients) used a large amount of hand and body language to communicate but a majority of this communication was not captured by the camera and presented on the TUI. For example, the social worker would use her fingers to list off items but none of these physical actions were seen by the remote patient. Health providers also gave physical instructions, such as, "If you were to take your finger and push into your leg, would you sense a flare up?" (a question related to gout). They would then try to show the patient instructions visually by pressing on their own arm. Again, this was not always transmitted on camera.

Following the consultation, we told the health providers that they used a lot of body language and hand gesturing which the patient could not see, yet many of the health providers were unaware of this (i.e., they imagined that patients could see their hands). This is especially interesting because the remote health providers are able to see a mirror view of themselves in the system. This finding suggests that it can be hard to remember to look at the mirror view to position oneself in the camera. It could also be the case that, given the location of the camera and user, it is simply not possible to do (the camera is too close to the user), or the consultation is too cognitively demanding already that this is not a primary concern.

Body Positioning

In all consultations, the health providers sat close to the TUI, and based on the position of the camera, it was common for the health providers to stare down and into the camera. This created a feeling of power and dominance, as reported in other literature [8]. It was also challenging to determine the level of openness and comfort of the health providers as most of the time only their faces were displayed. Such openness is often conveyed through body language, e.g., not folding arms, facing the other person directly. The patients' bodies, on the other hand, were fully exposed, and sat facing open and comfortably on a leather reclining chair.

Feedback

In general, it was difficult for the patient to comprehend what information (i.e., video or sound) was being communicated to the health provider, particularly in the OHC consultations where a majority of the time the patient had no feedback of what their own camera was capturing. Thus, throughout most of the consultation the patient was unaware of what the physician was looking at.

During all of the consultations, the health providers took hand written notes of their observations. However, based on the image feed, the patients could not see the health provider recording notes on paper because only their faces were displayed. Thus, the patient could only see the health provider looking down. This has the unfortunate conversational effect of suggesting disinterest in the remote patient.

In terms of auditory and visual feedback, patients and health providers sometimes experienced signal and volume problems. However, they were both unsure if the issue was a lack of clarity (signal) or loudness (volume) and would ask questions such as, "Did you hear my voice?" and "Do I need to speak louder?" This would often result in a lot of back and forth check-ins (e.g., "Sorry what was that?", "No, you go first"). At different moments during consultations, health providers muted the audio feed (not video) but this was not communicated to the patients. Thus, patients had no indication and were unaware at times when they were being heard or recorded.

Eye Contact

Health providers routinely looked at the patient on their TUI rather than the camera when communicating. This was more noticeable amongst health providers because they were sitting closer to the camera. As a result, it appeared that health providers were staring into the left lower corner of the screen and demonstrating a lack of eye contact. During the follow-up interviews with health providers, they commented that they were unaware that they were not making eye contact (i.e., they had assumed they were making eye contact with patients). Patients, conversely, spent about half of the time starting at the camera/TUI and the other half staring around the room.

Sound and Video Awareness

Interestingly, health providers did not do volume or signal checks with the patient at the beginning of the consultation. As a result, health providers often spoke with a very loud and clear voice. Health providers later commented that they felt that they had to speak louder. They also made comments that they felt their was an echo in the room (however, we did not observe this) and complained about certain signal lags. For example, during the consultation with NKCC, there were frequent short auditory lags. Health providers communicated this to the patients: "Sometimes there is a bit of a delay, so I will back-off and let you finish" – Dietician. The slight lag resulted in many interruptions.

Emotion

It was challenging to determine how much emotional discomfort the health provider could detect through videoconferencing, and how much technology plays a role in sharing this information. During one consultation, a health provider prescribed a particular drug for pain to the patient, and being physically present in the room, we (the observer) sensed that the patient felt uncomfortable with the health provider's recommendation and his concerns about addiction. Based on the conversation, it was apparent that the health provider could not sense the emotional discomfort in the patient. Luckily, during this consultation there was also a proxy nurse present in the room who picked-up on this concern. Following the consultation, the nurse brought this conversation back up with the patient and was more comforting. While it is unclear how much of this identification was based on the strengths and weaknesses of the health provider at detecting emotional and physical cues versus the technology discrepancy, it does demonstrate the advantage of having a health provider present in the room.

Socializing & Playfulness

Besides the exchanges of patient related information, both health providers and patients often communicated through jokes and associated facial gestures. For instance, P3 often used dead-pan humour by making subtle comments and jokes while keeping a straight face. This was usually undetected by the health provider. While there is a chance that this was a result of the technology setup, it could also have simply reflected a natural social interaction where one simply does not notice some instances of humor.

PATIENT INFORMATION

This section describes how information was shared between the patient and health provider.

Information Sharing

In general, the health providers asked questions and gave information (e.g., test results, medication, etc.) verbally to the patient. During certain moments the health provider would read information on patient health charts or in some instances hold up paper to the camera to show the patient. During this exchange, the paper took up the entire screen and the patient could not see the health provider. In addition, the health provider had a difficult time seeing what information they were pointing at (with a pen). The patient also had difficulty seeing the information and had to lean in to see the results.

However, most information was shared verbally. That is, it was read from paper aloud and often recorded via hand written notes on the receiver side. For example, health providers would read patient information (e.g., blood pressure) from health records and the patient would handwrite the information down on paper. Information was also shared between health providers in this manner. For example, proxy nurses present with the patient would record patients' health information (e.g., blood pressure, weight, etc.) and then verbalize the information to the remote nurse who would transcribe it onto paper.

Drug and medication names, which were sometimes long and complicated, were shared verbally. Surprisingly, this exchange presented no, or very little, communication or comprehension issues between patients and health providers. However, there were moments where it was unclear who had what information. For example, health providers would ask patients about their results and the patient responded, "I was about to ask you!".

Redundancy

For patients consulting with multiple health providerss, there was a lot of information repeatedly exchanged. For example, patients consulting with a dietician, social worker, and nurse were asked the same questions multiple times. However, at no time did the patient complain or communicate this to the health provider. Instead, they just answered the questions. During follow up interviews the health providers commented that they were unaware that they were asking repeat questions.

Discrepancy

There were moments when the information provided by patients seemed to contain discrepancies or uncertainty. For example, patients were asked a series of personal health information that they responded to off the 'top of their head' (e.g., self-reporting blood pressure results). In one instance, the patient used her memory to state the most recent blood pressure result which she estimated to have been recorded seven months prior.

Patients were asked a series of questions by the health providers on a 0-10 scale regarding pain. However, because this was given orally (i.e., not presented on paper) the patient responded not with numbers as directed, but with words and descriptions. For example, "How much pain are you experiencing with X?" and the patient would respond "No" or "None".

DISCUSSION & DESIGN RECOMMENDATIONS

Overall, we found that the current telehealth units could be vastly improved to better support the needs of health professionals and patients. While critical information was exchanged sufficiently during consultations, we observed key areas for improvement. We now turn to these areas and provide recommendations for future designs, specifically in terms of TUI design and environment, communication (body language & gesturing), feedback, eye contact and emotion, as well as discrepancy and redundancies of information sharing.

Recommendation 1: Manage Camera Privacy

Currently, the patient is unaware of the remote health provider's environment. For example, patients would stop the consultation to ask who was present in the room or if the door was open. This is a serious privacy concern and should be addressed with future telemedicine video systems. Designers should consider using wide field-of-view cameras or having systems with a portable camera that could be moved to show various parts of the room on an as-needed basis. This may include the use of pan-tilt-zoom cameras that can be easily adjusted by users at either the local or remote location, or the use of telemedicine systems that are coupled with tablets containing cameras. Such telemedicine tablets could be easily moved around the room to show who is around at various points in the consultation.

Patients were also sometimes unaware of the identity of the remote health provider (i.e., name and/or role), especially during consultations involving multiple health providers. We believe this may be due to the fact that the patient remains in the same room during all consultations, whereas in common face-to-face consultations the patient would be moving rooms and be exposed to location cues (e.g., room names, desk and shirt name tags, etc.). The name badges of health providers are also not visible over the video link very easily. This could be alleviated by providing on-screen information about which health providers are currently in the room, or will be coming in next. It could also involve software solutions that are linked to patient schedules listing out who will be seeing the patient and in which order. Thinking more into the future, one could even imagine systems with the ability to automatically show which health providers are present with the patient based on smart sensing of who is in the room. For example, RFID-enabled badges could be detected by software and this information could be shown to users on-screen.

Recommendation 2: Support Body Language

Another major concern with existing designs is the ability of the system to capture and share body language and gestures. For example, because the camera remains close to the health provider, actions with their hands (such as writing on the desk in front of them or body language with their hands) were not captured on camera. Design solutions should consider wide field-of-view cameras, the combination of multiple cameras (containing both wide and narrow field-of-views), or the use of a portable camera that could be moved to different distances depending on what is meant to be captured (one's entire body vs. one's face vs. body parts for examining). Similarly, designs could provide users with better video mirror facilities so they can more easily see themselves to know what is being captured by the camera. Given this, they could make adjustments if the system is not capturing them as it should.

While the systems we studied already utilized high fidelity video camera, it would be highly beneficial to couple this fidelity with displays that can show full bodies and present patients and health professionals in a life-size manner. For example, in the near term, this could be accomplished with large displays with a diagonal viewing distance of at least 50 inches. In the future, this could be accomplished through project technologies that project video displays on walls in a life-like manner. This would aid in fully presented body language over the video link and allow users to easily notice the body cues of remote users.

Recommendation 3: Support Eye Contact and Eye Gaze
Our findings also point to major challenges in maintaining eye contact and showing eye gaze between patients and health providers. Because the video feed of the proxy is displayed in the lower quadrants of the TUI, proxies tend to stare into the screen, rather than at the camera and, thus, there is a lack of eye contact. Design solutions should explore ways to align the camera with the video display's view. This would better support shared eye contact and gaze, which are critical components of communication. Designs should also consider the use of life-size views of remote users to further show eye contact and gaze patterns; this would be beneficial on both sides of the video link. Eye contact is used in normal face-to-face conversations as a way to show that one is paying attention to another person. Eye contact is also critical for establishing interpersonal trust, which in turn can lead to relationship building. These are all very important elements within health consultations and, as such, we feel strongly that eye gaze and eye contact should be better supported in telemedicine systems.

Recommendation 4: Support Information Awareness
There were also issues related to discrepancies and redundancies in communicating patient information (e.g. blood pressure recordings, medications, drug names, etc.). Displaying patient health information (e.g. patient's electronic medical records) on the TUI would decrease the redundancy of shared information across all health providers as well aid in miscommunication or discrepancies. Further, if handwritten notes were instead recorded electronically and dynamically on the telemedicine display, patients would be aware as to when the health provider is recording health information. For example, currently health providers show paper documents by holding them up to the camera and talking about them. This is somewhat crude and blocks the image of the health provider. Design solutions should look for ways to show two views—one of the person and one of the documentation—during information sharing.

To further support information awareness and sharing, ws telemedicine systems move forward, we see it being vital that they provide high fidelity video along with *high quality audio*. This will further support conversations between patients and health professionals throughout their consultation. The health consultations we observed were in specially designed telemedicine rooms at hospitals and clinics where external noise was not typically a factor. Yet as telemedicine systems become available in rural areas, patient homes, emergency vehicles, etc., high quality audio will become extremely important to support doctor-patient conversations due to a likely increase in background noise and other external factors.

Recommendation 5: Support Emotional Exchanges
Our results also described the difficulties for remote health providers in detecting emotional body and facial cues from remote patients. For example, only the proxy health provider may detect emotional cues. Thus, while telehealth consultations may suffice to exchange critical information to the patient, they may lack the ability to deliver proper emotional awareness or support. Design solutions should consider providing video feeds of the patient that are closer in distance to them, which would better capture critical body language and facial expressions. This could then be used to detect changing patient emotions. Again, this could be achieved by using multiple cameras, with some located close to the patient, or at various angles. As an alternative, one could also consider having mobile cameras that could be moved or zoomed in to the patient at various points to get different information about the patient. To fully present emotional cues, designers should also consider coupling the above camera technologies with large display technologies that can show life-size views.

Lastly, across all of the aforementioned design recommendations, we want to highlight that it is paramount that improved telemedicine hardware and software is simple and easy to use for even trained users. Our observations showed that even those trained in using the telemedicine systems still found them cumbersome to use and it was not always easy to change the systems beyond their default modalities. Improvements to software and hardware should not come at the expense of systems that are more complicated to use. Moreover, users should not have to rely on user manuals or training to operate the systems. This would make it so telemedicine systems are only usable by a small number of people. In contrast, if systems are easy to use by a large number of people without manuals or training, then they will have greater potential to be cost effective for the health care industry.

CONCLUSION

This paper has reported on the study of existing telemedicine systems that are mostly non-portable in nature and contain a single fixed camera. While some cameras can be moved or offer zoom capabilities, these features were not often used in our observations because of the difficulty in doing so. Through observations of patient consultations with remote health professionals along with interviews, we have found that while current telemedicine systems support consultations, there are serious design issues that still need to be addressed. These include issues relating to the privacy of the patient and knowledge about who can see them on camera, a lack of eye contact and eye gaze, poor support for seeing and understanding body language and gestures, and issues around emotional support. We suggest that these issues can be overcome by considering telemedicine systems that provide improved video feedback views along with multiple cameras, portable cameras, or the combination of this with both wide and narrow field-of-view cameras.

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