Dr.'s Eye: The Design and Evaluation of a Video Conferencing System to Support Doctor Appointments in Home Settings

Dongqi Han
School of Interactive Arts and Technology, Simon Fraser University, Surrey, British Columbia, Canada
dongqih@sfu.ca

Denise Y. Geiskkovitch
Department of Computing and Software, McMaster University, Hamilton, Ontario, Canada
geiskkod@mcmaster.ca

Ye Yuan
School of Interactive Arts and Technology, Simon Fraser University, Surrey, British Columbia, Canada
ye_yuan_5@sfu.ca

Chelsea Mills
School of Interactive Arts and Technology, Simon Fraser University, Surrey, British Columbia, Canada
chelsea_mills@sfu.ca

Ce Zhong
School of Interactive Arts and Technology, Simon Fraser University, Surrey, British Columbia, Canada
zhongcez@sfu.ca

Amy Yo Sue Chen
School of Interactive Arts and Technology, Simon Fraser University, Surrey, British Columbia, Canada
chenamyc@sfu.ca

Wolfgang Stuerzlinger
School of Interactive Arts and Technology, Simon Fraser University, Surrey, British Columbia, Canada
w.s@sfu.ca

Carman Neustaedter
School of Interactive Arts and Technology, Simon Fraser University, Surrey, British Columbia, Canada
carman@sfu.ca

ABSTRACT

The spread of COVID-19 has encouraged the practice of using video conferencing for family doctor appointments. Existing applications and off-the-shelf devices face challenges in dealing with capturing the correct view of patients' bodies and supporting ease of use. We created Dr.'s Eye, a video conferencing prototype to support varying types of body exams in home settings. With our prototype, we conducted a study with participants using mock appointments to understand the simultaneous use of the camera and display and to get insights into the issues that might arise in real doctor appointments. Results show the benefits of providing more flexibility with a decoupled camera and display, and privacy protection by limiting the camera view. Yet, challenges remain in maneuvering two devices, presenting feedback for the camera view, coordinating camera work between the participant and the examiner, and reluctance towards showing private body regions. This inspires future research on how to design a video system for doctor appointments.

CCS CONCEPTS

• **Human-centered computing** → Interaction design; Empirical studies in interaction design.

KEYWORDS

video conference, virtual appointment, mobile interaction, body privacy

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1 INTRODUCTION

Recently, it has become more prevalent to see a family doctor over video using one's smartphone without a need to visit the doctor's office. Virtual visits can help patients save travelling and waiting time in clinics during in-person visits. The recent spread of COVID-19 has also encouraged the general practice of video conferencing for doctor appointments. Such virtual visits have helped decrease the risk of spreading the COVID-19 virus, as there is no physical contact between patients and healthcare professionals [32]. A list of commercial applications for video doctor appointments, such as VSee, Telus Babylon, Medeo, etc., have emerged across North America, and provided secure video services for family doctor appointments. These applications share a similar user interface with video apps (e.g., Zoom or Skype) that people commonly use for general purposes like work meetings or casual relations. Yet, prior research found that such general-purpose applications face challenges in examining patients' bodies in a video appointment context [21]. This creates a design space for ensuring that video systems can meet the needs of remote doctor-patient encounters.

Prior research on video doctor appointments has focused on the use of existing video systems to support remote healthcare. Such

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work often aimed to distribute healthcare to areas short on medical resources or patients with mobility issues. They either investigated video appointments for a certain specialty, such as physical therapy [68], to understand whether video conferencing can be a substitute when in-person visits are unavailable, or explored if patients were generally satisfied with video appointments in primary healthcare [67]. However, few of these works investigated how a current video system could be improved and adapted to the specific needs within the doctor appointment context. Yet, capturing a patients' body in different ways has been found to be critical in video appointments [21, 58], which is influenced by camera work, denoting how patients would maneuver the camera to show their body while being examined by their doctor in different ways. Current video systems are not specifically designed to assist patients in capturing their body properly on camera.

In this work, we engaged in a participatory design process to develop ideas and features for a home doctor appointment system. We then created *Dr.'s Eye*, a video conferencing prototype to explore how to design video systems to support varying types of body exams in home settings. Our design includes four core and novel features: a video camera decoupled from the display for easier capturing video of a patient's body; a 3D-printed form as the camera enclosure to support flexible placement; a 'hide camera view' mode allowing patients to still receive visual feedback before they feel ready to show their body; and a 'virtual cover' mode to assist with showing limited camera views. In the system design section, we elaborate these features in detail. We wanted to investigate how patients would use our system and what features they would value for video doctor appointments. In this work, we also extended the boundary of video appointments to involve exams that require patients to expose private body areas, to see how patients would react to them when supported by new features to protect their privacy. In summary, we wanted to address the following research questions:

- (RQ1) How will patients use a video conferencing system that is specially designed for doctor appointments?
- (RQ2) What benefits and challenges do patients experience when using our video appointment system?

We conducted a lab study with eighteen participants where they attended mock video doctor appointments for five medical situations. These scenarios focused on camera work that requires participants to manipulate the camera to show a range of body regions. Scenarios included: diarrhea, sore throat, chronic pain in the knee, chest acne, and post-surgery recovery. We observed how patient participants used our system during these mock scenarios and employed semi-structured interviews to learn about their reactions as well as their thoughts on different features for capturing their body regions.

Our findings showed that decoupling the camera and display provided flexibility for capturing different body regions. Participants valued privacy protection features that could hide their camera view and cover portions of the body that were unnecessary to show to the examiner. Yet, challenges remain in maneuvering two devices simultaneously and in coordinating the camera work between the participants and the examiner when showing their body. We also found that the awareness about one's self-image, and changes from a clinical space to a virtual space might contribute to reluctance in showing private body regions in real video appointments. The study points to implications around decoupling camera and display, supporting camera control distribution, designing visual feedback with camera views, and supporting trust building for video appointments. In summary, we contribute a design and prototype of a video calling system for video doctor appointments, empirical understandings of our prototype's usage as part of the simulated appointments, and insights into the issues that future system should value for real video doctor appointments.

2 RELATED WORK

2.1 Video Conference for Doctor Appointments

Video conferencing has been used for doctor appointments in a broad spectrum of fields, such as dermatology [30], psychiatry [24], physiotherapy [68], and chronic disease management [59]. They usually share common ground in that the interactions between patients and doctors are largely through visual and auditory aspects, while physical interactions are minimal or unnecessary. In video conferences, doctors are reluctant to perform any kind of physical exam for diagnosis purposes to avoid potential misdiagnosis [21], which limits the capability and scope of video appointments. To prevent possible infections during the COVID-19 pandemic, physicians have started to provide video doctor appointment services, so patients are able to receive remote healthcare in their homes [32]. They typically choose doctor appointment applications that feature scheduling or virtual waiting room features like VSee [8]. All these systems leverage off-the-shelf devices easily accessible to patients such as smartphones, tablets, or laptops. Video streaming interfaces for the applications resemble each other, including two view windows—one for the video of the doctor and the patient, a hang-up button, as well as microphone and camera switches.

However, research has found challenges in using existing devices and software to capture the correct body regions or movements, and helping patients comfortably share their bodies over video [21]. Video appointments might require the patient to capture themselves in different ways depending on the health concern. For instance, a remote physiotherapy session might require the camera to be stationary at a proper distance from the patient [2], so that their body movements can be fully captured. An exam to look at leg fluid retention during a chronic heart failure follow-up appointment might need the patient to press on their leg; while they must place the camera close to the leg to provide a better view for the remote doctor [59]. A dermatological exam might require the patient to correctly orient the camera relative to a patch of their skin so that the doctor can clearly see nuances of the shape and skin texture [21, 29]. A family doctor video appointment context resembles the situations above, where patients may face various forms of camera work when showing their body to the doctor over video, whereas current video applications are not optimized to support such mobility [21]. This indicates that there is a design space for video systems to support patients capturing regions of their body and camera work actions with less effort.

Prior work has discussed challenges with video doctor appointments. Concerns have been raised on the quality of video conferencing for doctor appointments: the resolution of images, quality of lighting, and video latency can become obstacles that compromise doctor appointment outcomes as doctors expect to be able to examine nuances of a patient's body appearance in a manner similar to face-to-face visits [29, 31]. Addressing these challenges typically requires hardware upgrades, such as getting a better camera, a bright(er) lamp, or faster network access. Challenges remain in terms of whether virtual appointments can provide reliable diagnoses compared to in-person appointments [30, 54]. Further, doctor-patient communication plays a vital role in healthcare [39, 50]; verbal and non-verbal behaviors such as chit-chat or body language can help convey care and empathy, support doctor-patient relationships, and relieve patients' emotional discomfort [23, 48]. Yet, patients may perceive less care from the doctor in video calls due to their feelings of lack of attention from the doctor, and hurdles to get involved in the dialogue, which leads to less engagement [19]. To improve the experience, guidelines have been proposed around initiating the conversation and setting up the camera orientation and room background in the doctor's office to help patients feel comfortable and calm in a video appointment [60]. Prior work also explores the use of multiple cameras and video streams in the clinical setting to support patient-doctor communication [63], which frames an understanding of awareness of the environment, as well as attention to objects and actions when given more than one pair of camera-video interfaces. Despite the fact that doctor appointments over video saves patients' time for travelling and waiting in the clinic, it could also create barriers for some patients with accessibility issues, such as elderly patients who are unfamiliar with technology, or patients with visual, auditory, or cognitive impairments [11, 45]. A large volume of work in the video doctor appointment field also focuses on patients' and doctors' acceptance and satisfaction with video appointments, and health system outcomes such as efficiency, diagnosis, and treatment [6, 8, 52, 67]. Building upon this body of work, our study explores how to overcome user interaction challenges in both technical and socio-technical aspects that emerge in video doctor appointments.

2.2 Camera Work in Video Communication

Video communication has been extensively studied in the contexts of work, education, family, and social activities [4, 12, 42, 43, 71]. It builds up interpersonal awareness and engagement through presenting people over distance and conducting collaborative activities [5, 17, 65]. However, limitations arise due to narrow fields of view that limit showing a remote individual's body, lack of support for showing the surrounding space over the distance, or challenges in coordinating collaborative activities [34, 51, 69]. Research also shows that mobile phones cannot support camera work well in positioning the camera or screen to frame local individuals and time activities [18]. Design work has aimed to address these challenges. For example, a 360-degree camera could enable the local user to orient the camera to different perspectives in a remote touring activity, without the need to rely on the remote guide [64]. Still, it can be difficult to know where the local individual is looking at, because this approach decouples local and remote view directions. To resolve this issue, designs have investigated presentations of visual cues in the remote space, for example, mapping gaze range and projecting annotations in the real-world environment to inform awareness [61]. Researchers have also explored an approach to expand the field of view in the context of everyday life, where they increased the number of viewpoints by employing multiple cameras to see the remote home space [34]. This approach has also been used for work scenarios where cameras are looking at different task boards allocated in the office room, so that the local collaborator can get more engaged in the event without holding a mobile phone and chaperoning camera views [69]. Similar to a professional work or collaboration context, a doctor appointment context also involves camera tasks that center on the patient to capture their face, body regions, or actions [21].

Prior work has investigated empowering the camera for sharing collaborative activities by employing a first-person view that enables remote users to see from the same view perspective, for example, through mounting the camera onto glasses [53] or overlaying video streaming from both ends to synchronize activities [49]. Telepresence could also strengthen the awareness of remote users' presence, for example, by projecting the remote individual in real size onto a local room environment to create co-presence [51] or using a robot with human control as a form of physical embodiment [44]. This provides more mobility and autonomy for the remote user in a collaborative activity.

Privacy issues often come with the usage of video conferencing in various contexts. They usually focus on how people and their environments are revealed in a video call [10]. People might be unwillingly visible in other callers' camera views [47], disclose their background in the home environment, or worry about their appearance [28]. User privacy can be infringed upon during a video call in terms of autonomy of who can see the video, when they have the access, and what they can see [10, 34, 43]. Such privacy concerns are critical in a doctor's appointment context. As the conversation should be kept confidential between patients and doctors, patients prefer and desire to stay in a private space like their homes without possible interventions from their environment [21]. Exposing a patients' body, including private and non-private regions, rarely happens in everyday video chat contexts. This makes doctor appointments different from work scenarios or casual activities with family or friends over video. Little research has explored these topics. Previous research on privacy in video conferencing has focused on the security of video channels or private surrounding environments in the sharing space [9, 10, 52]. Yet, researchers have not investigated how to let users properly control the camera view, or what type of control is expected when showing something to the remote user. Conducting research in relation to human body privacy is also challenging in terms of balancing ethical concerns and realism. For example, a study on reproductive health education [3] employed augmented technology to help users learn intimate health knowledge without actually exposing their body. Wong et al. suggested a user-centered approach by engaging stakeholders in the design process and defining privacy problems based on contexts and practices [70]. Inspired by this research, our work aims to understand what patients value in different video doctor appointment scenarios and how the user interface should be designed to support capturing sensitive and non-sensitive body regions.

Table 1: Participatory Design Workshop Procedures

Workshop	Participant Activities	Engagement & Research Goals
1. Problem Identification	• Share virtual appointment experiences • Discuss challenges in terms of interaction, communication, and any technical or socio-related issues	• Explain research background, goals, and questions • Identify current challenges with virtual appointments • Develop video appointment scenarios that can reflect identified challenges
2. Ideation	• Brainstorm ideas that could solve design problems in various scenarios identified in workshop #1	• Generate ideas that could address previously identified challenges • Identify design requirements based on the ideas generated • Identify potential technology solutions based on the design requirements
3. Design Critique	• Reflect on the potential benefits and drawbacks of proposed products (from workshop #2) for each scenario (from workshop #1)	• Discuss pros and cons of potential technology solutions identified • Select one technology solution to further refine and implement

3 SYSTEM DESIGN

3.1 Participatory Design with Patient Partners

We employed a participatory design method [55, 62] that involved patients as our design partners to help understand design needs and assist with the ideation and refinement of the video system. We recruited a total of six participants (AVG = 53 years old, SD = 16; five females, one male). Participants were from a metropolitan area in Canada, where people often use mobile applications, like Telus Babylon [73], to make appointments and see family doctors over video calls. During recruitment, we gave priority to candidates with prior experience with video doctor appointments, and who work in industries which might provide additional insights to the design process. For example, we recruited participants with background in healthcare research, healthcare service, product design, social services, and community volunteering. All participants had used video conference tools with their family doctors or specialists for chronic or occasional health conditions such as physiotherapy or cardiology issues, in the year prior to the workshops. To maintain a small group size for thorough discussions and opportunities to hear from all participants in the group, we divided participants equally into two groups. Each group participated in a series of three design sessions with a researcher organizer. Each workshop session lasted two hours. We planned a one-week interval between workshop sessions to synthesize findings from the individual session and prepare for the next session. Due to the restrictions during the COVID-19 pandemic, we conducted all workshops online in November 2020. We used a collaborative whiteboard tool, Miro, to facilitate design activities. Each workshop session involved different activities and goals (Table 1): the first workshop focused on identifying challenges in the use of video conferencing for doctor appointments; the second one focused on brainstorming ideas for the challenges identified in the previous session; and the third workshop emphasized refining design ideas. In Sessions 2 and 3, we gave participants several types of doctor appointments as scenarios to reflect on. During the participatory design process, we also partnered with a family physician who had over thirty years of medical practice and developed four realistic video doctor appointment scenarios based on the challenges identified from the first workshop. We also used the scenario-based method to develop our study protocol (section 4.2).

Session 1: We asked participants to share their doctor appointment experiences, brainstorm about other medical situations, and think of what challenges could possibly arise during video appointments. Through group discussions about video appointment activities, we identified four main challenges in the use of video conferencing for doctor appointments:

- Examining different body regions; showing one's body parts (e.g., throat, arm, leg) using a single device is difficult.
- Performing one's own body actions and capturing body movement (e.g., walk) on camera is challenging with a single device.
- Sensitive topics or exams are concerning; showing certain body regions that involve removing one's clothes is often embarrassing.
- Patients are worried about privacy exposure, such as showing their surrounding environment, the camera being controlled by others, or video recording.

Session 2: Next we created four video doctor appointment scenarios in cooperation with the family physician partnering in this research, which covered the doctor appointment scenarios identified above, including sore throat, hurt leg, itchy chest, and depression. During Session 2, we encouraged our patient partners to brainstorm as many potential solutions as they could, to address the issues associated with each scenario. To facilitate the ideation process, we specifically prompted our participants not to consider how to implement the technology. We then had a group discussion to identify the commonalities across these ideas with our patient partners, and identified four major design requirements for the system:

1) The system should always show what the doctor is seeing.
2) The device should support being mounted on a surface or held in the hand.

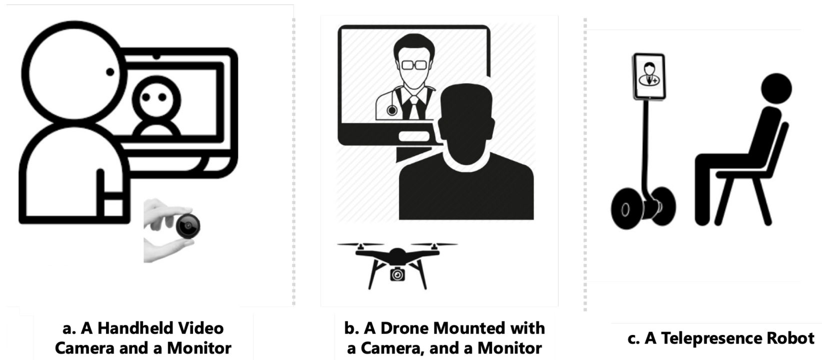

Figure 1: Examples of possible solutions of video systems for doctor appointments in low-fidelity storyboards.

3) The system should support showing patients' video of themselves but not always be transmitting to the doctor.
4) The system should protect patients' privacy by not exposing body areas that are unnecessary to examine.

Session 3: Following Session 2, we conducted a broad search on video-based systems and identified three potential technology solutions with systems features that meet the design requirements identified in the prior session. The solutions were presented as images depicting the type of technology and a textual description explaining how the system would work. We used these solutions for discussion with our participants in Session 3, to delineate the form of our final prototype. These solutions included:

- A handheld camera and a monitor (Figure 1(a)): Patients can see from the display what the camera is showing.
- A drone camera and a monitor (Figure 1(b)): The drone can be controlled to capture patients.
- A telepresence robot (Figure 1(c)): The doctor can control the robot to examine patients' body.

We provided patient partners with the same scenarios as in Session 2 and asked them to reflect on the potential benefits and drawbacks of using these three different systems. Patient partners recognized benefits of each solution but felt that the drone might be difficult to control in the home, and the robot as a telepresence platform was perceived to be intrusive. With thorough comparison and consideration, we decided to exclude these two solutions and to implement our system based on the idea of using only a wireless camera and a mobile display.

3.2 Design Characteristics and Interactivity

Based on the design requirements we uncovered in the participatory design study, we proposed four main features for a system to support various forms of visual doctor inspections:

1) *Decouple camera and display*: The patient can capture a view of their body using an external camera and see the video stream on the phone. This helps patients always have visual feedback on the display when moving the camera around, for example, when shooting body parts that are out of their direct view (e.g., throat, back).
2) *Free capturing*: The patient can put the camera on a table or attach it to any other surfaces, like a wall, without holding the camera in their hands. This could be helpful when it is not convenient for patients to hold the camera in their hand, for example, when performing body movements that involve both hands or when the user must be at a specific distance from the camera to show an entire body region.
3) *Hide my camera view*: When the 'hide my camera view' mode is on, the video stream sent to the doctor is disabled. Only patients see what the camera is currently showing. This enables patients to align the camera into an appropriate pose, until they are ready to stream images to the doctor.
4) *Virtual cover*: By selecting a part of the image in the camera view, patients can limit the area that the doctor can see. A slider can adjust the rest of the camera view between transparent and completely opaque. The system then also ensures that other body parts are kept hidden even when the camera moves. This approach aims to protect patients' privacy in that they can limit the view, to show the doctor only to the parts that are truly necessary.

3.3 The Design Process of Dr.'s Eye

Given these four design requirements, we created a prototype system that we call *Dr.'s Eye*. Dr.'s Eye contains two components: 1) an external camera embedded in a 3D-printed enclosure and 2) software running on a mobile phone that streams video between the patient and doctor. We created the final prototype through an iterative process, including brainstorming about potential form factors for the system (Figure 2(a)), hand sketching some selected ideas (Figure 2(b)), and iterating and creating 3D models around these ideas (Figure 2(c)). We also used paper boxes to create some low-fidelity prototypes based on the models created. Figure 2(d) shows some early drafts for the system design and Figure 3 presents a more detailed rendered 3D model. The implementation of our system prototype was widely informed by the technological probe approach [26].

1) External Camera (4): Inspired by the small disc-shaped resonator of a stethoscope, we designed a rounded form to highlight the camera's position. We adopted a hinge to connect the body and the camera component. Users can rotate the hinge to get a desired camera orientation. We also designed a form enclosure to enhance its flexibility. The base of Dr.'s Eye is flat so users can place it on

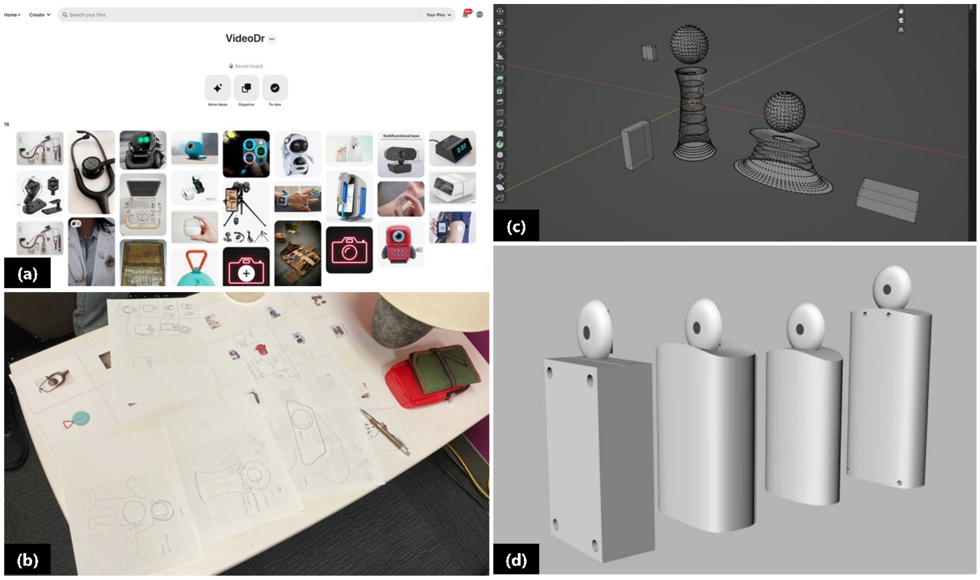

Figure 2: We created Dr.'s Eye through an iterative design process. We started by brainstorming possible form factors for the system (a) and sketched out some selected ideas (b). Then, we iterated on the ideas and created 3D models (c). We also used paper box to create some low-fidelity prototypes based on the 3D models. (d) shows early draft 3D models, which we then refined.

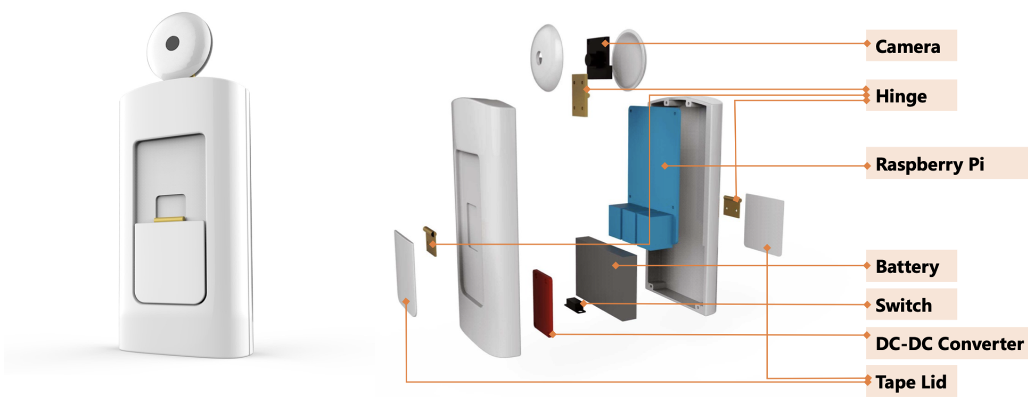

Figure 3: *Left*: The prototype (as an external camera) used together with a mobile phone (as a display), designed to assist patients in showing regions of their body in a virtual appointment. *Right*: Electronic components embedded in the prototype form, including a Raspberry Pi microcontroller and a compact camera module that allow patients to place and adjust its angle during the call.

the table surface. We intentionally added heavy-duty reusable tape on two sides of the form enclosure, so users can also stick Dr.'s Eye onto vertical surfaces, such as a wall. In addition, we designed the enclosure to be rounded to fit into a users' palm. The finalized form enclosure was designed with a slight anthropomorphic look to create a sense of accompaniment and to signal that the video stream would be delivered to a professional party in an appropriate context [16]. We produced one set of Dr.'s Eye through 3D-printing the final assembly. We used white-colored PLA material to print the form enclosure as it offers minimalist aesthetics and endurance for the study.

2) Mobile Phone User Interface: We used the web framework Flask and OpenCV to implement the video system. The design uses a mobile phone with a 6-inch screen to connect to the doctor who interacts with the system through a webpage. The user interface includes two camera views, a virtual cover button, a camera view

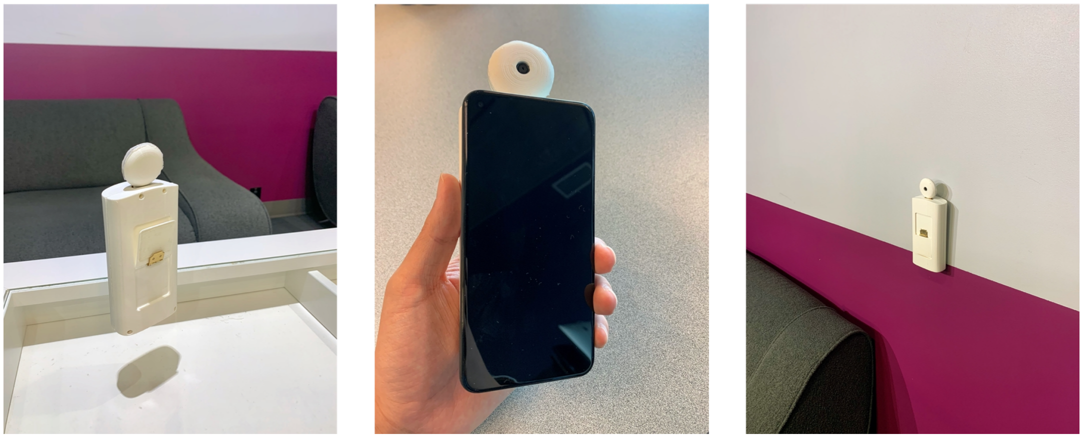

Figure 4: Dr.'s Eye external camera. It can be placed on a table or be attached to the back of a phone or onto a wall.

control button, a slider, and a text box (Figure 5(a)). Camera views come from Dr.'s Eye on the patient's side and the camera on the doctor's side. Patients can tap on the small camera view to switch which view they want to be shown larger at the top. When patients click the *Hide My Camera View* button, a message pops up at the bottom, saying "Doctor cannot see you now", to highlight that the doctor cannot see the patient's video stream until they click the *Show My Camera View* button (Figure 5(b)). When patients click the *Virtual Cover* button, their video stream to the doctor is automatically disabled, with a pop-up message stating "Doctor cannot see you now. Please select the area you want to show to the doctor". Users then can draw a circle by dragging (press down, move, and release) on their camera view to select an area they want to show to the doctor. After the selection is made, they can click the *Done with Selection* button (Figure 5(c)). The doctor will then only see the selected body area. Supported by a vision-based tracking system (see below), the circle follows the body region when the patients move the camera, to ensure that the doctor will not see other areas. Patients can also use a slider to change the level of desired transparency of the unselected body area. The doctor's webpage includes two camera views: a larger view of the patient, and a smaller one of the doctor.

4 STUDY METHOD

To form insights into our design's elements, our study aimed to understand how patients would use our video system in a series of simulated medical scenarios. The study was approved by our university research ethics board. This section describes how we conducted the study and collected data.

4.1 Participants

We invited 18 participants to participate in our lab study. They were all adults in the age range 21-75 (AVG = 41, SD = 16), eleven males and seven females. Participants were recruited via several strategies. We sent emails to university mail lists, posted ads on social media platforms, and posted posters on university and local library billboards. We also posted our study on the website of a provincial health research program, which sent recruiting emails to their patient network. We wanted our participants to cover a broad age group. We only included candidates who are familiar with the use of smartphones and video conferences.

4.2 Study Protocol

Each person participated individually in the study. First, we conducted a brief background inquiry to learn about participants' past experiences with family doctors in-person or over video. The inquiry was designed to help participants recall what situations they went to the doctor for, and how their appointment experience improved or deteriorated with the use of video conferencing.

Next, we conducted a lab study to investigate how the participants would use the new features of our video system. This required our study to be able to cover a range of scenarios that could potentially happen in existing or future doctor-patient encounters. Since the focus of our study is understanding our design features' usage and potential issues that might arise in real doctor appointments, we chose the approach of a lab study with simulated doctor appointments. In addition, we also recognized that having participants use our prototype in real doctor appointments might bring up significant privacy concerns. Doctor appointments and medical information are often considered to be confidential. Observing real doctor appointments can also be intrusive. Besides, participants may not be comfortable with sharing their health conditions. As such, we thought a good first step to understanding our system's usage and design was to use simulated appointments; this means that the design ideas could be understood more deeply and improved before future testing in real doctor appointments by us or others. In this way, we reduced the risk to our participants.

We were inspired by the scenario-based design and user enactment method [14, 46], which were generally applied to probe the design of artifacts with potential ways of usage within a lab setting. To understand the use of our video system in varying contexts, we designed a list of scenarios where a range of medical situations were presented. We asked participants to enact a patient as described in each scenario using our video system. Each participant was asked to go through all the scenarios using our system.

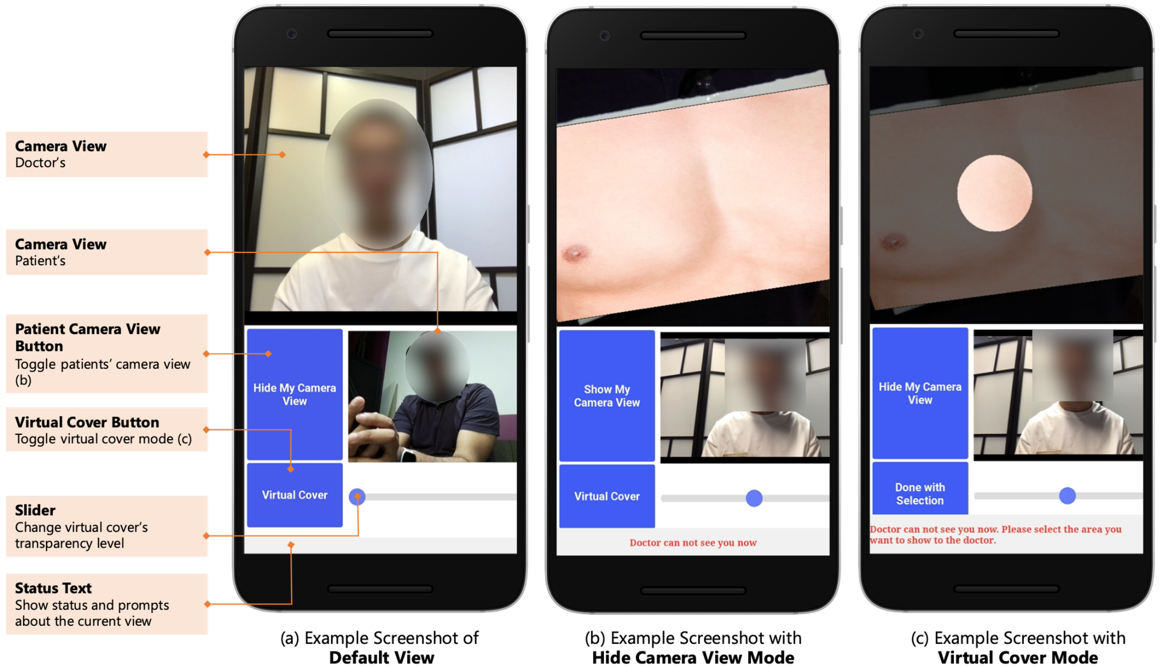

Figure 5: System interface on the patient's mobile phone. (a) Default page when the video call is initiated. (b) Video stream to the doctor is disabled when hide camera view mode is on. (c) Virtual cover mode is on. Patients select a circular area on the camera view. Only the highlighted body area is sent to the doctor.

We designed five scenarios representing varying types of situations where patient participants might use camera work differently when seeing a doctor actor. To design appropriate scenarios, we borrowed ideas from the participatory design study and brainstormed a list of medical situations based on how different features of our system could be applied when patients describe and present their symptoms over video. For example, decoupling camera and display can help a patient see what is being captured by the camera, when a body part to be shown that is out of their sight. Such body parts could be the inside of one's mouth, their neck, or back. Situations related to the mouth could involve a sore throat, swollen gums, or mouth sores. Then, we selected four scenarios which we believe could highlight the differences between our system and current video apps. We also included a situation which needed no camera work as the initial scenario, to help participants get acquainted with the process. This situation also served as a comparison point for the other scenarios so that participants could feel changes in using the system. Afterward, we iterated on the scripts for these scenarios and consulted with the family physician partnering in our research to ensure that the narrative corresponds to what happens in actual doctor appointments. Brief descriptions of the scenarios follow below where we describe the roles that the participants played. Table 2 listed what design features we expected to be the focal points for each scenario.

1) **Diarrhea**: The participant had diarrhea for a few days and consulted the examiner over video. The participant described their symptoms to the examiner. Then, the examiner prescribed a lab test and medication.
2) **Sore throat**: The participant had a sore throat and described their symptoms during the video call. The examiner asked the participant to open their mouth and say 'Ahhh' to expose the tonsils. Meanwhile, the participant held the camera to capture the tonsils clearly.
3) **Chronic pain in the knee**: The participant saw the examiner regularly for chronic arthritis on their knees. The participant was asked to lift and hold their thigh with two hands, and to extend the lower leg slowly to see if the pain was relieved. Then, the examiner asked the participant to show their ankle and press on it to check if it was swollen.
4) **Chest acne**: The participant had bumps on the skin of their chest. The participant was asked to show their chest to the camera. The participant needed to remove their top to show the area. (The participant did not actually remove their top; instead, they pretended to do so.)
5) **Post-surgery recovery**: The participant had surgery due to a lumbar disc protrusion. The participant video-called the examiner as scheduled to check on the recovery of the surgical site in their lower back. The participant was asked to pull down their pants to expose the surgical area and show to the examiner. (The participant did not actually pull down their pants; again, they pretended to do so.)

We took several measures to balance potential ethical risks with the realism of the video appointment scenarios. First, we did not ask participants to actually take off their clothes and expose their body parts, which would create significant ethical concerns. Instead, we printed fiducial markers and stuck them to participants'

Table 2: Features to be explored in the scenarios

Scenario	Decouple camera and display	Free capturing	Hide camera view	Virtual cover
1. Diarrhea				
2. Sore throat	✓	✓		
3. Chronic pain in the knee	✓	✓		
4. Chest acne	✓		✓	✓
5. Post-surgery recovery	✓	✓	✓	✓

Figure 6: Study room setting. Participants sat in the chair. The interviewer sat behind the divider during the mock appointments and returned to participants' space during the interview.

clothes. When our camera captures the marker, a vision algorithm recognizes the marker and replaces it with a generic picture of the corresponding part of the human body. Thus, the participant would see a camera view on the phone screen that was similar to their body being exposed. The purpose was to help participants experience a situation that reasonably faithfully simulates a real video appointment with a doctor. For example, in the *chest acne* scenario, participants were asked to put the camera close to the marker area. They would see a photo of a chest overlaid on the display. They could thus imagine how they would feel and what they would do in such contexts. We selected ten pictures for each body area, including chest and lower back, five from male and five from female bodies. At the beginning of the fourth and the fifth scenarios, we asked participants to pick the one they thought was closest to their own body. We explained to participants that the aim was to help create a feeling of realism, but that the video might not represent their bodies exactly. When participants role-played in these scenarios, the interviewer acted as a doctor and played the role of the examiner.

Participants completed the study from a mock home space in our research lab that contained couches, chairs, a television, a coffee table, etc. (Figure 6). For each scenario, we first gave participants enough time to read the script of the scenario and familiarize themselves with it. Rather than give participants specific instructions on how they should use different features, we told participants to go through the appointment in a way they felt comfortable with.

We set up a room divider to separate the interviewer and participant so they could not see each other during the mock appointment. The examiner (interviewer) saw participants using a laptop with a 13-inch screen and a camera. We muted the speaker so participants could hear the examiner's voice directly from the other side of the divider, to avoid audio issues such as overlapping audio or delay, and to ensure high communication quality during the study. After each scenario, the interviewer returned to the mock home space and interviewed participants. We adopted this approach rather than involving another researcher acting as a doctor for two reasons. First, observing participants from a third-person view might create a misunderstanding as to what exactly they showed with the camera. In comparison, the interviewer could observe participants directly from the first-person view of the examiner and might thus notice unexpected reactions from participants. Then the interviewer could bring up questions based on such observations. Second, a pilot study within the research team validated that the lab setting of dividing the space did not create a noticeable influence on 'patient' reactions, since the study was more task-oriented and ethical concerns had been minimized to protect participants' privacy. Despite this, we recognize this part of our method as a limitation of the work as patients might behave differently in their homes when compared to actual doctor appointments.

During the interview, we asked participants questions about their system usage and specific system features, such as "How do you feel about using the system for this situation?", "How do you feel about using the virtual cover feature in the video call?" and "How do you think the system can be improved?". In addition, we asked questions about system usage based on our observations. Questions included, "I noticed you did. . ., could you explain why you used it that way?" We asked questions that we felt would encourage participants to discuss challenges or concerns that might arise during real video appointments based on their experience interacting with the system, including "Is this something you could see working over a video call? Why or why not?" and "How is it different from using general video systems or in-person visits?" At the end of the study, we asked participants if there were other situations regarding video doctor appointments where our system could be helpful or challenging. The aim was to explore a wider range of contexts.

4.3 Data Collection and Analysis

The data collected from the study included audio recordings of the interview, video recordings of participants' behaviors in each scenario, and recordings of the examiner's (interviewer's) screen. Two researchers transcribed and coded audio recordings independently. We applied an inductive coding process to create codes. For example, codes like "position display" or "hold two devices" were created, representing challenges of participants operating our devices to capture their body in different scenarios. Then, the two coders discussed the codes, selected those we believed to be novel compared to prior work, and put them into a hierarchical coding frame representing different topics of camera work. Three high-level themes were created. These themes included *benefits and challenges in operating decoupled camera and display*, *camera coordination needs between patient and doctor,* and *patients' perceptions of viewing and sharing their own video streams.*

5 FINDINGS

In this section, we present the three high-level themes generated from our in-lab study data. The first theme (section 5.1) captures the benefits and challenges with our system in simulated appointment scenarios, which addresses our research question regarding how participants used the system designed for the simulated video doctor appointments (RQ1). The second and third themes (section 5.2 and 5.3) describe potential issues that might arise in real doctor appointments regarding participants' camera work coordination with the examiner and participants' concerns about viewing and sharing their own video streams, which both address our research question about challenges that patients may experience when using our system (RQ2).

5.1 Benefits and Challenges in Operating Decoupled Camera and Display

In this section, we describe both the benefits and challenges in using a system with a decoupled camera and display for mock appointments, including flexibility to capture body regions and difficulties in operating the system, based on our observation and participants' explanations.

5.1.1 Allowing Freedom to Capture Anywhere. Our participants recognized the benefits of having the camera separated from the display in those situations where they needed to capture a body region that was out of the range of their vision or when they needed to place the camera further away from themselves to show a view at an appropriate distance. In both cases, a separate display allowed them to view the camera's feedback, in situations where a coupled camera and display would have been hard to see. Participants shared the difficulties with traditional video cameras to be unable to see what the camera was recording. For example, in the *sore throat* and *post-surgery recovery* scenarios where throat and lower back needed to be examined, challenges arose if participants had to use the mobile phone's camera itself to capture the area and to simultaneously see what was showing on the screen, because the phone would be either under their chin or behind their back, which is clearly beyond a participants' capability to easily see. In comparison, the decoupled camera-display design allows participants to place the phone display in front of them and to move the unassociated camera around as desired. P5 discussed the ease of viewing the screen in these scenarios, "*since it was separate, I could bring it as close as needed*".

When using only a single mobile phone, the phone screen can be out of a patient' sight when the phone camera is set far enough away from the participant to capture more information (e.g., a full-body image, or performing movements). For example, participants brought up the issue in the *chronic pain* scenario where the phone might need to be placed on the floor at an angle where they could not see the display when walking forward or backward. Also, the phone might be too far away to see the phone image clearly. Yet, participants said that the separate camera could just be placed on its own, and they could still hold the phone in their hand to get a better view. P11 felt this scenario would be hard to do with traditional video technology, as "*you cannot just put the phone too far away from you*".

5.1.2 Challenges in Positioning and Operating Camera and Display. Despite the benefits of decoupling camera and display, our participants found challenges in holding the devices in their hands, coordinating two devices simultaneously, and getting used to orienting their sight to two different devices. The exams over video might be highly mobile so that patients may need to move their body in various ways, while the display would be expected to be mobile as well, to ensure that patients would have a comfortable viewing angle. Holding the display properly for it to be viewable to participants can became challenging. For example, in the *sore throat* scenario, participants held the camera in one hand in close proximity of their mouth (Figure 7 left). Meanwhile, they had to hold the phone in the other hand to see what was being captured by the camera. The situation worsened when they needed to raise their head up to get better lighting from the ceiling into their mount, since the inside of their throat was otherwise too dark to show the inside clearly. Thus, the phone had to be lifted higher, and it became challenging for participants to coordinate both devices. P1 commented that he had a hard time focusing on keeping the display up, so he "*had to basically prop the phone up*".

This issue also happened in other situations where it was not always easy for participants to put themselves into a comfortable

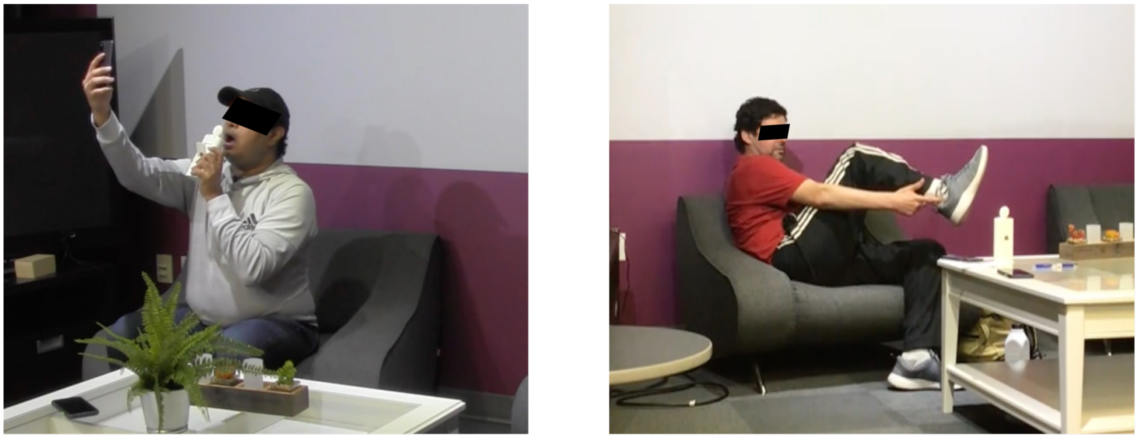

Figure 7: Examples of participants' usage of Dr.'s Eye (blurred and shared with proper consent from participants). Left: A participant showing their throat. Right: A participant showing their knee.

pose that affords a reasonably good view. We observed some participants laid the phone on the table and leaned their body forward to look at the screen; some used the plant container, which we had placed on the table for decoration, as a temporary "holder". Some participants raised the concern of finding a way to put the display in a fixed position to see it comfortably, especially when they "*had to work with both hands*" (P3).

In scenarios that involve fewer movements, operating two devices simultaneously can still be difficult as it increases the burden of usage. Participants told us they were not used to working with two devices simultaneously for a video call. In their prior experience, they were familiar with aligning a single phone to adjust the camera view. However, in the scenarios we investigated, they had to align the camera and simultaneously hold the phone steady to see what the camera was showing.

We also observed interesting behaviors in some participants when using our multi-device system. First, they felt confused by the camera and phone being separate when trying to capture something. When they were supposed to adjust the camera position or angle, their phone hand followed the camera hand involuntarily in performing the same action, or the phone hand shifted rather than the camera hand. Their upper limbs also appeared to become stiff and uncoordinated. Holding two devices seemed more of a struggle than holding a single device. P5 described this struggle with two devices: *"if I want to adjust this (camera) and I start adjusting this (phone) instead, and then, if I adjust this (camera) and subconsciously I have just moved it (phone) without like looking at it*".

To reduce the effort in using multiple devices, we found that our participants often set one device aside (fixed to a surface or semi-fixed to an object) and only focused on a single device. They generally preferred to fix the camera somewhere, for example, on the table, or "*stick it to the wall, TV, or something*" (P8) so that they would not need extra help from someone else. In the *chronic pain* scenario where we asked participants to stretch their leg and show their ankle, we expected they might place the camera on the floor. Yet, most participants twisted their body and leaned back in the chair to have their legs captured by the view of the camera standing on the table (Figure 7 right). Similarly, in the *post-surgery recovery* scenario, we expected participants to stick the camera to a vertical surface, like the wall or along the TV screen, and then stand in front of the camera to show their back to the examiner. Yet, at the beginning, they generally held the camera in their hand and curled their arm behind the back to try to capture that area. Then, they typically realized that it was difficult to capture all three markers that we had put on their back for overlaying the digital image on their body. Therefore, they then typically chose to stick the camera to the wall instead.

We assumed the reason behind this issue might be that participants tend to use the least effort to pose the camera. In these scenarios, bending down to place the camera on the floor would take more energy than lifting their leg; similarly, placing the camera in a stationary position, holding the phone, and moving themselves within the camera view takes more energy than moving the camera to show their back. We also asked participants for reasons behind their actions with the camera. They felt it "*just came naturally*" (P12) in a way they were "*very comfortable working with*" (P16).

In addition, participants unintentionally misaligned the camera view and the phone display. In a general video doctor appointment that solely uses the mobile phone, the camera is located right at the top of the display. The difference between the gaze orientation and the camera orientation is (relatively) minor, so that the user feels that they are looking at the remote person on the display. In our study, participants tended to place the phone face-up on the table and the camera standing beside the phone. This created a disparity between the gaze and camera orientation. In this case, they struggled with where to look at in the video call (i.e., to look into the camera or to look at the screen) with the examiner (P5).

5.2 Camera Coordination Needs between Patient and Doctor

In this section, we present camera coordination challenges we observed from our participants' usage of the system in mock appointments, and concerns that may arise in real doctor appointment behind distributing camera control.

Figure 8: Screenshot examples of participants' usage of Dr.'s Eye (blurred and shared with proper consents from the participants). Left: Not aware of an appropriate pose for the camera. Right: Uneasiness to reach to the camera and adjust its pose when showing body movements.

5.2.1 Lack of Communication and Awareness about Examiner's View. In our mock appointments, we found that the participants and the examiner often needed to coordinate over camera work, so that the examiner could instruct the participants to show enough information. When asked about challenges, our participants talked about their concerns on whether the image quality was good enough for an accurate diagnosis, and whether they could capture the correct region(s). The image quality is typically affected by lighting, image contrast, or camera angle. Participants doubted if the camera was able to show the details of their body as in the clinic, which led to a lack of trustworthiness with the system. Prior research has raised the lighting issue broadly, especially in teledermatology [30], where poor lighting showed skin color imprecisely and then led to misdiagnosis. This issue could be critical in general video appointment contexts as well. In our study, the issue refers to the fact that illumination is quite limited for certain medical situations. For example, in the *sore throat* scenario, participants had to turn toward the ceiling lights to get sufficient light into their mouth. They mentioned that they might have to do something similar in their homes or find an extra light source to help illuminate their inner mouth. Thus, it could be tricky to conduct such exams without special equipment like the handheld light used in clinics during real doctor appointments. Similarly, as P15 mentioned in the *post-surgery recovery* scenario, the lighting condition could be poor when participants fixed the camera on the wall and blocked the light, as they might stand close to the wall to capture their back. This suggests our device design should support extra lighting, e.g., by including a light in the camera device itself.

Our participants also talked about the lack of communication around what the examiner wanted to see, and the need for clear instructions from the examiner to "*move it (the camera) in a way for them to see it (the body)*" (P3). Specifically, they were not aware of what a 'right'/correct location to place the camera was, in terms of where to place it, which direction to orient it, and how far away to place the camera (Figure 8 left). Participants believed that visual feedback could help build communication and awareness about how to move the camera. They provided potential examples of the feedback, such as a visual sign on the display, as studied in prior research, e.g., in visual guidance for physiotherapy [66]. It could also be audio feedback or a combination of cues, as P1 suggested, "*when I bring it closer, maybe a target area is selected. So that's when it makes a beep sound that shows me a red circle*".

However, some participants told us that they did not need to see details on their display. They believed that only the doctor should have good visibility of their body. The role of patients was to provide the doctor with what they wanted to see, which was similar to a clinic context, where they did not have to see their own body when they were being examined. As P11 said, "*you don't need some details (of your body) . . . you only (need to) know what you need to provide to the doctors.*"

5.2.2 Concerns behind Distributing Camera Control to the Doctor. To improve the camera coordination between doctor and patient, distributing some camera controls to doctors could help resolve at least some of the communication challenges. Given a doctors' expertise or patients' limited mobility, many participants showed their willingness to have doctors more involved in their camera's controls. Participants told us that it was the doctor who was responsible for coordinating such work in their clinic, where patients generally comply with what the doctor asks them to do. In a video appointment context, patients need to take more responsibility to help the doctor get proper views of their body. Yet, our participants exhibited a reluctancy to spend extra effort. Thus, granting camera control to the examiner could help reduce the workload as they would not have to conduct all the camera work by themselves. This was especially noticeable when patients had limited mobility. As P10 told us, "*I think if somebody's in that much pain, where they are immobilized or not able to put a camera somewhere, they would likely have someone there to help them*." As a result, participants saw the benefits of handing over the camera control to the doctor, so that the coordination work for how they should precisely position the camera could be reduced.

Yet, challenges remain in deciding what types of control patients would like the doctor to have and how much control they are comfortable with handing over to doctor. The challenges mainly came from security and privacy concerns when sharing camera control and granting camera access. Some participants felt that it was appropriate for the doctor to make minor adjustments to the camera. This included zooming in or out, rotating the camera head, taking a picture, or controlling the light. Such "fine-tuning" camera control could be initiated when patients had already roughly oriented the camera to the area that needed to be viewed by the doctor. For example, in the *sore throat* scenario, holding the camera in front of the mouth was effortless. In contrast, subtle camera adjustments were usually needed to get the best orientation for the view of the tonsils, which might take substantial coordination work between the participant and the examiner. Participants indicated willingness to hand over camera zoom or rotation controls so they would not have to worry so much about showing the correct area. Such camera control could also help when participants placed the camera at a distance, e.g., to perform whole-body movements, where they could not easily adjust the camera (Figure 8 right). In this case, the camera's field of view might be limited to capturing what the examiner wanted to see, especially when participants needed to move around. Letting the examiner adjust the camera view to capture specific areas during participants' movements could also help participants concentrate on the task in these scenarios (P17, P14).

We found that the level of comfort with handing over camera control was related to a trusting relationship with their doctor. Participants with a good trusting relationship with their doctors were less concerned about letting the examiner take more control of the camera, similar to the access and power that doctors often had in clinical settings during in-person appointments (e.g., P4, P14). Still, unlimited camera control might allow the doctor to see their home space. Video doctor appointments can capture patients' personal information from their background, as P10 described, is like "*inviting people into your room*". Such information, like their "*favorite movie poster on the wall*", was often not shared when appointments were conducted in the clinical space.

Thus, participants preferred the doctor to focus the camera view only on their body, not elsewhere. This suggests a design space where the camera could be rotated or zoomed within limits when being remotely controlled by the doctor. Meanwhile, participants hoped they were able to manage when the examiner had the camera access and to supervise what the examiner was looking at after giving over the control, to assure that the examiner was not looking at something they deemed inappropriate. As P10 said, "*it would make the patient feel like they're in control of their own privacy.*"

Participants also raised concerns about trusting the system regarding its access to the camera. Once the camera was capable of being remotely controlled, there could be risks of being accessed outside of the appointment time, or even controlled by third parties. P5 mentioned that they expected the control to be properly revoked after completing the video call. Our participants also wanted to have a physical cover for the camera on our prototype to avoid it being accessed without awareness, as mentioned by P17, "*you never know if somebody can hack in and start viewing things without your permission*." Such physical components for revoking camera access are simple to include but can make participants feel to have more control over the device and reassure their privacy is protected.

5.3 Patients' Perceptions of Viewing and Sharing Their Own Video Streams

During the interviews, our participants talked about issues and concerns that might arise in real video doctor appointments, especially around viewing and sharing their own video streams with the examiner. In this section, we present findings on our participants' perceptions of viewing their own video on the display and their needs around controlling the sharing of their video in video appointments.

5.3.1 Patients' Perceptions of Viewing Themselves on the Display. Our participants talked about how seeing their body on the display can create a feeling of discomfort, which might discourage them from using such a video conferencing system for real doctor appointments, even though they understood it was necessary to see themselves as part of the visual feedback to know what the examiner was looking at. Participants explained that this discomfort might come from showing parts of their body that were not normally shown in a video call context, in contrast to only showing faces in more regular video-mediated communication. Our scenarios involved showing the throat, chest, and lower back. These body regions, as well as areas they would not expose in a normal social context, were considered 'private', and could make participants feel uncomfortable during real video appointments, as "*it wasn't necessarily what I do every day or even any day*" (P1). Showing such body parts over video was deemed poor self-image management by participants. They further interpreted that self-image created issues solely in a human-human interaction context, as seeing themselves in a mirror would not create uncomfortable reactions because no other individuals were involved.

Moreover, participants felt the experience of video appointments can be different from their experience in the doctor's office. They explained that when they were examined in person, it was usually the doctor who focused on their body rather than themselves. Yet, in video appointments, patients must set up the device containing the camera and focus more on their own body. Thus, not seeing their own body in the clinic might reduce consciousness of their self-image. This was reflected by comments from our participants as well. For example, P15 said that instead of just sitting there and letting the doctor do the exam when visiting in person, during video appointments the patient had to "*tape it themselves and figure out the angle and all of that*", making it uncomfortable. Therefore, a participant considered it might be better to send pictures or videos rather than show their body live to reduce their exposure level. If patients need to consult about chest area problems, they could just take "*a picture of [the] chest in advance instead of doing it on the call live*", which might be easier for patients (P5).

5.3.2 Patients' Needs in Controlling Their Video Stream's Viewing and Sharing.

Our design features *hide my camera view* and *virtual cover* allow participants to control the timing of sharing their video stream and the amount of information they want to share. Participants felt that these features could be helpful for real doctor appointments. *Hide my camera view* was treated as an initial process during which patients might need to take off their clothes and adjust the camera before exposing their body to the doctor. They felt it to be inappropriate and awkward to remove their clothes in front of the camera during video appointments. Having such a feature would also allow participants to still receive images from the camera, without having to go to another room to prepare for the exam (P18). This was different from current video systems which disable seeing images from the patients' side when the camera is turned off.

In addition, participants thought that the *virtual cover* feature could help them hide what was not necessary to show to the examiner during video appointments. For example, in the *chest acne* scenario, participants felt that the examiner only needed to see the bumps on the skin, and that it was unnecessary to have the whole chest area exposed. Some participants also believed that the level of exposure is lower with our virtual cover feature in video appointments, compared to the level of exposure in in-person appointments. (P3).

We also observed that participants tended to place the camera on the table rather than holding it in their hand close to the chest in the *chest acne* scenario. This was in contrast with showing the ankle in the *chronic pain* scenario, where they generally placed the camera very close to the foot. Still, this might reflect that the virtual cover feature could reduce the workload of maneuvering the camera. Direct area selection on the camera view should help the patient and examiner focus only on the area needed to examine, as expressed by P1, "*from a perspective, if I only wanted to source certain region of the body and focus on that, that makes sense.*"

Video systems not only need to provide privacy-preserving features like hide camera view and virtual cover in our prototype, but also need to better communicate how patients can control the viewing and sharing of their video streams. More specifically, systems need to communicate the status quo of their video stream (e.g., what is shared and what doctors can see). Our participants expressed the feeling that the feedback was confusing when they turned the hide camera view or virtual cover features on. They said they still saw the same image of themselves when using the *hide camera view* feature, though there was a prompt at the bottom saying that the examiner cannot see their image. This might create the illusion that the examiner can still see them. As P7 told us, "*I think I can hide my camera view, but because in my phone it still shows myself, so I feel a bit unsafe about that.*" Participants are apparently used to current video systems' design, in that other individuals can see them when they are able to see themselves on the display. Thus, participants desired more obvious feedback, for example, a popup message on their images, or a change in the coloring of their camera view (P5).

Our current implementation of the virtual cover feature with a slider to change the transparency of the unselected area also resulted in ambiguous feedback to participants. They felt that changing the transparency was a way of blurring how much the examiner could see. For example, when the image was generally darkened out with only a specific area visible, P1 imagined the examiner would be able to see the exact video feed as what the patient was seeing. Thus, our participants wished to have fewer options for how they could see their blurred body, while they could still use the image as a reference for where to position the camera. As P6 told us, "*It was great on the plus side to be able to see [on] the phone what is happening, I was able to glance at it and move the camera device.*" Moreover, some participants suggested that their camera stream should be darkened when the virtual cover button was pressed. Then the area they selected could be highlighted to indicate the area to be shown, which would be clearer than using only a red circle to identify the area. They also suggested supporting free selection in case there might be multiple places they would need to show.

6 DISCUSSION

In summary, our study confirmed the benefits of decoupling camera and display and provided directions for potential improvements for such a multi-device video system. We identified current challenges in coordinating camera controls and in adjusting the video feedback, suggesting future system features to support these needs. Our findings also revealed patients' concerns behind distributing camera controls and sharing their video stream during a video appointment, highlighting the importance of trust in remote doctor appointments. In this section, we discuss ideas for future design implications based on patients' use of our system.

6.1 Support Decoupling Camera and Display

Our study revealed that decoupling the camera and display can provide more flexibility to help patients capture various body regions. Otherwise, they must rely on the examiner's verbal instructions to receive feedback. When using a single device such as a mobile phone, tablet, or desktop computer, it can be challenging for patients to see the display while capturing different parts of their body. Current video systems typically do not support such features, unless initiating a triadic video call by, for example, using a laptop and a mobile phone to join the meeting. This typically adds further challenges in terms of positioning two devices and coping with dual cameras, views, and audio channels. Prior research has explored configurations for and usage of multiple devices in the workspace [13, 72], where people might integrate several devices simultaneously to achieve a task. However, the supported tasks in that work are quite different from our body exam tasks. In a workspace scenario, users usually work in a limited area and devices are generally stationary without having to be highly mobile during the tasks. In contrast, in a body exam context, the camera and display should be able to allow patients to capture and to view feedback simultaneously. Stevenson employed similar setups in healthcare facilities for patients in a doctor appointment room with multiple monitors and cameras [63]. Their study provided similar insights about supporting examination from and mutual awareness of different views in remote doctor appointments. Our work extends their communication framework to the home setting, where patients may have limited access to devices and may not have the additional assistance that might be available in a healthcare facility. The examining work becomes more challenging in a home setting, as such work is at least partially transferred from the doctor to the patient. Patients must play two roles: both *examinee* and *examiner*. Unlike the prior work which investigates a decoupled configuration in surgical interventions where the examiner dominates the camera control [38], our work discusses considerations for this configuration emphasizing a patients' perspective.

To deal with positioning and orienting challenges in using two devices, an intuitive idea is to reduce patients' work as an *examiner*. One approach could be decreasing patients' work of moving the camera or display. Previous research has explored camera control with panning and tilting functions, which can automatically follow a user's specific body part [15]. The system may employ such features to capture a patients' body movements, such as during walking, to avoid the need for manually adjusting the camera or giving over camera control to the doctor. The display could also be flexible, for example, by mounting it onto flexible stand that can support high degree-of-freedom positioning in a space [35]. Such an assembly could provide patients with feedback on the camera view from a range of perspectives without the need to hold the display within their view. Prior research in surgical collaboration explored the use of Google Glass to support information sharing, images interaction, and shared decision making [37], where the collaboration happens between two professionals. The doctor-patient context in our study differs in that a notable knowledge gap exists between them. The context involves more instructing than collaborating, which is also validated from prior work showing that communicative asymmetry [22] is magnified in the use of video conferencing for medical appointments, as patients have to take more responsibilities [1]. This suggests a design space in considering how the patient may interpret instructions from the doctor in the form of images or annotations when they are asked to show a part of their body or body actions. Another approach could be handing over camera control to the doctor. Telepresence robots have been used in conferences or homes [44, 71] and could potentially be used in video appointments. This would resemble examinations in a clinic, yet the doctor would be embodied in the robot and examining patients in their homes. However, for such a robot solution, our participants shared concerns about showing too much of their home space and the robot being out of their control. Such concern is also related to doctor-patient trust relationships. Thus, future research might explore how to manage the doctor's control and the coordination work between doctor and patient. In addition, we also see emerging approaches that use smartwatches as the display, while the phone camera is used to take photos or record videos. A similar method could involve other wearable devices, for example, smart glasses [40]. One central issue is that such pricy devices might not be accessible to patients in their home. Low-cost cardboard goggles where users can embed their phone [49] might help with the display positioning issue.

6.2 Support Distributive Camera Controls and Adjustable Video Feedback

Conducting video appointments in the home gives patients more autonomy and control over what the doctor can see. Participants were willing to grant the minimum camera control needed to achieve the examination task. They hoped the examiner can only see what is necessary to assess their conditions. This raises a design challenge. Patients must be aware of what kinds of exam the doctor will conduct, so they can set up the boundary of the camera view that the camera may cover. This might require the virtual appointment system to offer pre-guidance before the appointment to inform patients what might be involved in the exam. Still, the set-up process for an appointment should be efficient to avoid occupying too much time. To implement the control strategy of setting up the camera's view range, the video system should support features recognizing patients' bodies. Because the camera might need to be positioned differently, the system should be able to understand which area the camera is capturing. Prior work adopted a 360-degree camera for video conferencing, where the local user sees a portion of the remote environment [61, 64], which means the camera view is virtually controlled. This inspires a design that could allow patients to set up a virtual boundary that limits what the doctor can see. Prior work [36] also explored the use of touchless interaction where the device is distal from users, which unfolds interaction mechanisms among devices and collaborative parties. Applying their insights to the doctor-patient coordination context, cameras or displays from the patient's end could work as shared devices and could be controlled by both the patient and doctor to facilitate body capturing and presenting.

The 'hiding the camera view' and 'virtual cover' features allow patients to show only what is necessary to examine. However, the interface design in our current system caused confusion about what the examiner could see. Common video doctor appointment interface designs follow the principle of *seeing what other people see*. To comply with this principle, an extra viewport could be added on the patient's side, showing a view that shows what the doctor can see on their screen. Then, patients would know what the doctor is seeing, which would reduce confusion. Another solution could be providing clearer visual cues, for example, employing a translucent filter, adding a camera-off icon on the camera view, or using a pop-up prompt. Future work might explore what types of view feedback might be easier to perceive. The transparency changes of the unselected body area also created confusion whether the doctor could see it. Considering that seeing one's private body parts could lead to discomfort, future designs should keep darkening the unshown parts of the camera view.

6.3 Support Patients' Trust Building During Video Appointments

Patient trust plays an important part in doctor appointments, especially in remote settings. Prior literature often discusses patients' trust in technology systems [27, 56] as well as their trust in medical professionals [7, 57] in the healthcare context. Our findings also highlight the critical role that trust plays in video doctor appointments and suggest trust-building as an important consideration for future video appointment systems.

When asked about concerns, our participants expressed mostly privacy and security concerns with a video doctor appointment system. Prior work in studying patients' trust in technology systems discusses the importance of the permission and consent process in gaining trust, especially for systems that collect highly sensitive data [33]. Our participants also discussed the needs for consent or legal agreement during a system's onboarding process to help address their concerns. The system's physical design can also help build patients' trust in the system by letting patients have physical means to protect their privacy. For example, adding a physical cover to the camera to help patients hide their camera feed, or having a removable battery source to completely turn the device off. Thus, both interface and physical components should be considered when designing future video system features to support patients' trust building with the device.

Our study found that changes from offline to online settings (e.g., patients need to play roles both as an *examinee* and an *examiner,* with camera control responsibilities in remote exams) could potentially affect doctor-patient relationship dynamics. Although most of our participants expressed their trust in doctors, they talked about potential scenarios and tasks they feel less comfortable with over video calls because they may not know the doctor well. The insights on distributing camera work responsibilities between doctors and patients demonstrate how patients' trust level affects how much control they feel comfortable giving doctors over the camera (section 5.2). Previous work often talks about supporting doctor-patient trust building as a more long-term process for promoting positive health outcomes for patients [20, 25, 41], while our study shows some insights on potential factors behind patients' trust during short-term video appointments. To support trust-building over video doctor appointments, future systems should consider design features that help doctors set a professional atmosphere and communication, to mimic the clinical setup that patients are used to. For example, having a built-in "start examination" feature for patients and doctors provides step-by-step instructions for doctors to walk through and lets patients adjust their camera feed (hide, cover, or show everything) at the beginning of each step. Future system design could also consider providing patients with more transparency over what doctors can see and control during a video appointment, to ensure doctors' access and control match patients' level of trust in them.

6.4 Limitations and Future Work

Our work focused on understanding the use of the camera and display with our system prototype to generate early insights about potential issues that might arise in real doctor appointments. This informed our decision to study our research questions in a lab setting using scenarios that simulated doctor appointments. This approach allowed us to observe participants' usage of the system prototype closely and understand their concerns and challenges with our design features without infringing on participants' privacy. That said, our findings are affected by our lab setting as well as our participants' demographics. Having participants use the prototype from places that are dissimilar to our lab setup might generate different insights about the system usage and challenges. Although we recruited participants from a broad age range, we did not specifically recruit people with accessibility issues or those who were unfamiliar with technology. Future work investigating these groups of patients' can provide insights about their challenges in video doctor appointments. In addition, we did not involve doctors in our lab study nor did study our system's features in real doctor appointments. Future studies with doctors or using real doctor appointments as a study context can thus provide further insights on the issues that we uncovered in our lab study.

7 CONCLUSION

We designed Dr.'s Eye, a video system to support patients capturing their body using separated camera and display for virtual appointments with a doctor in a home setting. We contribute an understanding of how people use our system in simulated medical situations and insights into potential issues that might occur during real medical appointments. Our findings reveal that by providing additional freedom through an external camera device Dr.'s Eye can support participants in showing different body regions, while also protecting their privacy. We highlight design challenges in terms of operating two devices, distributing camera control, as well as managing self-consciousness and the environmental change in the virtual appointments. With the findings and challenges identified from the study, our work contributes discussions of design thoughts for future video systems, on view feedback, camera artifact usability, and camera work collaborations.

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