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Towards Better Remote Healthcare Experiences: An mHealth Video Conferencing System for Improving Healthcare Outcomes

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Abstract. This work investigated how to combine mobile cloud computing, video conferencing and user interface design principles to promote the effectiveness and the ease of using online healthcare appointment platforms. The *Jitsi Meet* video conference technology was selected from amongst 27 competing systems based on efficiency and security criteria. This platform was used as the foundation on which we designed, developed and evaluated of our video conferencing system specifically designed for improving doctor-patient interaction and experiences. Nine doctor-patient functions were developed in order to facilitate efficient and effective online healthcare appointments, such as providing the doctor with the ability to collect specific video and images and full integration with existing Electronic Medical Records (EMR). The effectiveness and usability of our system were evaluated by 36 participants–31 laypersons acting as patients and doctors, and 5 actual healthcare professionals. The mean System Usability Scale (SUS) usability score was 76 (high) indicating an overall positive UI design and effective system.

Keywords: Video conferencing · Telemedicine · Healthcare · Mobile health · Mobile cloud computing · AI and Healthcare

1 Introduction

The healthcare industry uses a variety of technologies for enhancing patient services in an assortment of ways [18]. Specific technologies enable physicians to examine and zoom in on specific parts of the patient, storing images or videos and seeking counsel from other physicians through remote collaboration [3]. These technologies also provide patients with convenient services to address their chief complaints all from a location of their choice while saving both patient and doctor time.

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From an environmental perspective, online appointment systems decrease the carbon footprint since they reduce the number of transportation trips to physician offices [2,12]. The number of diagnosed diseases, especially with seniors, is significantly increasing [10]. Furthermore, the length of stay of elderly people admitted to hospitals is growing too [10]. Online healthcare appointments address these issues by providing a more convenient healthcare appointment system which in turn potentially reduces the number of seniors admitted to hospitals and the length of their stay in the hospital [28]. The number of patients and the size of the wait list at Emergency Departments in various cities around the globe is also increasing [18]. This problem is further exasperated since most people who visit an Emergency Department do not need to be admitted to hospital [10]. In 2017, the Canadian Institute for Health Information found that 9 out of 10 people left the Emergency Department within 7.8 h [10]. This means 10% of people had to wait even longer. To improve or at least maintain the health services being provided at present, the number of physicians, nurses, and caretakers have to be increased or the communication means have to be more efficient [10,18]. Another motivation for a dedicated doctor-patient videoconferencing system is that seniors who are homebound may not be receiving the necessary personal care that a personal support worker or nurse could provide on a regular basis because they are not able to drive, their family members may be too busy to care for them or take them to a clinic or hospital, or they may be located in a remote community where there are no doctors available [18]. These limitations have a significant impact on the quality of life for these important members of society. Our work aims to improve accessibility of healthcare services by developing an easy to use an online platform to facilitate healthcare appointments by combining video conference calling, mobile computing, cloud computing, and wearables. The main contributions of this work include: (1) an easy to use and secure video conferencing platform; (2) a simple and secure authentication process; (3) a user-friendly interface model for mhealth video conferencing applications, and (4) a novel combination of video conferencing, mobile cloud computing, AI and wearables.

This paper is structured as follows: Sect. 2 presents a background review of similar work in this area, Sect. 3 presents the methodology employed to create and evaluate the system, Sect. 4 presents the findings (analysis and evaluation), Sect. 5 is the discussion, and Sect. 6 presents the conclusions.

2 Background

This section discusses the area of mHealth, its benefits and limitations including background of using the technology to facilitate online doctor appointments and the proposed system.

2.1 MHealth and the Online Services

Dr. Christine Walters, Global Health Industries at PwC (PricewaterhouseCoopers) indicates (2019) that aging societies are intensifying pressures on health systems and demanding new directions and innovations in healthcare delivery, particularly in long-term care and chronic disease, citing mobile health's (mHealth) potential, in technology and analytics, for cost-effective solutions to prevent disease and bring greater precision to predicting patient behavior and detecting/diagnosing diseases [28]. PwC indicates that in the next five years, globally, 25% of healthcare will be provided virtually [28]. PwC also estimates that together the U.S. and Canada form a strong emerging market in mHealth, capturing 28% of the market by 2021. PwC states that most of 40 million patient visits a year in the States alone could be avoided (e.g., hypertension) through mobile health [28].

The current adoption rate for online health-related services is affected by the age of the patient and varies from country to country [27]. Research has shown that a lower number of seniors (65+) use online health services compared to younger patients [2,27]. However, this trend is changing rapidly due to the aging population that is becoming increasingly tech-savy [7,12].

2.2 The Jitsi Meet Platform

A variety of different generic video conferencing systems were evaluated to find the best one suitable for our needs. The main features we were looking for were: 1) healthcare focus, 2) works seamlessly in browsers without the requirement of any plug-ins or app downloads, 3) cross device support (runs on any phone, tablet, laptop or desktop), 4) security, 5) ease of use, 6) API for extendibility, and 7) open source-so we could build our custom doctor-patient functionality. We evaluated 27 video-conference systems using this criterion [7]. Table 1 shows the results of the top 5 systems: Secure Video, OmniJoin, Vsee, Vidyo.io, and *Jitsi Meet*.

Table 1. Evaluation of various video conferencing systems

Criteria	Secure video	OmniJoin	Vsee	Vidyo.io	Jitsi meet
Healthcare focus	✓✓✓	✓✓✓	✓	✓	✓
Works in a browser	×	×	✓	×	✓✓✓
Cross device support	✓	✓	✓	✓✓	✓✓
Security	✓	✓	✓✓	✓	✓✓
Ease of use	✓✓✓	✓✓✓	✓	✓	✓✓
API	✓	✓✓	✓	✓	✓✓✓
Open source	×	×	×	×	✓✓✓

Legend: ✓: acceptable, ✓✓✓: very good, ✓✓: good, ×: poor

Only a limited number of video conferencing systems are built for browsers such as *Jitsi Meet*. *Jitsi Meet* immediately makes our application more accessible for cross platform and independent of form (mobile devices) than other video conferencing systems. For example, a patient can easily join a call with his/her doctor by a simple click on a link. This link could be provided through email, SMS, or any other form of communication. Once the patient clicks the link, s/he will be placed into the call–no downloading or installation is needed, as the video conferencing is all done through the browser. Similarly, for the doctor, a link can be generated from the associated EMR system based on a patient booking schedule for instance. Alternatively, the doctor could generate a virtual room and send an invite to the patient in a secure and confidential manner. The doctor has a specific view that provides physician features that are activated via URL parameters in the web link.

3 Methodology

The methodology in this project involved the following steps: create the architecture for our novel mHealth video conferencing system; design and implement specific functions to facilitate effective remote doctor appointments; design and implement the video conferencing user interface; conduct 2 experiments: Experiment #1: Evaluate our mHealth system's user interface and functionality using survey designs (e.g., System Usability Scale); Experiment #2: Engage healthcare professionals to evaluate our mHealth system and lastly analyze and evaluate the results.

3.1 Architecture of Our New mHealth Video Conferencing System

Our mHealth video conferencing system is built on the *Jitsi Meet* platform that uses Selective Forwarding Units (SFU) to efficiently relay audio and video among two or more participants. The architecture of our system has two main components (see Fig. 1). The first component is a signaling server and the second is a media server. This separation helps in implementing the SFU for selecting an optimal path between the endpoints in a conference. The system uses a STUN (Session Traversal of User Datagram Protocol [UDP] Through Network Address Translators [NATs]) server to allow NAT clients (i.e. IP Phones behind a firewall) to setup phone calls to a VoIP provider hosted outside of the local network [25]. The STUN server allows clients to identify their public address, the type of NAT they are behind, and the Internet side port associated with the NAT with a particular local port [25]. This information is used to set up UDP (User Datagram Protocol) communication between the client and the VoIP provider to establish a call (see Fig. 1).

Cascading SFU Problem. *Jitsi Meet* selects multiple forwarding units to establish a conference connection among multiple callers. The selection of the best combination of forwarding units is a challenging problem called the Cascading SFU (Selective Forwarding Units) problem [11]. *Jitsi Meet* implements cascading SFU by using multiple servers in a conference so that each caller connects to a local server while server to server communication has been allowed [1]. The *Jitsi Meet* separates a signaling server (*Jicofo*) and a media server/SFU (*jitsi-videobridge*). This separation enables *Jitsi Meet* to select an optimal path between the endpoints in a conference [8].

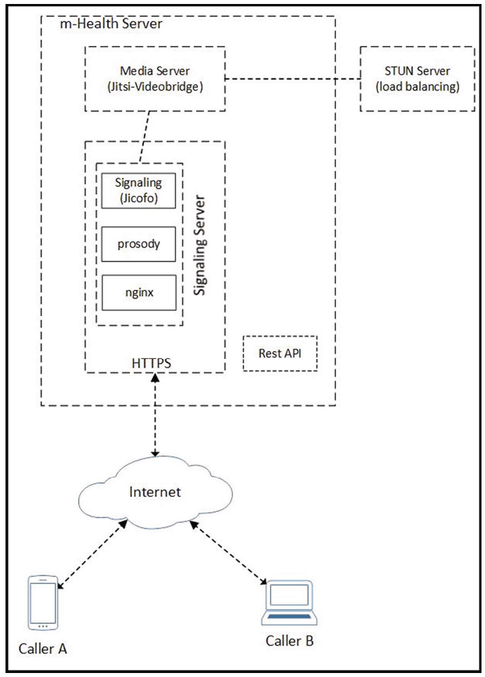


Fig. 1. High-level architectural model

REST APIs. REST APIs provide multiple functions. First, it provides a secure robust communication for the video conferencing application and the server to save all media from each call. The REST API receives metadata for each media type and converts the data into the appropriate file format and saves it in an EMR. Currently, the naming convention for each media file is *conference id* followed by the time the media was captured. Secondly, the REST API is made for SQL insertions in the database. The database can be used to record call details, such as the IP addresses of the participants, call length and conference ID. Thirdly, it authenticates the doctor's credentials using a password to ensure the integrity and confidentiality of the video session with the patient. This is done by making the doctor type in his/her password on the client-side that is encrypted and sent to the REST API to verify the password is correct and sends a response code back. Based on the response code, it will either let the doctor in or ask for the password again.

3.2 Design and Implement Specific Functions to Facilitate Effective Remote Doctor Appointments

Four categories of new functions were developed to facilitate doctor-patient online appointments. These categories include patient information functions, examination enabling functions, media functions and prescription generation functions. This section provides brief descriptions of these functions.

Patient Information Functions. This category of functions facilitates the access to patient information such as the patient's chart during the video conference call. This category includes two functions. The first displays the patient information to the doctor during the video call. The patient information includes the name, reason for the call (chief complaint), *conference id* and the date (see Fig. 2). The second function enables the doctor to open the patient chart during the call.

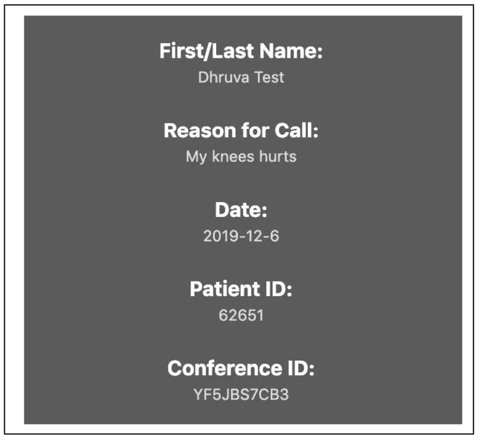


Fig. 2. Patient information

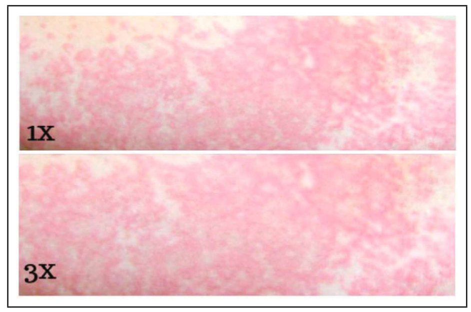


Fig. 3. Zooming on a video

Healthcare Professional Examination Enabling Functions. This group of the functions was developed to enable doctors to examine various body parts or patient behaviours online during or after the video call. This category includes four functions: Screenshot, Snippet Recording, Zooming, and Artificial Intelligence (AI). The Screenshot function enables the doctor to take a screenshot of any part of the body such as the arm and refer to the image during or after the call. The Snippet Recording function works in tandem with the Screenshot function. The Snippet Recording function is used when the doctor needs a small video clip rather than a single frame. There are numerous diagnoses that require the doctor to see the patient perform a particular movement or action [23]. For example, suppose a patient has Lateral Epicondylitis (tennis elbow), the doctor could record the degree of flexibility the patient can comfortably demonstrate as she moves her arm. The snippet will appear in the media list to be viewed or deleted after the recording has finished. The Zooming function helps doctors to get a closer look as depicted in Fig. 3. We implemented an AI function when the doctor takes a photo. The image is submitted to a computer vision AI service that assists the doctor in the diagnosis process. Our AI implementation is currently using the Google Cloud Vision REST API service. This service sends back a list of the top three most probable diagnoses the AI believes it to be based on the supplied video/image (see Fig. 4).

Prescription Generation Functions. Our mHealth video conferencing system also supports the generation of prescriptions by doctors during the call if needed. This feature is provided in the interface as a separate tab. Details can be easily selected through drop-down menus of commonly administered medicines and dosages and an intuitive interface to enter specific instructions for the pharmacist. Once completed, a PDF file will be created for the doctor to send to the patient's pharmacy (see Fig. 5).

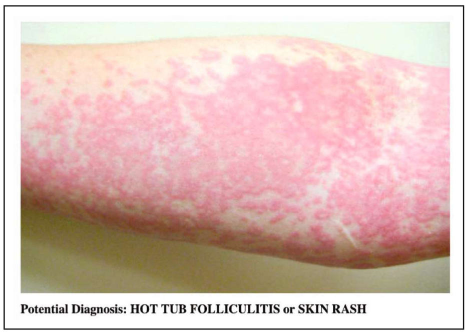
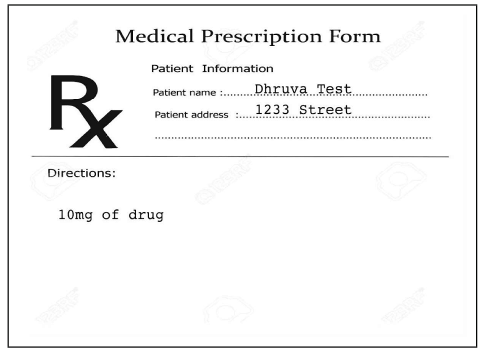


Fig. 4. AI diagnosis


Medical Prescription Form

Patient Information

Patient name : Dhruva Test

Patient address : 1233 Street

Directions:

10mg of drug

Fig. 5. Prescription

Media Functions. The media functions enables the doctor to access the media files and check the quality of internet connection. This category includes two functions: Media List and Video Quality. The Media List function displays all recorded media during a call. This includes screenshots and video snippets (see Fig. 6). The doctor can also view any media during or after the call has finished. All media are available in a separate tab which ensures a clean interface and consistent video interaction between doctor and patient. Any media can also be easily and securely deleted by the doctor at any time. The Video Quality function displays the call quality in real-time. The options are AUX (audio only), LD (Low Definition, 240p), SD (Standard Definition, 480p), and HD (High Definition, 720p) (see Fig. 7).

Currently, the images and snippets are saved on the host EMR server which also hosts the video conferencing system. The media stored can be retrieved with a REST API function, where the doctor could search for *conference id* and be presented with all relevant media associated with that call. A search page also enables the doctor to efficiently find patient data and associated media.

Medical Data Security. The data from each video call is saved on a secure server that can only be accessed from the local network of the medical facility. The system complies with HIPPA. Furthermore, *Jitsi Meet* has built-in end-to-end encryption [1]. *Jitsi Meet* uses hop-to-hop encryption, which means all data are encrypted, then decrypted on the server.

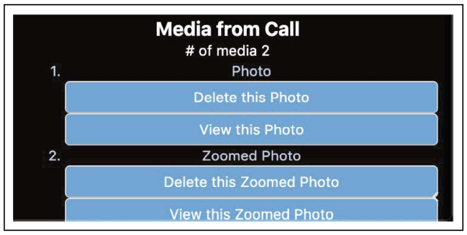


Fig. 6. The media list function

Fig. 7. Quality label

3.3 Design and Implement the Video Conferencing User Interface

This section describes the method by which we designed and implemented appropriate user interfaces for doctors and patients in our videoconferencing system that used the newly created services. The UI was designed to satisfy our requirements for the system to be completely cross platform and device agnostic (web, Android and iOS devices).

Web Applications. The UI design went through several agile development iterations. After testing the system with various stakeholders including our industry partner, we refined the UI such that the video view section represented 75% of the screen. The motivation for this is to allow the doctor to see more of the patient. At the same time, we removed the notes section and the small self-video window. Collectively, this allowed us to make more room for the main video window. We added a dedicated button for taking screenshots and grouped it with the other feature buttons that we implemented. The final version of our system is based on the latest version of *Jitsi Meet* with the media list and Artificial Intelligence modules. Figure 8 presents the doctor view of the final version of our mHealth video conferencing system.

Mobile Application. The mobile app version of our system (i.e. for tablets and phones) went through a similar agile refinement process but retains the essence of the web version. The only substantial differences include a button that allows the doctor to put in a password on the main screen, and enabling the doctor to generate a room from his/her phone. Patient's running our app on a mobile device however, do not have access to this feature and can only use the app to enter a call from their mobile device.

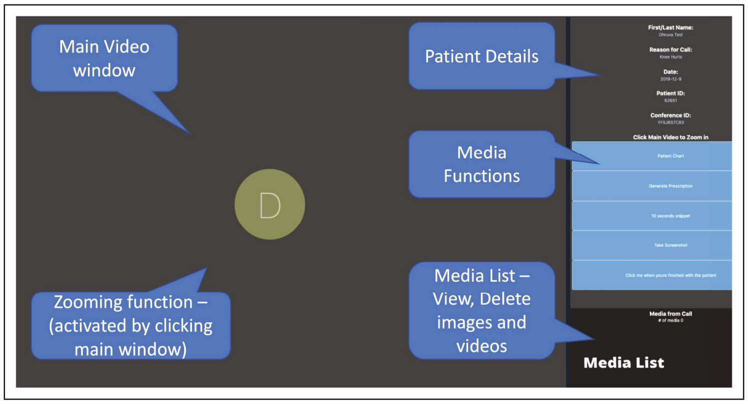


Fig. 8. Final user interface of our mHealth video conferencing system (Doctor-view)

3.4 Experiment #1: Evaluate Our mHealth System's User Interface and Functionality Using Survey Designs (e.g., System Usability Scale)

An experiment was designed to test the effectiveness of the mHealth video conferencing system with participants by eliciting their responses regarding the functionality and usability of the app. This section presents the participants, the survey questions and the experiment design. This Experiment focuses on general participants's feedback but Experiment #2 focuses on doctors's feedback.

Participants. In this experiment, we asked volunteers to serve as healthcare practitioners and later as patients. These participants were not healthcare professionals but offered a layperson's perspective. We did this because it was extremely difficult to elicit professionals to volunteer in this study. The total number of participants was 31. The participants were gathered by convenience sampling (students from the educational institution). Some participants were comfortable with technology, while others had little to no technology background. The professions of the participants were also diverse. Some people were in healthcare and fitness, others were in property management and hospitality, and some in business and finance. The ages sampled were quite varied, which allowed us to get a perspective from a diverse spectrum of ages and computer abilities. The youngest was 20 years old and the oldest was 61. The mean was 32.1. All gave written informed consent and the educational institution's Research Ethics Board approved the protocol.

The Procedure. Participants were first introduced to the system. A brief orientation manual was provided at the beginning that illustrated the features and components of the user interface. The researcher demonstrated the system as a walkthrough for each participant. Participants were also welcomed to ask any questions during the demonstration. The participant was asked to read the patient instructions, then act as a patient. After the participant felt s/he was ready to start, the patient evaluation procedure commenced which involved testing each of the features of the system from the patient perspective. Once completed, the patient survey was administered. After a brief break, the participant was asked to take on the role of a doctor and read the doctor's instructions. After the procedure was finished, the participant completed the doctor survey. The researcher was present during the entire procedure and responded to any question the participant had. This served to gain invaluable insights into how actual doctors and patients may use the system in the future.

Data Collection. In this experiment there were three distinct survey instruments used. The first was an opening survey that collected information about the participant's age, gender, computing background, etc. The second survey was the well-established System Usability Scale (SUS) that facilitated evaluating the participant's opinion on the usability of the mHealth system [4]. The third survey was a closing questionnaire which captured the participant's general impression of the system and elicited anecdotal feedback.

3.5 Experiment #2: A Survey for Healthcare Professional to Evaluate Our mHealth System

This mHealth video conferencing system was built for healthcare professionals. We created a custom survey designed for the purpose to elicit feedback from this population specifically.

Participants. We conducted an extensive outreach effort to recruit doctors, physicians, surgeons, nurses, and other healthcare professionals, regardless of whether they were part of a bigger facility or if they managed their own practice. We reached out to 105 doctors, physicians, surgeons, nurses, and other healthcare professionals. The method of recruitment was diverse and encompassing. We used multiple search engines (e.g., Google, Bing, and DuckDuckGo) using key words, such as "doctor", "physician", "surgeon", etc. We searched locally, across Canada, and the United States. Our recruitment goal was to elicit as many healthcare professionals as possible. We then contacted these medical professionals using email, and web-based forms provided on their site. 80 respondents expressed interest. From this pool, many expressed that in order to complete a research survey would require financial compensation that we were not able to provide. In the end, we had 5 participants that provided their professional opinions on our mHealth system that completed the survey.

Healthcare Professional Survey Design and Procedure. The healthcare professional survey that we created is divided into three sections. The first part elicited information about the background of the individual. The second part elicited responses on the application layout and user interface based on video and images that explained the various functions and features of our video conferencing system (these videos/images were embedded in the survey). The third part asked the participant's opinion on the unique features we implemented in our system (e.g., zooming, image and snippet storing, integration with EMR, etc.). The survey was provided in a Google Forms, which allowed the survey to be accessed from almost any device or computer around the world. This form also enabled demonstrative videos and photos of our system to be embedded in the actual survey so that the healthcare professional could easily see, review and assess the custom implemented features.

3.6 Analysis

Both quantitative and qualitative analysis were performed: the principal method was evaluating our system using survey designs and usability studies involving diverse backgrounds of participants.

- The effectiveness of our system was measured on eliciting feedback from the two participant groups.
- The usability of the system was determined by using System Usability Scale (SUS) surveys and researcher observation as the participants tested our system [5]. An analysis of 5000 SUS results in 500 studies across a variety of applications found that the average score is 68 [4]. A SUS score above 68 would be considered above average [4].

4 Findings (Analysis and Evaluation)

This section presents the main findings from experiment #1: user interface and usability testing involving participants serving in the roles of patient and doctor; and experiment #2: real healthcare professional's opinions on our system.

4.1 Experiment #1 Findings)

This following presents the summarized results:

- All of the participants showed enthusiasm and eagerness while learning about and using our system.
- After a suitable learning period, all participants felt comfortable using the system as both patient and doctor roles.
- From the patient perspective: The system is easy to launch, easy to use and provides a good UI for interacting with a doctor to discuss patient issues.
- From the doctor perspective: The system is easy to launch, easy to use once familiar with the UI (requiring 10–15 min of training) and offers unique video conferencing features that have perceived benefits for doctors for real remote medical appointments.

Determine the Effectiveness of the System Based on Feedback from Participants. The main finding from user testing indicate that most participants found the system quite easy to use and effective for patient-doctor interactions. Representing the patient's perspective, all users stated that the system was easy to join a call, easy to understand and voiced an overall pleasant experience.

When performing as the doctor, however, the responses varied from person to person. We observed that the participants' responses generally depended upon their age, their comfort level with using computers and their experience using technology. Some participants felt overwhelmed at first but then became much more comfortable shortly thereafter. Many participants commented that there is a modest amount of information one needs to know in order to be effective from the doctor's perspective. This section presents comments from participants and notes from research observation after participants used the system as a patient and as a doctor.

- *Positive Comments from Patient Perspective*
  - ✓ Most participants enjoyed the patient perspective.
  - ✓ The user interface and experience were very well received.
  - ✓ The ability to click a link to join a call was a welcoming feature, as it made joining the call simple and easy.
  - ✓ "Super easy and really enjoyed just clicking a link" or "very seamless" was usually the response from the patient.
- *Positive Comments from Doctor Perspective*
  - ✓ When it came to the doctor perspective, the participants were satisfied with the amount of functionality the doctor had access to.
  - ✓ The overall user experience was received positively, a couple of participants described it as "the user experience was the great after learning the user interface".
- *Negative Comments from Patient Perspective*
  - ✓ The main negative comment for the patient perspective came from reading the instructions.
  - ✓ Since we started every participant the same, read the system instructions, a lot of the participants would describe the instructions as "a lot of initial information".
- *Negative Comments from Doctor Perspective*
  - ✓ "Took some time to understand everything", since the doctor perspective is more intense.
  - ✓ Most of the participants found the user interface and functionality of the doctor a little overwhelming at the start. As participants used the system, it became much easier for them.
  - ✓ "At first it was challenging" was the feedback provided by most people when it came to the doctor perspective.

Usability. Regarding the findings from the questionnaires, the SUS odd-numbered items (I1, I3, I5, I7 and I9) express positive statements on our system[1]. All of these scored 4 or 5 ("strongly agree" or "agree" with the statement), except for I1, which scored mostly 3 ("indifferent"), largely because the question asked participants if they would use the system frequently, which was likely not the case, particularly if they were not a doctor. In total, 16% of the respondents gave scores of 4 or 5 to I1; 77% to I3; 77% to I5; 61% to I7; and 48% to I9. Figure 9 presents positively rated items showing user satisfaction. In summary, this shows that the participants thought the system was easy to use, found the functions were well integrated and felt that others could learn the system easily and quickly. The SUS mean score of the 31 participants' responses was 72.18 (min = 52.5, max = 90, $\sigma = 9.646$). This SUS mean score indicates that the participants' satisfaction with the usability of the system and user interface design is above average. The average SUS score from 500 studies is 68 [4]. A one-way ANOVA was performed which showed there was a statistically significant difference between the groups at the 0.05 level, $F(1, 60) = 5.627$, $p = 0.021$, indicating that the usability of our system is above average (see Fig. 10).

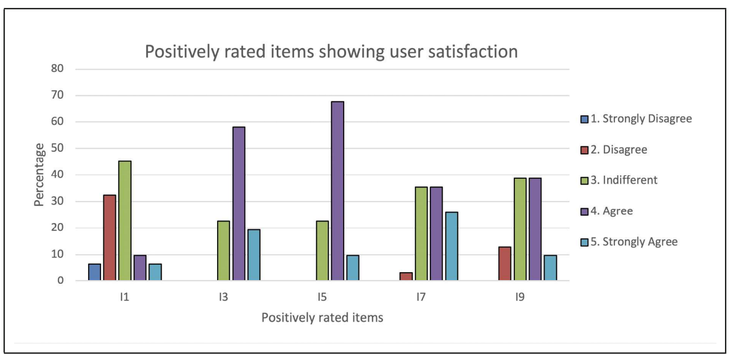


Fig. 9. Positively rated items showing user satisfaction

The even-numbered items in the SUS questionnaire (I2, I4, I6, I8 and I10) express negative statements in using the system[2]. All of the respondents gave scores of 1 or 2 ("strongly disagree" or "disagree") for all items except for I10 where 38% responded with "agree", or "strongly agree", collectively indicating a high user satisfaction (see Fig. 11).

[1] SUS positive rated items: Item I1: "I think that I would like to use this system frequently" Item I3: "I thought the system was easy to use", Item I5: "I found the various functions in this system were well integrated", Item I7 "I would imagine that most people would learn to use this system very quickly", Item I9: "I felt very confident using the system"

[2] SUS negative rated items: Item I2: "I found the system unnecessarily complex", Item I4: "I think that I would need the support of a technical person to be able to use this system", Item I6: "I thought there was too much inconsistency in this system", Item I8 "I found the system very cumbersome to use", Item I10: "I needed to learn a lot of things before I could get going with this system".

SUMMARY

Groups	Count	Sum	Average	Variance
mHealth video conf. system	31	2237.5	72.177	96.142
SUS average	31	2108	68	0

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	270.488	1	270.488	5.627	0.021	4.001
Within Groups	2884.274	60	48.071			
Total	3154.762	61				

Fig. 10. One-way ANOVA: between treatment condition effects of our mHealth video conferencing system vs. the average SUS rating.

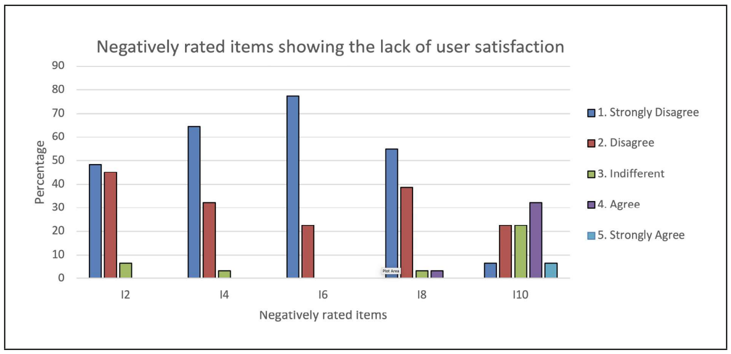


Fig. 11. Negatively rated items showing user satisfaction

The System is Easy to Learn and Easy to Use. After acting as a doctor and as a patient in using the video conference app from their preferred platform, 79.35% of the participants strongly agree on that the system is easy to use, 76.77% of the participants strongly agree on that most of the users will learn how to use the system quickly and 55.48% of the participants strongly agree on that they would like to use this system frequently. The participants have various levels of skills in using technology. However, these three statistics reflect the satisfaction of the participants with an easy to use interface that facilitates learning how to use the system quickly (see Fig. 9).

Training on Using the Online Doctor Appointment Functions is Recommended. Online doctor appointment using videoconferencing is different from family or business meetings. The doctor appointments allow doctors to zoom in and use smart tools to analyze images. Also, the doctor appointments might require patients to wear specific wearables such as the Apple watch or other devices that enable reading of vitals. 69% of the participants strongly agree that they need to learn a lot of things before they could use the system. This confirms the need for the training not only for technology skills but also for understanding the processes and terms related to healthcare appointments (see Fig. 11).

The System Functions are Well Integrated and Effective. After acting as a doctor and as a patient in using the video conference app from their preferred platform, 77.4% of the participants strongly agree on that the system's functions are well integrated and 69% of the participants strongly agree on that they felt very confident using the system. The participants were diverse in age and occupations. These two statistics reflect the satisfaction of the participants with the functionality and effectiveness of the system that helped them to feel confident using the system (see Fig. 9).

4.2 Experiment #2 Findings

This section presents the findings from the Healthcare professional's evaluation of our system. The pie charts in Fig. 12, 13, and 14 present the results from the medical professional's survey. Each chart describes a different question from the survey and gives more context on how the medical professionals felt about the video conferencing system. Figure 12 presents the type of healthcare professional and his/her area of specialty. The majority were General Practitioners (GP, Medical Doctors) at 40% with an equal representation from other disciplines, namely naturopathic, naturopathic doctor, and physician assistant. Figure 13 shows that 100% of this group is "very satisfied" or "satisfied" with the System layout and UI; and 60% feel the system is "very secure". Figure 14 presents the respondent's opinion on the image taking, recording and zooming features. 100% of the respondents stated that it is necessary to allow doctors to record images and/or video snippets of the appointment when needed; 80% of the respondents felt the zooming feature was also beneficial. Regarding our AI module for assisting doctors during diagnosis, 60% felt it was "very useful" and 20% felt it was "relatively useful".

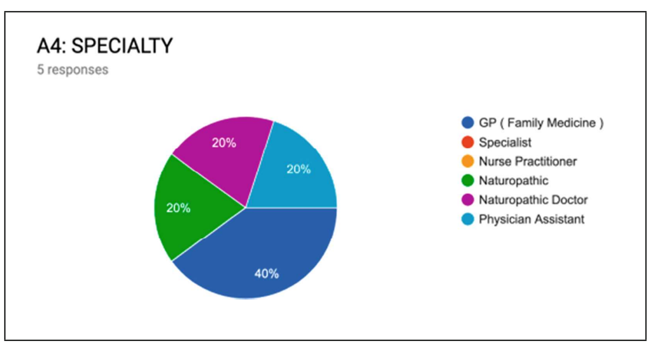


Fig. 12. Type of healthcare professional and specialty

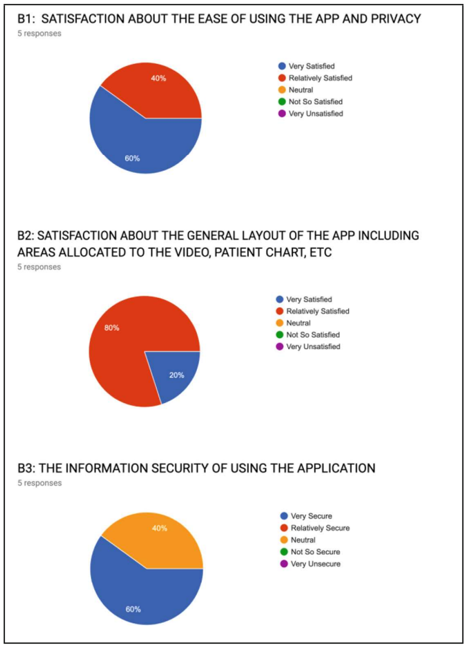


Fig. 13. System layout, UI, privacy and security

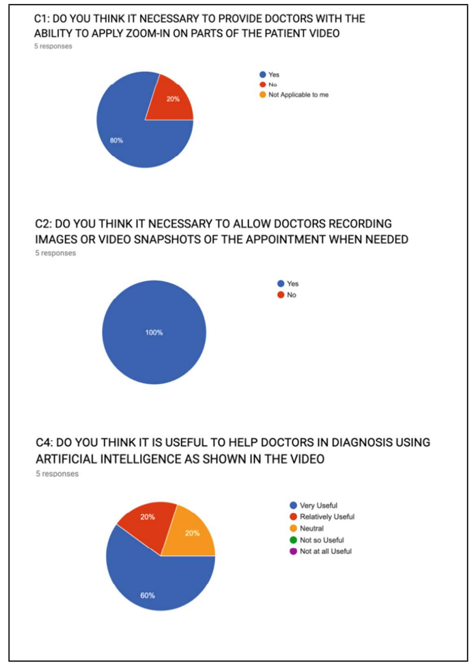


Fig. 14. Healthcare professional's opinions

Healthcare Professional Survey Findings. In summary, these findings indicate a positive response to our system. Our closing question on the survey asked, "Will you introduce your friends and relatives to our online service when they need to see a doctor?" to which 80% responded "Definitely will", or "Probably will". Only 20% were undecided.

5 Discussion

This section presents the limitations and future work based on the empirical findings from this work.

5.1 Limitations

This section presents the limitations of our mHealth videoconferencing system and identifies the steps to rectify them.

Unnecessary Complexity and Inconsistency. In experiment #1, after acting as a doctor and as a patient in using the video conferencing system on their preferred device and platform, 30.61% of the participants agree that the system unnecessarily complex, 30.96% of the participants agree that the system cumbersome to use, 24.5% of the participants agree that there was too much inconsistency in the system. One the participants said s/he would need the support of a technical person to be able to use this system. Part of these results reflect the 19% of the participants who have no previous experience in using video conferencing software or computing devices. It was recommended that a short video tutorial would be beneficial to provide fundamental computing knowledge and skills (see Fig. 11).

Reliance on *Jitsi Meet*. Our mHealth videoconferencing system was built on *Jitsi Meet*, and like all open source software, there is a reliance on the developer community to keep improving the software, address bugs, and provide security patches for vulnerabilities for each new release. This reliance has risks, but at this time, the community is very strong.

5.2 Future Work

This section presents four directions for the future development of the system. These directions are: generalizability of the system, promoting Artificial Intelligence utilization, integrating the system with EMR, and enabling same day appointments.

Generalizability of the System. The potential for generalizability of our system exists in the following areas: performance, new clinics and new applications. This section discusses the generalizability and scalability of our system.

- *Scalability in performance*: The system is scalable and can be used for patients in other countries while maintaining high performance for the video stream because of the cascading SFU in which we can install multiple media servers which will facilitate selecting the optimal routes for efficient and effective video conference calls.
- *New Clinics*: The system can be used by different types of clinics. Our system has not been designed for any specific clinic or program. The features of our system are abstracted enough so that it can be easily deployed and used by doctors and patients with different specialities and needs, respectively. The zoom feature, media recording and analytics functions are general functions that can be used for different programs, such as diabetes and pregnancy care programs.
- *New Healthcare Applications*: The system could be used for new applications. The current application of our system is to support a clinic for long-term care programs. However, it could be used for walk-in clinics with little modification (e.g., adding a virtual waiting room).

Promoting Artificial Intelligence Utilization. Interest in AI, machine learning and deep learning has grown considerably over recent years [21]. The impact of AI on the medical community and in patient's lives has been significant [21]. AI is gaining traction in the areas of medical image recognition and classification [21]. From our study, 80% of the healthcare professionals stated that AI is important in assisting doctors in diagnoses. This recognition of AI and its impact on the medical field is in alignment with the views from other medical professionals [10]. Our system currently uses AI by providing potential diagnosis to the doctor in real-time based on an image taken during the appointment. But more work in this area is needed.

Future work involves creating custom medical classification models for the most common medical issues that doctor's encounter in current telemedicine visits, walk-in clinics, and ER visits [14,19,20]. This work involves creating computer vision models that will improve the proposed diagnosis of the AI module [9,21]. We are currently exploring Faster R-CNN [24], Single Shot Multibox Detector (SSD) [13], and You Look Only Once (YOLO v3) [22] with open medical datasets, such as the Medicare Dataset [15], and the Registry of Research Data Repositories [17]. The improvement of the AI model will also include identifying the near optimal parameters for the models using the auto-calibration technique presented in [6].

Such work will be a novel contribution to further the quality of care doctors can offer patients during remote appointments. It will enable doctors to provide even better diagnosis for their patients. Furthermore, it will also improve the effectiveness and value of our videoconferencing system. Future work in this vein includes using the video feed to determine the patient's heartbeat, and blood pressure as shown by recent work by Sugita et al. (2019) that suggests this approach has promise [26]. With enhanced AI functionality, our system could glean imperceptible biomedical information and draw insights into the patient's health that may go beyond what the doctor is able to see. After all, since 2017, we now have computer vision systems that can detect objects better than humans [16]. The average error rate for humans is between 5% and 10% while the best computer vision detector boasts 3.6% error with improved models being developed almost on a weekly basis [21].

EMR Integration. Abstracted Electronic Medical Record (EMR) integration would also be an appropriate next step to make this application work with a number of different EMR systems. Our system, based on *Jitsi Meet*, is a generalizable and scalable solution that can enable doctors to help many patients by using video conferencing as opposed to traditional face-to-face appointments.

Same Day Appointments. One of the doctors provided feedback on the survey describing that prioritization of same day appointments is important. The ability to identify who needs to be seen today and who can wait until the next available appointment is a scheduling problem that our videoconferencing system could also support. A future feature in our system will enable patients who need to be seen and who can be delayed. Creating this functionality could enable the doctor to make this decision and enable critical patients to be seen more readily.

6 Conclusion

We created and evaluated an mHealth video conferencing system that contributes to the field in the following ways:

- Identified a video conferencing platform that facilitates secure and efficient doctor-patient communication and enables custom healthcare-focused functionality to be added.
- Investigated how to combine mobile cloud computing, software engineering, and human computer interaction to develop a platform for online healthcare appointments.
- Developed additional healthcare-focus functions to facilitate online healthcare appointments.
- Enabled the access to the system from: browsers, Android devices and iOS devices.
- Developed a user-friendly interface for doctors and patients.
- The effectiveness and usability of our system was evaluated by 36 participants–31 laypersons acting as patients and doctors, and 5 actual healthcare professionals. The mean System Usability Scale (SUS) usability score was 76 (high) indicating an overall positive UI design and effective system.

In conclusion, we created a platform based on combining mobile cloud computing, software engineering and user interface design principles to facilitate online healthcare-related appointments. Through the experiments conducted, it was demonstrated that our system is a viable solution for online healthcare appointments. In the spirit of furthering science and this work, the source code, and data sets will be openly available on the author's and/or journal's website. We hope this will encourage other researchers to explore and extend our work.

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