TELEMEDICINE QUALITY IMPROVEMENT STUDY

A THESIS IN

Bioinformatics

Presented to the faculty of the University of
Missouri-Kansas City in partial fulfillment of
the requirements of the degree

MASTER OF SCIENCE

by

EMILY DEUTCH

BA Chemistry, University of Kansas, 2012

Kansas City, Missouri

2019

TELEMEDICINE QUALITY IMPROVEMENT STUDY

Emily Deutch, Candidate for the Master of Science Degree

University of Missouri-Kansas City, 2019

ABSTRACT

Telemedicine is a novel field that contributes to the modernized healthcare system we have today, wherein a need exists for further refinement of applied methods and technology that is readily available and economical. Telemedicine (TM) is the modern-day spinoff of a telecommunication system that has roots back to the early 1900s. The creation of Voice Over IP (VoIP) and synchronous communication allows individuals at two or more locations to communicate live in real-time, this is the margin that we use to develop and refine telemedicine technology at a reasonable cost. Success is measured in direct benefit to the patient in terms of quality of care and cost, and to the provider in terms of increased work flexibility and minimal technological difficulties. Mixed reality devices may further contribute to the telemedicine platform that is proven to increase provider and patient access and decrease both monetary cost and time spent traveling and waiting for appointments by providers and their patients alike.

This quality improvement comparative analysis study consisted of simulations representing current-state and future-state telemedicine consultation appointments. The future-state consultation utilized a developer edition of HoloLens, a mixed reality head-mounted computer processor display that is untethered allowing for free-range mobility. This was compared to current-state technology made by InTouch Health. Feasibility and

acceptability data from the provider perspective were gathered via administration of a REDCap survey.

Our findings suggest that with further refinement in HoloLens technology, providers will accept this technology when conducting telemedicine appointments. Added usability of ancillary devices and refinements to ensure simple three-way communication would place the HoloLens at the same level of performance – if not higher – compared to the current InTouch platform. The HoloLens program as it develops should include device and technique training, and technological support. Adding HoloLens to the Children's Mercy Hospital program could further enhance pediatric telehealthcare in prevention and treatment of disease regardless of physical location.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the School of Medicine have examined a thesis titled "Telemedicine Quality Improvement Study", presented by Emily Deutch, candidate for the Master of Science in Bioinformatics degree, and certify that in their opinion it is worthy of acceptance.

Supervisory Committee

Mark Hoffman, Ph.D., Committee Chair
Department of Biomedical and Health Informatics

Sarah Fouquet, Ph.D.
Children's Mercy Hospital Human Factors Research

Timothy Hickman, M.D., M.P.H., M.Ed., FAAP
Department of Biomedical and Health Informatics, Pediatrics

Karen Bame, Ph.D.
Department of Molecular Biology & Biochemistry

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ACKNOWLEDGEMENTS

I am grateful for the instruction, guidance and support I have received from Dr. Mark Hoffman and his team at Children's Mercy Hospital. I would like to extend my gratitude to some of the telemedicine program management team at CMH including Chad Stotler and Elizabeth Cook who worked with me from concept development to the end result. I am thankful to Dr. Alvin Singh for allowing me to shadow telemedicine appointments and assisting in refining my simulation script. Thank you to the pleasant providers who responded with interest and showed up on study day. A big thank you to my advisor Dr. Karen Bame for leading me towards a degree I am proud of, and for welcoming me into the UMKC Master's program with an open door. Thank you to all those I have not specifically mentioned who had a part in my project, family and friends who have encouraged and supported me throughout the years.

CHAPTER 1

INTRODUCTION

Telemedicine is the exchange of medical information from one site to another via electronic communication technology with the intent to support and improve patient clinical health status. Use of technology in medicine enables care delivery even when the patient and provider are separated from each other by geographical distance [1] and encourages providers to perform consults even when they are not hospital-based, or they are reluctant to travel. This increases provider availability and involvement so that communities which lack specialists residing in the community nevertheless receive high quality care [2]. Access to pediatric subspecialists is particularly lacking and a significant forerunner in telemedicine evolvement. We hypothesize that an untethered mixed reality computer processor is a feasible method in which to deliver equal quality of care to patients regardless of geographical location.

The telemedicine program at Children's Mercy Hospital (CMH) currently uses InTouch Health equipment to facilitate three-way communication with real-time video plus audio for clinical appointments. InTouch Health is a successful system that allows CMH to run four regional telemedicine clinics and offer services for over 30 pediatric specialties. A telemedicine quality improvement study is herein developed and assessed at CMH in Kansas City, Missouri using Microsoft's HoloLens (HL) personal computer which contains mixed reality (MR) technology. HoloLens is used in this study because it offers the provider and facilitator the ability to view information in various capacities while at the same time interacting more directly with the patient. This allows access that no previous studies, to our knowledge, have delivered in clinical teleconsultation. Additionally, the HoloLens is compatible with Microsoft applications in use at CMH.

We hypothesize that by using HoloLens to facilitate a clinical telemedicine appointment the provider will interact with the patient equally or to a more involved degree than with current-state telemedicine technology, and therefore HoloLens will gain acceptance amongst providers. This may be viewed as a feasibility study in which we explore the intersection between pediatric telemedicine consultation in a hospital-based setting and mixed reality technology.

CHAPTER 2

REVIEW OF LITERATURE

Telemedicine

Introduction

Healthcare continues to center increasingly around patient desires, preferences, and needs which promotes relevance for telemedicine due to its cost-effective convenience for the patient as well as the provider. Telemedicine is the practice of medicine over a physical distance typically through synchronous audiovisual communication. Significant milestones leading to current state telemedicine (TM) date to the latter 1950’s when Secretary of Defense Neil McElroy signed a directive launching the Advanced Research Projects Agency (ARPA). This led to the creation of the Internet [3] and Voice Over Internet Protocol (VoIP) technology which allows for phone service through an internet connection. Consequently, asynchronous (recorded) or synchronous (live real-time) audiovisual communication was crafted. While TM is patient-centered it relies on acceptance by providers caring for their patients. Provider acceptance is the most important factor in determining TM use and development [4]. Additionally, if providers willingly practice telemedicine, then this field can overcome trepidations such as initial low demand, problems with technology, and poor financing.

Audio-video telecommunication links have been utilized for the provision of medical services since the 1950s [5]. One famous example of telemedicine occurred in 1999 when a physician on a research assignment in Antarctica found a lump in her chest and due to weather conditions was forced to diagnose and treat her breast cancer via satellite and video equipment, and chemotherapy drugs delivered by the US Air Force [6]. Due to rapid development in digital technology, telemedicine has since expanded throughout the medical field and across many specialties.

Telemedicine has considerable advantages over conventional in-clinic or in-office healthcare, this includes increased access and convenience at reduced costs [7] while obtaining the same quality of care as a conventional in-person visit. Patients residing in remote locations or living with unique health disabilities are able to get treatment that would otherwise be unavailable. Additionally, findings have shown positive benefits to families by reduced time away from work and school [8]. An example of this is outlined in an American Academy of Neurology publication which discusses migraines as having common prevalence in the pediatric population and equally there is a shortage of trained pediatric headache providers. This publication discusses how the University of California San Francisco developed a TM option for outpatient follow-up visits and out of 51 people surveyed in this prospective study, all patients and families thought TM was more convenient compared to in-person clinical visit and caused less disruption in daily routine. Providers involved in this study noticed the TM visits tended to run on time and there was a decrease in no-shows and late arrivals compared to in-person appointments [9]. The significance of TM is evident in an article published on the behalf of the American Heart Association discussing the use of pediatric tele-echocardiography. A prospective study method was used to validate remote interpretation of echocardiograms performed in a remote hospital by a sonographer experienced in pediatric echocardiology. The transmitted images had sufficient quality and echocardiograph diagnosis was correct in all but one of the 191 cases (98%) as confirmed by face-to-face consultations. The authors postulated that reasons for inaccurate diagnosis may include inadequate or incomplete clinical examination by the referring physician, inability of pediatric cardiologist to examine child, lack of experience for the examining technician, or lack of visual clarity of heart structures. It was noted that increased training and videoconferencing may overcome these specific limitations [10]. Furthermore, an article published in the New England Journal of Medicine references statistics from the Department of Health and Human Services, which estimated in 2017 that more than 60% of all health care institutions and 40 to 50% of all hospitals in the United States use some form of TM. Health organizations report using telemedicine for purposes such as filling gaps in care that result from provider shortages, providing access to services after normal clinic hours, and reducing patient and family travel burdens [11].

Current Limitations

Telemedicine growth and development is still hampered due to technological, stakeholder, state and legal compliance (such as licensure across state borders), and financial barriers [16]. Current technologies are known to lose connection and glitch during appointments and are still confined to areas with space for a machine and a power outlet to plug into. These current technologies require software and hardware development in order to lessen video feed lag and downtime, improve video quality, improve provider ability to troubleshoot, and allow for added mobility.

Pediatrics

Disparities and access to care are larger problems in pediatric care as compared to the adult population because there are fewer subspecialists and they are more regionalized than adult subspecialists [5]. Likewise, lack of pediatric expertise in combination with lack of equipment leads to lower quality of care, less accurate diagnoses, and suboptimal therapies. In a study that included 320 children presenting to rural emergency departments in California, Dharmar et al. reported patients and their families rated many aspects of quality medical care to be significantly higher when the child received telemedicine consultation. Additionally, specialists monitoring patients in hospital wards are able to evaluate acute changes in condition and periodically check in at flexible times [12].

Children younger than fifteen years old in the United States make an estimated 71 million office visits annually for acute problems, which is the leading cause of parents having to miss time from work [13]. A study conducted at CMH compared asthma outcomes over a six-month span in children managed via telemedicine versus in-person. This non-inferiority analysis showed 95% likelihood that there was no clinically meaningful difference between patients seen in-person and those seen through telemedicine [14]. The Journal of the American Academy of Pediatrics reported on research which compared telemedicine to bedside care in children with respiratory distress. The research found significant agreement in clinical impression of respiratory distress when comparing bedside treatment to telemedicine treatment, also suggesting that clinical gestalt is not lost with telemedicine [15]. The social and economic burden in caring for ill children can be significant, and telemedicine encounters have proven to notably decrease this burden.

Mixed Reality in Healthcare

Introduction

A substantial surge in medical studies utilizing virtual reality or augmented reality technologies is evident, and novel mixed reality studies show encouraging outcomes. Virtual reality (VR) is the complete immersion of the user in a computer-generated environment. For example, a user wearing a VR headset in which they are riding a roller coaster will show the seat as if they are sitting in it, with a theme park view in peripheral vision. The user cannot see his actual surroundings; only the virtual world of the roller coaster and theme park grounds. Augmented reality (AR) superimposes a computer-generated image on the user's view of the real world. An example of this is Pokémon GO, a mobile phone game where the user walks around the real world, and Pokémon characters appear on the game map which mimics a map of the real world. Additionally, characters appear as the phone camera displays real world surroundings. Mixed reality (MR) can be considered an advanced form of AR wherein the user views superimposed computer-generated images in his or her environment and the images are placed flush with surfaces such as on a countertop or secure on a wall. Studies utilizing VR and AR technology span across several medical capacities including postoperative care, surgical telementoring, telerehabilitation, teleeducation, and virtual rehabilitation. To the best of our knowledge this is the first study to utilize MR technology for clinical teleconsultation.

The benefits of these technologically advanced immersive systems have attracted the attention of researchers in a variety of fields [17]. Telepsychiatry is one example within the field of telemedicine that realizes an advantage. Virtual exposure therapy is used to address the current shortage of pediatric mental health specialists in underserved communities. Exposure therapy is a first-line treatment for several anxiety disorders, and it uses VR environments to manage exposure. The ability to replicate triggers that would be difficult to expose a patient to in-person is advantageous, with simulations ranging from taking a flight in an airplane to watching spiders crawl nearby [18]. Another example of virtual use in pediatrics happens during rehabilitation for a child with a brain injury. Glegg et al. discussed the benefits of clinicians to control the characteristics of the virtual environment while modifying the degree of challenge to suit individual patient needs such as reducing number and speed of visual stimuli, removing auditory feedback, and directing stimuli to only one side of the body. Cerebral palsy, stroke, brain injury, autism spectrum disorder, and chronic pain populations are among the top five pediatric subfields using virtual rehabilitation technology [19].

Augmented reality (AR) is different from virtual reality in that it adds to a user's own environment, allowing the user to see computer-generated images while viewing the real environment around them. In a search of the PubMed library for "augmented reality" and "pediatric telemedicine" or "augmented reality" and "telemedicine", 54 total articles populated, and the majority of these articles describe surgical applications. This is understandable given that surgeons benefit from telementoring at times when the patient is at her most vulnerable and time is most valuable. Boulanger et al. describes how AR may be used to collaborate on training within the manufacturing industry. The user wears an AR device to share his view with the trainer on the other end, allowing the trainer to talk through the task and manipulate the trainee's view to point out certain objects [20]. Current AR research occurs across industries and generally focuses on outlining potential, addressing problems, and surveying the state of this technology since it is in early stages of development.

Mixed reality (MR) is similar to AR with the addition of the user ability to place objects or view objects flush to their environment. Placing a computer-generated image of a pen holder on the desktop the user is sitting at or pinning a computer-generated framed picture to a wall in the user's office [21] utilizing MR technology. Further investigation is crucial to bring these displays to the foreground of health communications.

HoloLens

Introduction

Microsoft's HoloLens (HL) is the first MR head mounted display (HMD) computer that is capable of spatial capture of the user's environment and completely untethered. Hong et al. references the HoloLens device as "one of the most advanced devices and currently the best candidate for use within the AR research space, due largely in part to the hardware design choices" which combine high performance and quality imaging with user comfort [22]. A PubMed search for "HoloLens" displayed over 62 papers, several of which appeared due to the keyword "holographic" which displays research on three-dimensional content created within a HL app, such as HoloStudio. Many of these studies reference HL in AR rather than MR context and to our knowledge ours is the first study utilizing HL in the clinical teleconsultation realm.

Hardware

HoloLens enables human-computer interaction via gestures, voice commands or a clicker depending on user preference. There are now two versions of the HL available. HL I developer edition was released in 2015 and HL II was publicized in February 2019. HL I is the focus of this literature review since this is the technology used in our study. The HL I HMD shows a resolution of 2536 x 1440 or 1268 x 720 pixels per eye with a 16:9 aspect ratio and 60 Hz refresh rate. This untethered device runs on a charge which allows approximately 90 minutes of runtime before recharging is needed. The tinted holographic lenses sit atop the user's eyes as a visor (glasses may be worn underneath this visor). Four cameras track movement, surroundings, and ambient light with an additional main camera in the middle and slightly above the user's eyes (see *Figure 1*).

HoloLens I has 64 GB of storage capability and Bluetooth ability. HL II has the same storage capability and is advertised to have a larger 3:2 aspect ratio, a camera positioned in a way that leads to less strain on the head and neck during use, a more ergonomic fit around the head, and a run time of 2-3 hours before recharge is needed. Full technology specs may be found on the Microsoft website.

Figure 1: HoloLens I design

Concept

HoloLens allows users to see and hear by means of a semi-transparent visor. Holographic images and applications are superimposed on the user's surroundings through surface mapping, allowing objects to be "pinned" to a location contextualized to the user's location. Even application screens (such as the Microsoft Teams login screen) can be "pinned" as if it is attached to a wall in an office space. A preview version of an anatomy trainer application developed by Case Western Reserve University projects a semi-transparent human body using the HL. The user is able to walk around the body and view from all angles and can focus on specific organs. Galaxy Explorer is another HL application which allows users to zoom in on the semi-transparent Milky Way Galaxy and visualize individual planets. HoloStudio allows the user to import small computer-generated structures so he can visualize them in three-dimensions. One study has successfully used HoloStudio to import an aspirin molecule and rotate, resize, and recolor the image as it floats in an office space. Similar successes make us aware of potential to improve understanding of molecular docking, such as drug-protein interaction [23, 24].

The benefit to an immersive three-dimensional environment is evident in early work of Watson and Crick. They developed a visualization of the human DNA structure using a 3D tabletop model. Established software-based molecular modeling applications allow users to build or interact with representations of biological structures using flat screen monitors. New technologies have the ability to free the user from limitations of traditional flat screen monitors. The completely immersive Occulus Rift has been demonstrated in this capacity within the pathology specialty [23]. Google Glass was the first major venture into a new visualization approach within telemedicine and beyond healthcare. Impediments such as low visual resolution, flat two-dimensional representation along with privacy concerns have caused use of newer augmented reality technology such as Google Glass to taper.

In Medicine

A study in which HL is used to merge and display graphics onto the surgeon's field of vision allowed the surgeon to view the patient's head in the real world while at the same time viewing scanned CT images positioned appropriately on the patient's face. Experimental results showed this method to have exceptional efficiency and accuracy [25]. One study had control participants complete simple procedural tasks on spaceflight hardware using a paper instruction method and experimental group participants complete the same procedure using an AR instruction method on the HL. The results concluded that HL can enhance procedural work for simple tasks in an operational setting [26]. A transcatheter pulmonary intervention study utilizing 3D-printing technique with HL noted potential value but lack of prospective trials [27]. Research on complexities that shorten the drug development process used HL for its mixed reality capabilities and noted through retrospective analysis of efficiency gain "a more efficient, hands-free method of knowledge transfer and information sharing". This research team demonstrated a "minimum 10-fold gain in efficiency, weighing in from a savings in time, cost, and the ability to have real-time data analysis and discussion" [28]. HL potential is also recognized in clinical and nonclinical pathology applications. Notable comments include acceptable ergonomics, sufficient image resolution ("improved in comparison to Google Glass and Oculus Rift"), and sufficient computing power. While gesture input limited the user, it did provide adequate interaction and all cases were performed successfully [29]. Likewise, a team using HoloLens, Skype, and 3D modeling were successful in performing multiple telementoring sessions [30].

CHAPTER 3

METHODOLOGY

Participants

We identified providers at CMH that were currently practicing telemedicine and sent a recruitment email to these providers inviting their participation in our study. Screening questions included provider credentials, amount of years spent in clinical and telemedicine practice, degree of familiarity with InTouch (currently the main system used for CMH telemedicine appointment), interest in learning new technologies, and previous experience with virtual, augmented or mixed reality technologies. Five providers, all currently practicing MDs participated (N=5) on March 7th, 2019. The providers have a combined average of 16.4 years in clinical practice. The average time providers have practiced telemedicine is 3 years. One participant was unfamiliar with InTouch and has only previously used Polycom audio for telemedicine. The other participants use InTouch regularly in practice. One participant had previous to day of study used a VR, AR, or MR device. The Children's Mercy IRB determined all work herein is that of a quality improvement study.

Technology Preparation

At the start of the study design process we determined it essential to show HoloLens could enable three-way communication between the provider, facilitator, and patient in order to replicate current-state telemedicine as closely as possible. The HoloLens had not previously been tested as a tool to facilitate three-way communication, to the best of our knowledge. For this reason, it took extensive planning and trial-and-error to develop a proper communication system that incorporated the HoloLens. We acquired an encryption key to access the medical Wi-Fi network which allowed the HoloLens to connect to the internal CMH network on the fastest connection possible.

Materials

We used an office in the Pediatric Clinical Research Unit (PCRU) at CMH that was previously equipped with the supplies we required: a PC connected to the CMH network with InTouch software installed, monitor (with built-in webcam and speaker), mouse, and keyboard. These supplies were essential for the provider to complete the participation consent form, conduct the InTouch and HoloLens simulations, and complete the post-simulations survey.

We used a scripted role-playing approach. The same nurse facilitator and youth volunteer completed the simulations with all providers. The facilitator and patient were located in an exam room in the PCRU at CMH. This room was equipped with an exam table, a PC connected to the CMH network, monitor, mouse, keyboard, portable InTouch unit, otoscope, laryngoscope and stethoscope, external speakers, and a HoloLens (*Figure 2*). REDCap with reCAPTCHA was the tool used to build the survey, distribute the survey, and collect survey data. REDCap is a secure web platform used for building and managing online databases and surveys. Several survey questions were developed with the intent to assess specific interest or disinterest in current and new or future technologies, and to establish a viewpoint on the general telemedicine program. The survey was built utilizing five-point Likert Scale anchors (Table 1) and assessed using stacked bar charts in Excel. The stacked bar charts allowed us to determine variations between statements, as well as between the different providers.

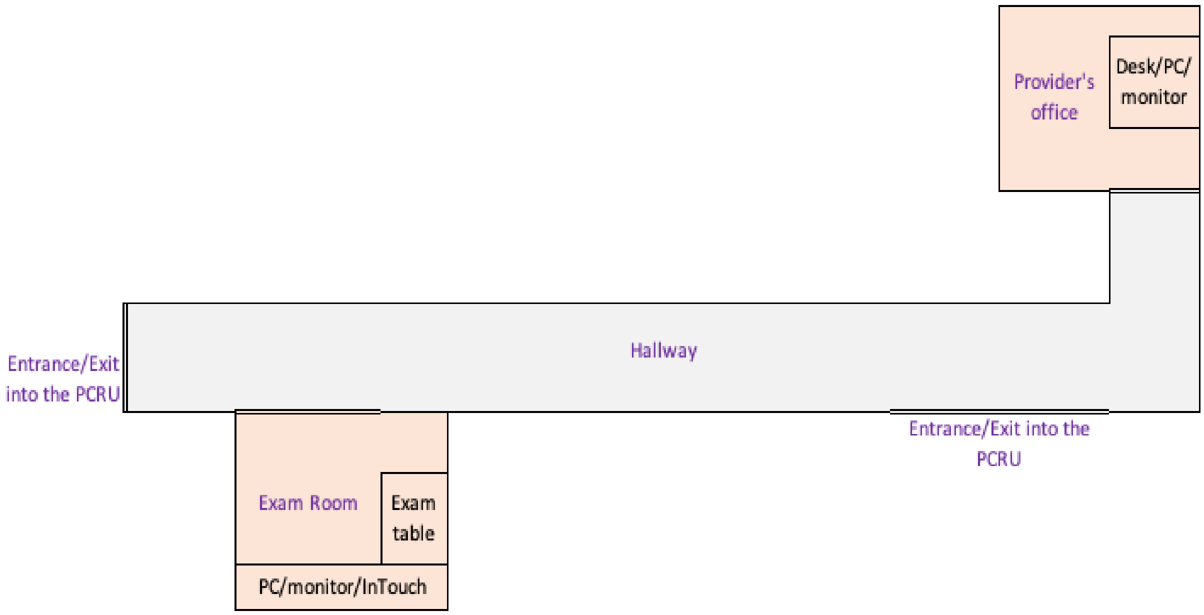


Figure 2: PCRU setup

Table 1: *Five-Point Likert Scale Response Anchors*

Answer Choices Available:	Number assignment
Strongly Disagree / Strongly Disinterested	1
Disagree / Disinterested	2
Neutral	3
Agree / Interested	4
Strongly Agree / Strongly Interested	5

Procedure

Overview

Each provider was scheduled for one hour in the PCRU (located at the Adelle Hall campus at Children's Mercy Hospital). Upon arrival participants were asked to electronically complete a consent to participate. The REDCap web tool (with reCAPTCHA protection) was used to confirm consent. See *Appendix B* for the "Consent to Participate" form. The provider was then directed to start the simulation by reading from a script that depicted a current-state InTouch telemedicine appointment. The facilitator and patient (who were acting on behalf of the study team) were located in the exam room and read from a copy of the script, taking turns as the script guided the appointment.

After the script concluded, a second script was recited by the same three people. The second script included the same format and information as the first script; however, it was slightly adjusted for a future-state telemedicine appointment by replacing the InTouch components with the HoloLens hardware and Microsoft Teams, Remote Assist and Skype for Business software that were previously installed on both PCs. While the HoloLens does have a USB port, it does not yet support ancillary clinical devices. Therefore, the provider was instructed to rely on the facilitator's suppositions on ENT sounds and visuals. See *Appendix A* to read a copy of the two scripts.

Technology

For the first script (Script 1) the provider was instructed to open the InTouch software installed on the PC in the office and click on the appropriate exam room name. This connected the provider to the InTouch hardware in the exam room and initiated the video and audio feed. Meanwhile in the exam room the InTouch portable unit was plugged into the wall by the facilitator and ready for the provider to remote in. Ancillary devices plus two speakers were plugged into the InTouch unit so the provider could hear the facilitator and patient (the InTouch system allows three-way communication between the provider, facilitator, and patient).

For the second script (Script 2) the provider again was instructed to sit at the desk in front of the PC monitor, and then to make a Microsoft Teams call to the facilitator in the exam room. The facilitator was wearing the HoloLens and answered the Teams call by using finger gestures (which acts as a clicker or mouse) with the HoloLens. The facilitator muted the sound once the connection was established. The provider also muted the volume on the Microsoft Teams audio. Once connected, the provider was able to see him or herself on the PC monitor, also visible was the video feed of what the facilitator was seeing in the exam room. The provider then made a Skype for Business call to the facilitator who had Skype logged in on the exam room PC. The facilitator accepted the Skype call and the provider presented the Microsoft Teams window using Skype for Business. This made the provider visible to the patient on the exam room PC and allowed the patient and provider to interact directly. The facilitator could see the provider in a Microsoft Teams window that was "pinned" next to the patient (made visible by the semi-transparent visor she was wearing). The image of the provider was "pinned" next to the patient so that the provider was made visible on the exam room PC monitor at the same time the facilitator was facing and interacting with the patient. An external speaker from the InTouch system was placed next to the patient and plugged into the exam room PC so the provider could better hear the patient.

The provider was still able to hear the patient without this external speaker and this was not a necessary part of the communication setup. See *Figure 3* for a visual of the three-way communication and *Appendix C* for images.

Conclusion

Once the two scripts had ended the provider was asked to complete an additional survey in REDCap. Responses were required for all questions and statements. The provider was then informed the study session had ended and they could leave the PCRU. All simulations took less than 30 minutes to complete.

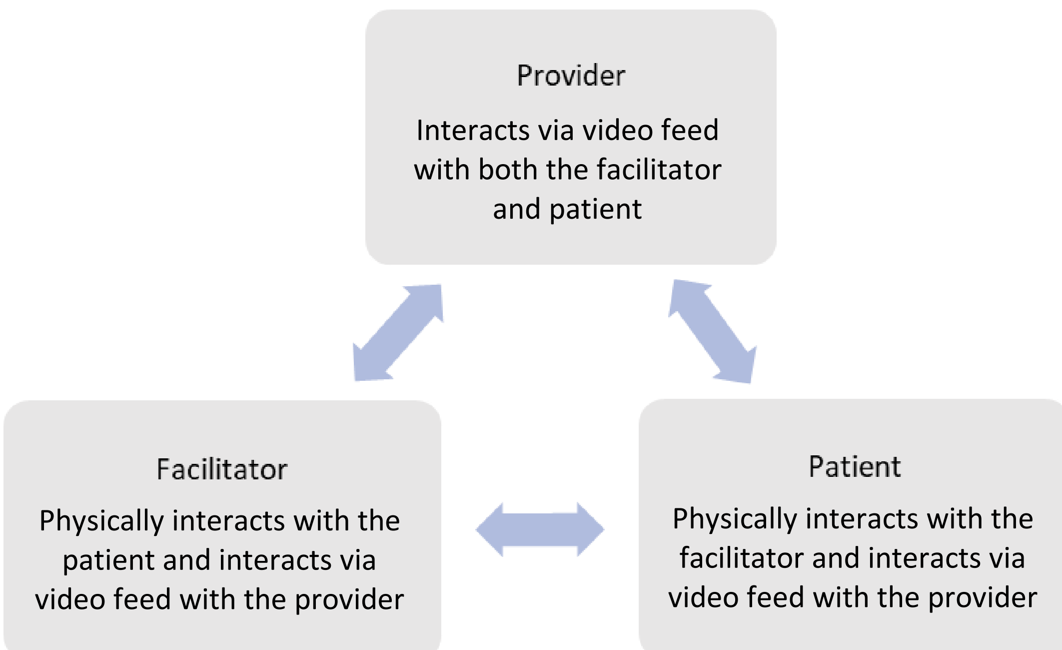


Figure 3: Three-way communication interaction between the provider, facilitator, and patient for the simulations.

CHAPTER 4

RESULTS

The Likert Scale data were extracted from REDCap into a excel spreadsheet and grouped (*Figure 4 – 6*). Table 3.1 shows the available answer choices for these statements. The short answer questions were developed to understand acceptability of current-state compared to future-state technologies amongst providers currently practicing telemedicine. Hypothesis I stated that the providers would be accepting of a new TM technology compared to current TM technology, indicating the HoloLens use may be feasible to further investigate in telemedicine. In order to test this, we used aggregated stacked bar charts and compared individual response to overall group similarities and differences. Participant level of agreement with positively-shifted HoloLens statements showed favorable responses, likewise provider level of disagreement with negatively-shifted HoloLens statements showed favorable responses.

First, we assessed statements regarding the HoloLens viewpoint that were shifted positively towards using the device in healthcare. One participant had prior experience with the HL and this person indicated “strong agreement” with each positive HoloLens statement in *Figure 4,* while the remaining 4/5 (80%) participants “agreed” that HL has potential in a clinical setting as well as in the greater healthcare setting. 40% of participants (2/5 providers) were “neutral” on whether HL could benefit the patient or provider and 60% (3/5 providers) “agree” to some degree that HL could benefit the patient and provider. Acceptance for HL having potential in a clinical or other healthcare setting was 100% and benefit of HL to either patient or provider was 60%.

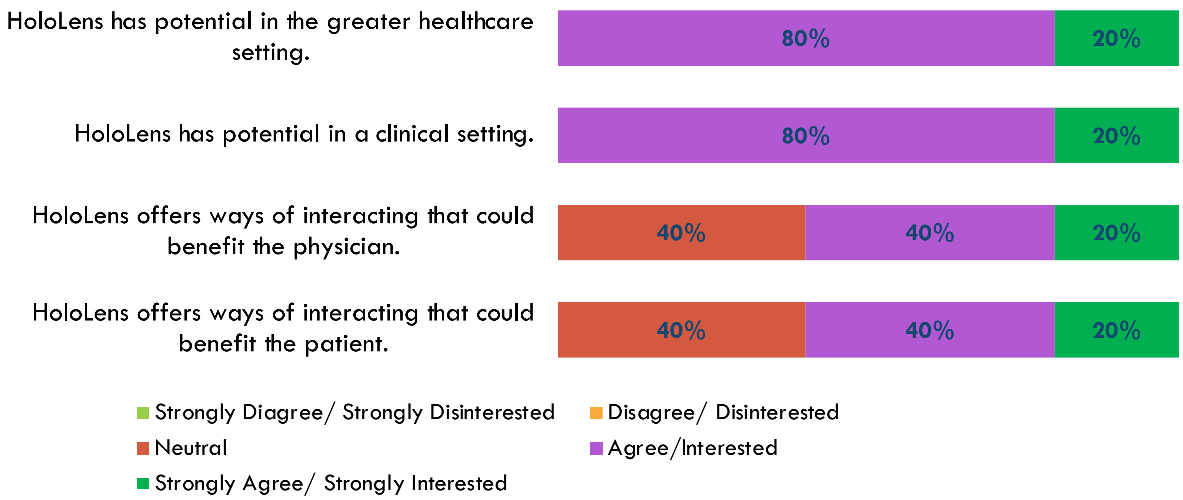


Figure 4: Positively-shifted HoloLens Statements

We then assessed statements regarding HoloLens viewpoint that were shifted negatively towards its use in a healthcare setting. 80% of participants (4/5) "disagreed" that HL functionality could negatively impact the facilitator – patient interaction, and 1 participant was "neutral". These responses indicate that the facilitator-patient interaction is least likely to be affected by the HL while providers are most likely to be negatively affected by the HL use. 60% of participants "disagreed" that HL may have a negative impact to the provider – patient and provider – facilitator interaction. For both statements, 1 participant was "neutral", and 1 participant "agreed" that the provider – patient and provider – facilitator interaction may be negatively affected with HL. With the statement "I found the HoloLens workflow difficult to understand or utilize compared to InTouch," 40% of participants (2/5) "agreed", 40% were "neutral", and 20% "disagreed" (1/5). See *Figure 5*.

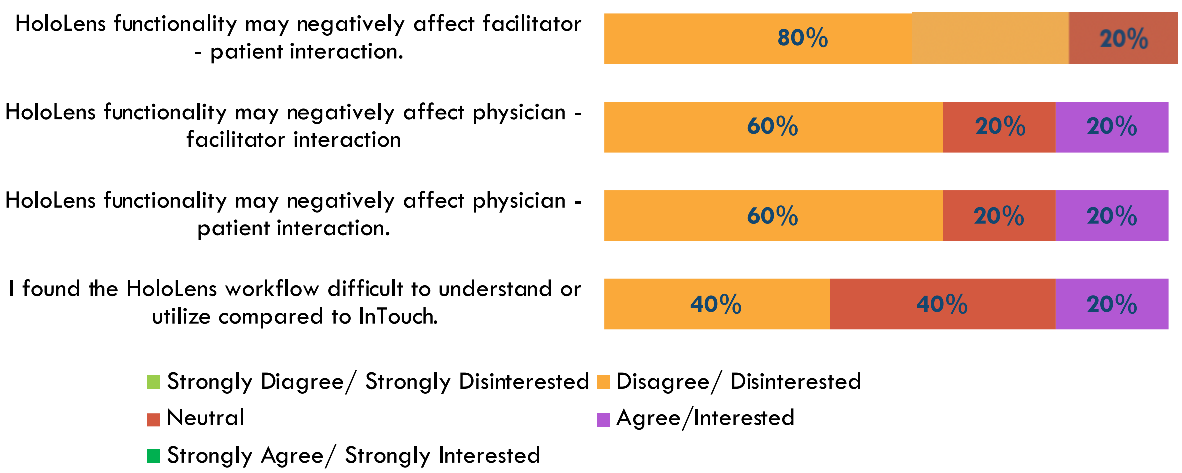


Figure 5: Negatively-shifted HoloLens statements

Afterwards we gauged **g**eneral interest providers have in new telemedicine technologies, as shown in *Figure 6*. 100% of participants were "strongly interested or strongly agreed" that they had interest in learning new technologies in general as well as new forms of TM that are unfamiliar to them. 60% of the participants either "agreed" or were "neutral" on whether they were satisfied with current-state TM and 40% of the participants "did not agree" on the statement that they are 'satisfied with current state TM.' All participants showed strong or accepting willingness to learn a new mode of TM if given proper training and support. Lastly, 80% of providers "agreed" the scripts in the two sessions related to a real-world clinical scenario and were plausible, while 1 participant was "neutral".

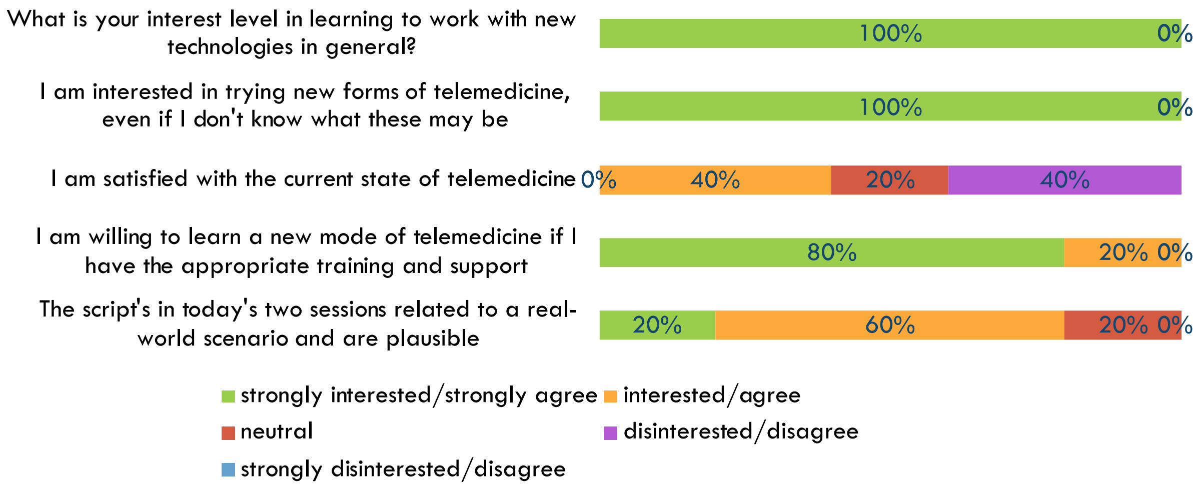


Figure 6: Gauging general interest in telemedicine.

Lastly, we considered short answer question responses. We asked the providers what they like about telemedicine. The benefits to telemedicine include increased access to patients with decreased travel for both patients and providers, decrease in costs, and overall convenience. Improvements that could be made in the opinion of providers included development of ancillary device use so that patients could use themselves, and so that providers can better hear and see their patients. For example, one provider noted that microphones for the stethoscope could be improved. The ENT provider noted that a provider must be with the patient in order to insert scopes, etc. thus telemedicine for them currently relies on audio call communication rather than video with a facilitator present on the other end. Additionally, technology currently used can have slow or choppy connections and “equipment failure” (Table 2).

Additional feedback shared by providers regarding this simulation focused on improvements the providers would like to see in the HoloLens setup. One participant noted that at first the facilitator was too close to the patient, but when she moved back the view was improved and acceptable. Another participant noted that as an ENT the provider would absolutely need to see inside the ears, nose and throat so would either need to do InTouch along with HoloLens or produce some adaptation with the HoloLens to do this. A GI provider made the comment, “Although I don’t reply on cardiorespiratory exam often as a GI provider, it may be difficult to give up heart sound interpretation to the telefacilitator (not being able to hear it myself).” It was clear the largest improvement to be made for future studies from a provider perspective is centered around the need for ancillary devices to connect to HoloLens so providers can see and hear the patient themselves, rather than relying fully on the facilitator for input. One provider noted the HoloLens was “great technology with very clear images”. All five providers mentioned not being able to hear or see and reliance on the facilitator as the one significant downside.

Table 2. *Short answer responses to general telemedicine questions.*

Short Answer Responses	
What do you like about telemedicine?	**What could be improved in telemedicine?**
Increased access to patient or provider when otherwise out of office or on vacation	Ancillary exams (user-friendly for patients, more testing availability with POC tests, tests done via apps and devices that can go to smart phone or computer (like pulse ox reader, ecg reader, glucometer, etc). Larger view of the room the patient is in
Same quality of care to patients that are far away	Better microphones for stethoscope
Ability for provider to lead a clinical appointment without travel in comfortable surroundings	Connections can be slow or choppy, equipment failure
Decreased travel cost and time	ENTs require providers on the other end in TM to insert scopes etc. making TM more likely for phone call over video call with a facilitator
Minimized need for facility and multiple steps before appt start (registration, triage, vitals, waiting room, etc.)	Scheduling is difficult when telefacilitator is needed
Ease of connectivity to patients	Would like to help perform procedures that could be done via TM but would require someone on other end capable of doing this (such as inserting scopes)
Not dependent on weather, traffic, parking, physical location	Opportunity to provide TM to patients outside of KS/MO difficult due to licensure and payment requirements
Access-related	Equipment-related
Travel-related	Telefacilitator-related
Other	Other

CHAPTER 5

DISCUSSION

We conducted an exploratory comparative analysis of a clinical telemedicine visit by comparing the current telemedicine capability at Children's Mercy Hospital with a future state depiction. We determined the future state representation of clinical telemedicine in which an untethered mixed reality technology was used would be practicable and accepted by telemedicine providers. The comparative analysis method allowed our team to establish a baseline in order to offer a realistic comparison of the proposed future state system.

CMH currently utilizes three separate outside companies to facilitate video and audio conferencing depending on department or conference room location and none are compatible with one another. These technologies include Polycom, WebEx, and Microsoft (Skype for Business or Teams). Polycom is typically used for telemedicine audio calls and InTouch is typically used for telemedicine video calls. Because CMH is transitioning the organization to Microsoft Office 365 products, we centralized our efforts around Microsoft products. We initially planned to operate HoloLens with Skype (not Skype for Business) which was a concern because Skype is not HIPAA compliant. This would render our work unable to scale into practice. However, a software update eliminated the possibility to use Skype with HoloLens. This complicated the manner in which we would represent three-way interaction between the provider, facilitator, and patient. Microsoft replaced Skype with an application called Dynamics Remote Assist. Dynamics Remote Assist (DRA or Remote Assist) allows the HoloLens user to accept an incoming Microsoft Teams call or make an outgoing Microsoft Teams call. Although CMH already owns Dynamics 365 as part of a Microsoft subscription bundle, the purchase of a separate license to enable the DRA application on the HoloLens was mandatory. After multiple conversations with a Dynamics 365 representative, we learned that group calling or adding a third party to a video chat in DRA was not available but in the product roadmap. This is significant because the way in which a three-way video call transpires with HoloLens in the future should be less complex than the method we used. We developed a three-way communication method in another more cumbersome way by running both Skype for Business (which is HIPAA compliant) on the PC in the provider's office and on the PC in the exam room, Microsoft Teams on the provider's workstation and Remote Assist on the HoloLens PC. The way in which the provider and facilitator manage this is explained in Chapter 3.

We focused on recruitment of providers that currently practice telemedicine. The providers specialized in different areas of medicine, including gastroenterology and pulmonology. Four out of the five providers were extremely familiar with InTouch, and the one provider who was not familiar was still able to perform the InTouch simulation. This provider whom specializes in hematology-oncology indicated that the Polycom audio system is primarily used when conducting telemedicine appointments. In order to simulate a plausible clinical scenario for the providers, a CMH pulmonologist was observed during one morning of clinical telemedicine appointments. This pulmonologist was requested to help refine the script and in order to do so tried on the HL headset.

The provider who helped refine the script participated as one of the providers in our study, and "strongly agreed" with all positively-shifted HoloLens statements (*Figure 4*). It is possible this provider strongly agreed to all statements due to increased understanding of

HoloLens functionality. All providers agreed on the statement that "HoloLens has potential in a clinical or other healthcare setting" suggesting positive reactions from providers with increased use and understanding of device functionality.

The negatively-shifted HoloLens statements in conjunction with additional provider feedback via short answer response reiterates the need for ancillary devices to connect to the HoloLens. Provider judgment that the interaction between provider and facilitator may be negatively affected could be due to the providers' reliance on the facilitator for communication on the patient's heart and stomach sounds and ear, nose, and throat images. This may discourage the provider and put additional pressure on the facilitator. Moreover, providers were wary of the provider and patient relationship with the HoloLens technology which suggests the reliance on facilitator feedback may jeopardize the provider's patient health determination.

The following statement assessed the requirements for providing three-way communication with the HoloLens: "I found the HoloLens workflow difficult to understand or utilize compared to InTouch." 40% of participants (2/5) "agreed", 40% were "neutral", and 20% "disagreed" (1/5). This suggests the workflow was rather complex and may be difficult for providers (and even facilitators and patients) to grasp. One provider that agreed with this statement of HoloLens workflow in comparison to InTouch workflow is also the provider that had previous experience with HoloLens, suggesting that regardless of comfort and understanding of functionality there are still several steps in the communication initiation process could overshadow the technology benefits. Therefore, once Microsoft develops a system in which HoloLens users can communicate with more than one other individual, this concern should diminish.

100% of participants were strongly interested or strongly agreed that they had interest in learning new technologies in general as well as new forms of telemedicine that are unfamiliar to them. This percentage could lessen in a study that recruits providers not already utilizing telemedicine in practice. Providers that are unfamiliar with telemedicine may have more difficulty accepting and using technologies to replace a clinical in-person visit with a remote visit. For this reason, it is imperative providers have a user-friendly high-quality technology to conduct remote appointments. Patients may not be willing to transition to a new telemedicine program for similar reason. Fear of losing the personal aspect of seeing the provider in person may also be a deterrent in telemedicine evolvement. Ongoing training and support for the provider and facilitator is an important aspect to technological evolvement and the easier the technology is to utilize the more accepting providers, facilitators, and their patients will remain.

The technology caused little delay, for both InTouch and HoloLens simulations. The facilitator was forced to restart the InTouch unit during one simulation when the software froze. The most significant cost will come from initial setup of the HoloLens device. Our IT developer worked for several months to successfully establish three-way communication with the HoloLens. However, once this was vetted ease of use and connection quality greatly improved. Although dependent on the specialty, many telemedicine systems include use of portable medical devices that plug in to a video feed via port such as USB. This was a downside in using HoloLens and future studies should ensure ancillary devices can connect to HoloLens. This will allow providers to see and hear the patient themselves, rather than relying entirely on the facilitator interpretation.

Providers have a responsibility to engage with innovators of healthcare programs when it offers benefits to their patients, and the HoloLens with further technological refinement is a viable option to pursue as the telemedicine program evolves. The American Medical Association Council on Ethical and Judicial Affairs directs professionals and their institutions to support ongoing refinement of technologies and to develop clinical standards for telemedicine [31]. Discrepancies and access to care are problematic in pediatric healthcare and with fewer subspecialists that are more regionalized in comparison to adult subspecialists, HoloLens could offer a mobile cost-effective alternative.

Appendix A: Script

Ian – youth acting as a patient

Liz – nurse acting as a facilitator

Dr. X – participant acting as a provider

Chad – assistant I reading instructions to Ian and Liz in exam room

Sierra – assistant II reading instructions to Dr. X in exam room

<u>PAGE 1</u>

Ian and Liz will be in the exam room in the PCRU that is ready for the simulations. Dr. X will be seated in the office down the hall at the PC that is ready for the simulations.

Chad: "You are here today to participate in a study that will utilize current-state telemedicine technology. You will read and act from the script handed to you. You will read aloud from the script from start to finish taking turns as your name appears.

Ian, you will be acting as the patient in our simulation. You will stay seated here on the exam table and interact as the script says. Liz, acting as the nurse and appointment facilitator, you will use Intouch to interact with the doctor, and you will interact with Ian as the script reads.

The reason for today's visit is Ian has a persistent cough and sore throat, with pulmonary aspiration that occurs inconsistently during eating and drinking. Begin the script once you see the doctor."

Sierra: "You are here today to participate in a study that will utilize current-state telemedicine technology. You will read and act from the script only as your name appears. You will stay seated at the desk as you would a typical telemedicine appointment. You will use Intouch to interact with Liz who is acting as the appointment facilitator and Ian who is acting as the patient.

The reason for today's visit is Ian has a persistent cough and sore throat, with pulmonary aspiration that occurs inconsistently during eating and drinking.

Please begin by logging in to the InTouch system and connect to Portable 2. Begin when you see the room with Liz and Ian."

PAGE 2

Part I Current State (Will be using InTouch)

Dr. X: Once you see the room with Liz and Ian in it, say: "Hello! Can you hear and see me?"

Liz: Reply "**Yes"** or **"No"** depending whether you can actually hear and see the doctor.

Dr. X: To Ian, say "Hello Ian!"

Ian: Say hi once you see and hear the doctor say hello to you.

Dr. X: To Liz/Ian say "I understand Ian is still having aspiration and his chart says the neurologist didn't suggest a second visit after the MRI. How has Ian been since we last met?"

Liz: "Ian has still been coughing with some difficulty breathing when eating and especially when drinking. It isn't every meal, but it is many meals. He hasn't had fevers lately and no choking. He has had trouble with snoring or heavy breathing when sleeping also. He can speak and hear normally and has had normal stools."

Dr. X: “This is a difficult case. Neurology doesn’t see a concern with the MRI and the cause for the aspirating when eating and drinking is not clear. I am glad Ian has been doing well overall and is sleeping well but we need to resolve this issue, so it does not become persistent. Let’s start with the stethoscope - I want to listen to the heart, then the lungs front and back and his belly.”

PAUSE for Liz to do this. *Liz: Use InTouch equipment to listen to the Ian’s heart, lungs, belly. The doctor will be able to hear via ancillary device connections.*

Dr. X: Once you hear Liz’s report say, "Thank you. Let’s also take a look inside his ears, nose, and mouth.”

PAUSE for Liz to do this. *Liz: Use the provided equipment to show the doctor the patient’s ears, nose, and throat. The doctor will be able to see via ancillary device connections.*

Dr. X: “Thanks Liz. I am going to order a sleep study to confirm nothing out of the ordinary is going on while Ian sleeps. Ian, your heart and lungs sound great. I am going to talk with the neurologist and see if he agrees to one more MRI and evaluation. I’d like to reach out to some contacts to get a second opinion and in the meantime, I will also order the sleep study. There may be some inflammation in Ian’s airways, but saturations are pretty good. Functionality and physical exam are both excellent. Growth and development are on track. If another x-ray shows patterns consistent with excess mucus, we may try albuterol to loosen mucus and congestion. I'm going to finish typing Ian's discharge instructions. Please check the printer in a few minutes. Bye Ian and Liz!

End the call.

Chad: "Session One is now complete. We will move on to the last part of the simulation."

Sierra: "Session One is now complete. We will move on to the last part of the simulation."

PAGE 3

Part 2 Variation (Will be using HoloLens, Microsoft Teams, Microsoft Remote Assist)

Chad: "We will go through one more script following the same directions as the original script. Liz, go ahead and put on the HoloLens and let's get started.

The reason for today's visit is Ian has a persistent cough and sore throat, with pulmonary aspiration that occurs inconsistently during eating and drinking. Begin the script once you see the physician.

Dr. X will now be calling."

Sierra: "We will go through one more script following the same directions as the original script. However, you will now use Microsoft Teams and Skype for Business to interact with Liz and Ian in the exam room. The reason for today's visit is Ian has a persistent cough and sore throat, with pulmonary aspiration that occurs inconsistently during eating and drinking. Begin the script once you see the physician.

Please begin by logging into Microsoft Teams and Skype. You will be placing a call to Liz and Ian in the exam room."

Steps to call the exam room:

1. Liz will already be logged in on HoloLens. Dr. X will be logged into Microsoft Teams and Skype for Business. Dr. X will place a call through Microsoft Teams to the HoloLens in the exam room. Liz will accept.
2. Dr. X will call the exam room PC via Skype and Liz will accept in the exam room.
3. Dr. X will immediately mute audio in Skype to reduce feedback, and will share screen and present the Microsoft Teams screen which will allow Liz and Ian to see and hear Dr. X in the exam room.

Dr. X: Once you see Liz and the child, say "Hello! Can you hear and see me?"

Liz: Reply "**Yes"** or **"No"** depending whether you can actually hear and see the doctor. Then ask, "Can you see the exam room I am in with Ian?"

Dr. X: Respond **"Yes"** or **"No"** to confirm connection.

Once you can see Liz, say, "Hi Liz and Ian! Good to see you again. I understand Ian is still having aspiration and his chart says the neurologist didn't suggest a second visit after the MRI. How has Ian been since we last met?"

Liz: “Ian has still been coughing with some difficulty breathing with coughing when eating and especially when drinking. It isn’t every meal, but it is many meals. He hasn’t had fevers lately and no choking. He has had trouble with snoring or heavy breathing when sleeping also. He can speak and hear normally and has had normal stools.”

Dr. X: “This is a difficult case. Neurology doesn’t see a concern with the MRI and the cause for the aspirating when eating and drinking is not clear. I am glad Ian has been doing well overall and is sleeping well, but we need to resolve this issue, so it does not become persistent. Let’s start with the stethoscope. Please listen to his heart and lungs – front and back, and then listen to his belly. Please let me know how it sounds.”

PAUSE for Liz to do this. *Liz: Use the provided equipment to listen to Ian’s heart, lungs, belly and report back. Dr. X will be unable to hear these sounds.*

Dr. X: Ancillary devices will not be attached for you to listen; you will need to wait for Liz’s report.

Once Liz reports back say, “Okay, thanks Liz. Please also take a look inside his ears, nose, and mouth before I make a decision on the next steps.

PAUSE for Liz to do this. *Liz: Use the provided equipment to check the child’s ears, nose and mouth, and report back. Dr. X will be unable to see these areas.*

Dr. X: Ancillary devices will not be attached for you to look; you will need to wait for Liz's report.

Once Liz reports back say, "Thanks Liz. I am going to order a sleep study to confirm nothing out of the ordinary is going on while Ian sleeps. Ian, your heart and lungs sound great. I am going to talk with the neurologist and see if he agrees to one more MRI and evaluation. I'd like to reach out to some contacts to get a second opinion and in the meantime, I will also order the sleep study. There may be some inflammation in Ian's airways, but saturations are pretty good. Functionality and physical exam are both excellent. Growth and development are on track. If another x-ray shows patterns consistent with excess mucus, we may try albuterol to loosen mucus and congestion. I'm going to finish typing Ian's discharge instructions. Please check the printer in a few minutes. Take care!"

Ian/Liz: "Bye!"

Dr. X: *End the call with Liz.*

Chad: "Session Two is now complete. You have now completed the research study simulation. Liz and Ian, thank you for your participation. No video or audio interactions from the study session will be saved. You may break."

Sierra: "Session Two is now complete. Please follow me into the hallway and take the next 10 minutes to fill out the survey we will pull up on the computer screen. Once we acknowledge successful submission, you may exit. No video or audio interactions from the study session will be saved. Thank you for your participation in this study."

END OF SIMULATION

Appendix B: Consent to Participate and Survey Questionnaire

Consent to Participate

Acknowledgement of study objectives:	You are being asked to take part in a research study conducted at the Children's Mercy Hospital (CMH) Adele Hall Campus in the Pediatric Clinical Research Unit (PCRU). The primary investigator of this study is Dr. Mark Hoffman, Associate Professor in the UMKC School of Medicine and Chief Research Information officer at CMH. Qualified research personnel working on the study may act on Dr. Hoffman's behalf. The purpose of this study is to evaluate initial performance, feasibility, and interest for a new developing technology (HoloLens) to be used in clinical telemedicine, from the viewpoint of the physician. This study will utilize technology currently used in telemedicine (InTouch) and will measure degrees of acceptance of a new technology by you after taking part in simulated clinical appointments carried out via scripted dialogue. After the simulation, you will be asked to complete a questionnaire via REDCap. The results of this research may be published or presented to others. You will not be named or otherwise identified in any reports of the study simulation and survey results. By choosing "Yes" you consent to participate in today's clinical telemedicine simulation including completion of the succeeding questionnaire. By choosing "No" you do not consent to take part in this study and your participation will end at the submission of this form.

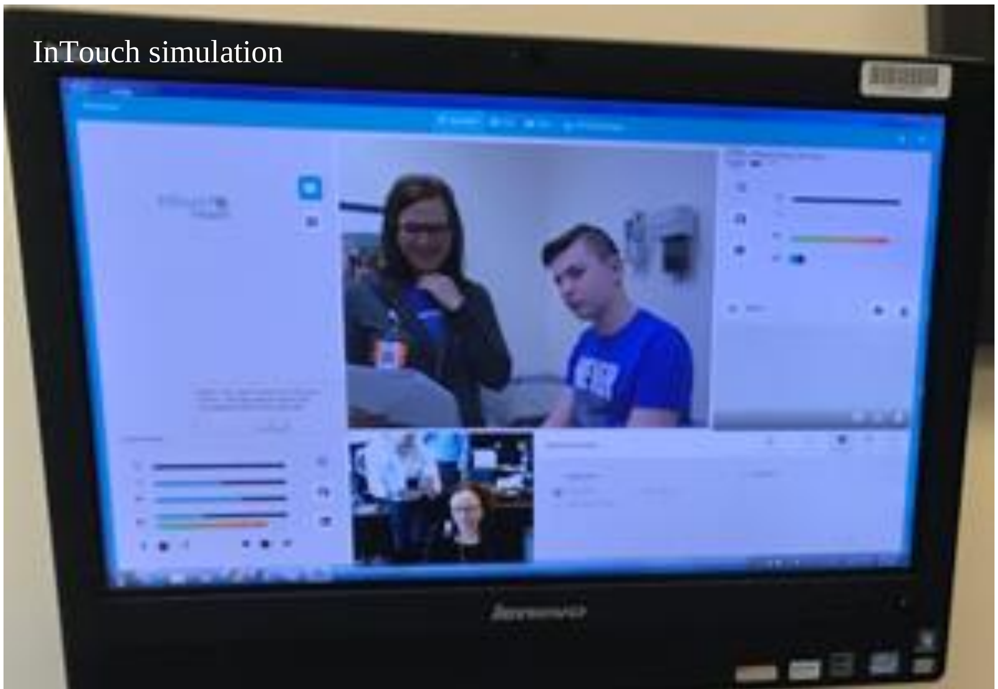
Survey Questionnaire	Response Type
Have you previously used Intouch for Telemedicine?	Yes/No
Clinical Credential(s)	Multiple Choice
Years in clinical practice	Short Response
How often do you practice telemedicine? Please select the option that best applies.	Multiple Choice
Have you used a virtual reality (VR), augmented reality (AR) or mixed reality (MR) device (examples include Oculus Rift, Google Cardboard, HoloLens, HTC Vive)?	Multiple Choice
What is your interest level in learning to work with new technologies in general?	Likert 5 Scale
I am interested in trying new forms of telemedicine, even if I don't know what these may be.	Likert 5 Scale
I am satisfied with the current state of telemedicine.	Likert 5 Scale
I am willing to learn a new mode of telemedicine if I have the appropriate training and support.	Likert 5 Scale
I found the HoloLens workflow difficult to understand or utilize compared to InTouch.	Likert 5 Scale

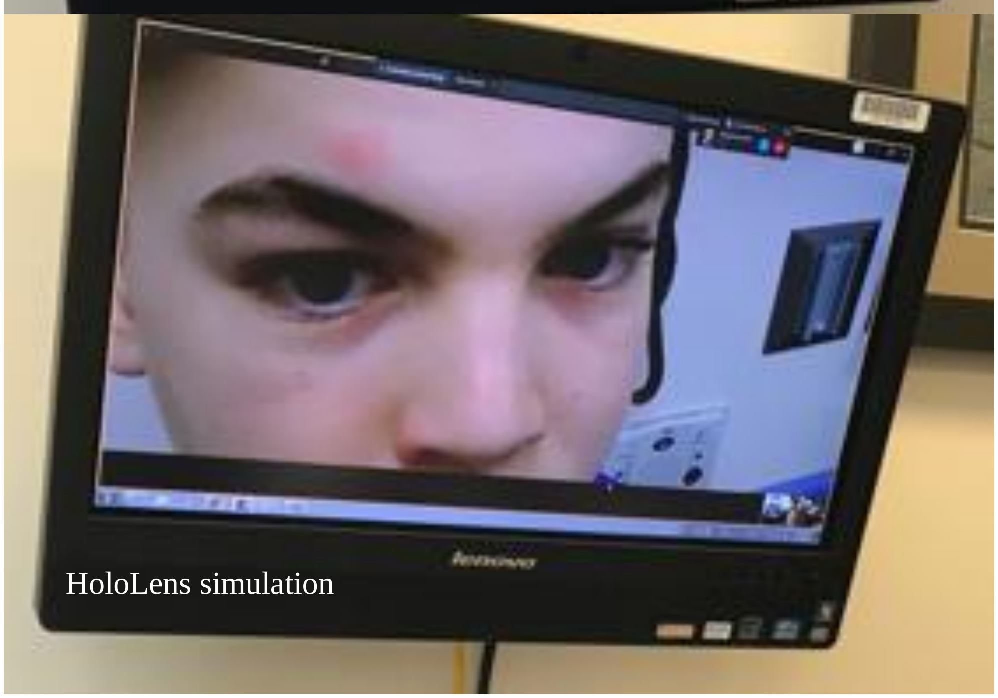
Survey Questionnaire continued	**Response Type**
HoloLens offers ways of interacting that could benefit the patient.	Likert 5 Scale
HoloLens offers ways of interacting that could benefit the physician.	Likert 5 Scale
HoloLens functionality may negatively affect physician - patient interaction.	Likert 5 Scale
HoloLens functionality may negatively affect physician - facilitator interaction	Likert 5 Scale
HoloLens functionality may negatively affect facilitator - patient interaction.	Likert 5 Scale
The scripts in today's two sessions related to a real-world scenario and are plausible.	Likert 5 Scale
HoloLens has potential in a clinical setting.	Likert 5 Scale
HoloLens has potential in the greater healthcare setting.	Likert 5 Scale
What do you like about telemedicine?	Short Response
What do you not like or think could be improved in telemedicine?	Short Response
Was this your first time seeing a view of an exam room or space via HoloLens?	Yes/No
Please share feedback regarding this simulation:	Short Response
Thank you for participating in the HoloLens Usability Study! If you have additional comments, please record in the space provided and then submit the survey.	Short Response

Appendix C

Images

A. Provider Office - The monitor where the provider sees the patient and facilitator during the InTouch simulation, and the patient during the HoloLens simulation.





Exam Room – the exam table with facilitator, patient, ancillary equipment and speakers for the InTouch and HoloLens simulations.

InTouch simulation

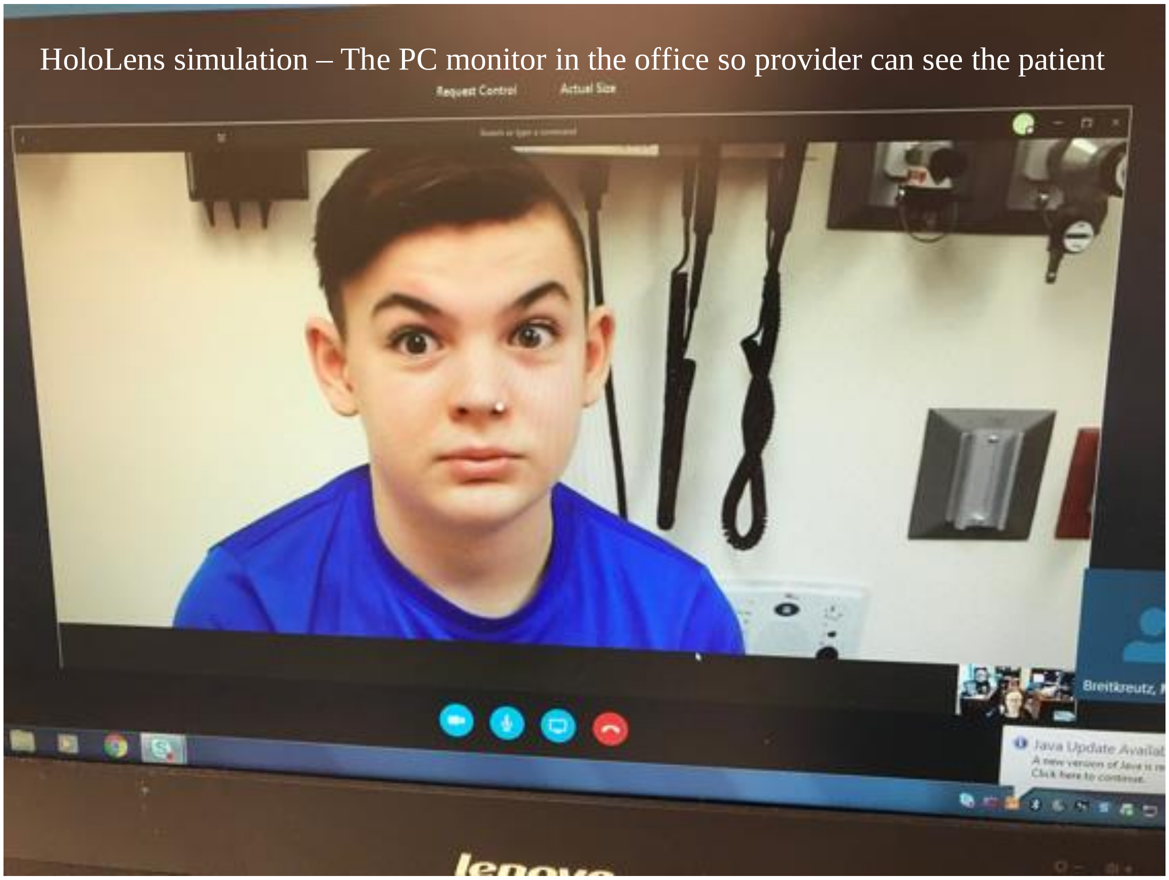
InTouch simulation

InTouch simulation

InTouch simulation

HoloLens simulation

HoloLens simulation – The PC monitor in the exam room so patient can see the provider.



HoloLens simulation – The PC monitor in the office so provider can see the patient

REFERENCES

1. Elliott T, Shih J, Dinakar C, Portnoy J, Fineman S. American College of Allergy, Asthma & Immunology position paper on the use of telemedicine for allergists. *Ann Allergy Asthma Immunol* 2017;119:512-7.
2. Portnoy, JM, Waller, M, Farrell, K. Telemedicine improves allergy care for hospitalized patients. *J. Allergy Clin Immunol Pract.* 2018;6(6):2041-2042. doi:http://dx.doi.org.proxy.library.umkc.edu/10.1016/j.jaip.2018.05.016
3. Fitzpatrick T. A brief history of the internet. Science node. https://sciencenode.org/feature/a-brief-history-of-the-internet-.php. Published Feb 9, 2017. Accessed June 21, 2019.
4. Waller M, Taylor L, Portnoy J. The medical virtualist: Is pediatric patient care using telemedicine, a new specialty? *Pediatric Annals.* 2019;48(6). doi:10.3928/19382359-20190520-01.
5. McSwain, DS Marcin JP. Telemedicine for the care of children in the hospital setting. *Pediatric Annals.* 2014;43(2), E44-E49. Retrieved June 6, 2019, from Healio.com/Pediatrics.
6. Waller M, Stotler C. Telemedicine: a primer. *Current Allergy and Asthma Reports.* 2018; 18(10):54. doi: 10.1007/s11882-018-0808-4.
7. Dorsey ER, Topol EJ. State of telehealth. *New England Journal of Medicine*. 2016;375(14):1399-1400. doi:10.1056/nejmc1610233.

8. Vyas S, Murren-Boezem J, Solo-Josephson P. Analysis of a pediatric telemedicine program. *Telemedicine and e-Health.* 2018;24(12):993-997. doi:10.1089/tmj.2017.0281

9. Qubty W, Patniyot I, Gelfand, A. Telemedicine in a pediatric headache clinic. *Neurology*. 2018;90(19). doi:10.1212/wnl.0000000000005482

10. Satou GM, Rheuban K, Alverson D, Lewin M, Mahnke C, Marcin J., . . . Sable CA. Telemedicine in pediatric cardiology: A scientific statement from the American Heart Association. *American Heart Association, Inc.* 2017;135(11), E648-E678. doi:10.1161/cir.0000000000000478

11. Tuckson RV, Edmunds M, Hodgkins M. Telehealth. *New England Journal of Medicine.* 2017;1585-1592. doi:10.1056/NEJMsr1503323

12. Dharmar M, Romano PS, Kuppermann N, et al. Impact of critical care telemedicine consultations on children in rural emergency departments. *Crit Care Med.* 2013;41(10):2388-2395.

13. Burke BL, Hall RW. Telemedicine: Pediatric Applications. *American Academy of Pediatrics.* 2015;136(1). doi:10.1542/peds.2015-1517

14. Portnoy JM, Waller M, De Lurgio S, Dinakar C. Telemedicine is as effective as in-person visits for patients with asthma. *Ann Allergy Asthma Immunol.* 2016;117(3):241-5.

15. Siew L, Hsiao A, Mccarthy P, Agarwal A., Lee E, Chen L. Reliability of telemedicine in the assessment of seriously ill children. *Pediatrics*. 2016;137(3). doi:10.1542/peds.2015-071.

16. Brophy PD. Overview on the challenges and benefits of using telehealth tools in a pediatric population. *Advances in Chronic Kidney Disease.* 2017;24(1), 17-21. doi: 10.1053/j.ackd.2016.12.003.

17. Cipresso P, Giglioli I, Raya M, Riva G. The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature. *Frontiers in Psychology*. 2018;*9*. doi:10.3389/fpsyg.2018.02086.

18. Aboujaoude E, Salame W. Technology at the service of pediatric mental health: review and assessment. *The Journal of Pediatrics*. 2016;171, 20-24. doi:10.1016/j.jpeds.2015.12.009.

19. Glegg S. Virtual rehabilitation with children: Challenges for clinical adoption [from the field]. *IEEE Pulse.* 2017;8(6), 3-5. doi:10.1109/mpul.2017.2750858.

20. P Boulanger. Application of augmented reality to industrial Tele-training. *Proc. 1st Can. Conf. Comput. Robot Vis*. pp. 320–328, 2004.

21. The difference between virtual reality, augmented reality and mixed reality. Julia Tokareva. https://www.forbes.com/sites/quora/2018/02/02/the-difference-between-virtual-reality-augmented-reality-and-mixed-reality/#3807ae2b2d07 . Published February 2, 2018. Accessed June 21, 2019.

22. Hong K, Sakamoto Y, Irani P. The use of head-worn augmented reality displays in health communications. *Studies in Health Technology and Informatics*. 2019;257, 163-169. doi:10.3233/978-1-61499-951-5-163

23. Hoffman MA. The future of three-dimensional thinking: A new holographic platform holds promise for enhancing education, research, and collaboration. *Science AAAS.* 2016;353(6302), 876.

24. Hoffman MA, Provance JB. Visualization of molecular structures using HoloLens-based augmented reality. *AMIA Joint Summits on Translational Science proceedings. AMIA Joint Summits on Translational Science*. *2017*;68–74.

25. Wu M, Chien J, Wu C, Lee J. An augmented reality system using improved-iterative closest point algorithm for on-patient medical image visualization. *Sensors*. 2018;18(8), 2505. doi:10.3390/s18082505.

26. Braly AM, Nuernberger B, Kim SY. Augmented reality improves procedural work on an international space station science instrument. *Human Factors: The Journal of the Human Factors and Ergonomics Society*. 2019. doi:10.1177/0018720818824464.

27. Witowski J, Darocha S, Kownacki Ł, Pietrasik A, Pietura R, Banaszkiewicz M, . . . Kurzyna M. Augmented reality and three-dimensional printing in percutaneous interventions on pulmonary arteries. *Quantitative Imaging in Medicine and Surgery*. 2019;9(1), 23-29. doi:10.21037/qims.2018.09.08.

28. Forrest WP, Mackey MA, Shah VM, Hassell KM, Shah P, Wylie JL, Helmy R. Mixed reality meets pharmaceutical development. *Journal of Pharmaceutical Sciences*. 2017;106(12), 3438-3441. doi:10.1016/j.xphs.2017.08.020.

29. Hanna MG, Ahmed I, Nine J, Prajapati S, Pantanowitz L. Augmented reality technology using Microsoft HoloLens in anatomic pathology. Archives of Pathology & Laboratory Medicine. 2018;142(5), 638-644. doi:10.5858/arpa.2017-0189-oa.

30. Mitsuno D, Hirota Y, Akamatsu J, Kino H, Okamoto T, Ueda K. Telementoring demonstration in craniofacial surgery with HoloLens, Skype, and three-layer facial models. *Journal of Craniofacial Surgery*. 2019;30(1), 28-32. doi:10.1097/scs.0000000000004899.

31. Chaet D, Clearfield R, Sabin JE, Skimming K; Council on Ethical and Judicial Affairs American Medical Association. Ethical practice in telehealth and telemedicine. *J Gen Intern Med*. 2017;32(10):1136–1140. doi:10.1007/s11606-017-4082-2.

VITA

Emily Joelle Deutch was born on May 7, 1990, in Overland Park, Kansas. She graduated from Blue Valley Northwest High School in 2008. She earned her BA in Chemistry at the University of Kansas in Lawrence, Kansas in May 2012. She received a Research Experience Program certification on her diploma by working with the Chair of the Chemistry department in his pharmaceutical laboratory.

In Spring 2016 Emily began a master's program in the Department of Biomedical Health & Informatics at the University of Missouri Kansas City. After working as a FSQR Chemist at Cargill in Kansas City, MO from 2012 to 2016, Emily was hired as the FSQR lab manager and is currently in this role. She will complete the Master of Science in Bioinformatics degree in Fall 2019.