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Application Of M.E.A.N Stack Restive API And WEBRTC In The Design Of A Real-Time Telemedicine Service

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Abstract: ***Most real-time Communication (RTC) systems that are frequently used in video based telemedicine services require plugin to work correctly, and are also proprietary and often too expensive to acquire and maintain. The aim of this study was to develop a telemedicine platform for real-time interaction between caregivers and patients using an open standard to enable real-time interaction in or outside the hospital and to ensure improved quality of service without the need for plugins, installation and downloads. We focused on developing the application using an orchestration of latest technologies ranging from MongoDB, ExpressJS,*** **JADE view engine,** ***Node. JS and WebRTC to bring more flexibility. The study was conducted through a user centred approach. Qualitative and quantitative data were collected from potential users and used in the development process. The application was tested and evaluated by users. The evaluation results showed that there was easy and real-time interaction between caregivers and patients. The application also indicates the potentials to improve communication, quality of healthcare services and cost of healthcare services especially for people living in remote communities across the country.***

Keywords: JADE, ExpressJS, NodeJS, REDIS, IETF, RTC, WebRTC, MongoDB, Telemedicine, Caregiver, Patient.

I. INTRODUCTION

Telemedicine is a branch of Tele-health that offers consultation services, diagnosis and treatment even within long distances. This is done using approaches like videoconferencing or transmission of digital files by healthcare professionals to those on the scene. The Internet and the web are emphatically important and a dependable platform to almost everyone. The Internet is vital for the transfer and retrieval of information ranging from individual to corporate information. For this reason, the Internet Engineering task Force (IETF) and the World-Wide Web Consortium (WWW) are collaboratively working on JavaScript API, communication protocols, standards and numerous other efforts to bring about seamless possibilities of Real-time Communication within the dependable web ecosystem for the benefit of its users (Johnston & Burnett, 2014; Burnett & Narayanan, 2012). This study considered the local environment, to explore and uncover most of the related benefits in healthcare information interchange.

In the study, attempt was made to create a real-time solution from the composition of recent technologies and deploy the solution for Telemedicine service. This will enable communication between caregivers and patients within and outside JUTH remotely. Sime (2016) found that this will also enable first–hand quality interactive care and increase patients' participation. The application was also implemented and evaluated using Heroku platform as a service (PaaS) cloud hosting. Panagiotakis, Kapetanakis & Malamos (2013) and Dutton (2012) revealed that if Real-Time Communication (RTC) in the web is simplified as text input operations, the quality of communication will increase and will offer new ways for people to interact efficiently. One major challenge for the World Wide Web over the years has been the inclusion of human communication through voice and video RTCs (Chiang-Yen et al., 2014; Sergiienko, 2014). Similarly, integrating existing content, data and services with RTC technologies had been difficult on the web and time consuming due to issues such as licencing or implementation.

RTCs may require expensive and dedicated hardware

facilities in order to host multimedia contents as a result of resource consumption. Hence, this demand has left RTCs implementation for larger corporations with financial capabilities. One critical problem and practice has been that, most RTC require appropriate plug-ins, installation and downloads of certain software to work correctly as seen with the Skype application which uses Flash, Google Hangouts with Google Talk plugin, Silverlight and flex. The end product of this research is a hypermedia meant for improving accessibility and interactions in telemedicine healthcare in the University of Jos Teaching Hospital (JUTH) and its environment. The reason for using the enumerated development tools for realizing the aim of this study is that the technologies are young and emerging. They are also free and open source, cross platform, consistent model, less hardware and cost effective (Cryer et al., 2012).

We utilised the capabilities of MEAN stack RESTive API described by Haviv (2014), along with WebRTC and its related standards such as Network Address Translation (NAT) (Helsingin, 2015), Session Traversal Utilities for NAT (STUN), Traversal Using Relays around NAT (TURN) (Dutton, 2012), JavaScript Establishment Protocol (JSEP), Interactive Communication Establishment (ICE), Session Description Protocol (SDP), User Datagram Protocol, (UDP) (IETF, 2012; Bergkvist, 2012), SRTP (Baugher et al., 2004), socket.IO protocols to support any kind of communication over distances and to ease transfer of files across platforms. The use of plug-ins or downloads have been limited to the barest minimum and increase users accessibility and affordability by leveraging on WebRTC.

This research therefore utilises these technologies to offer patients medical services within and outside the hospital (Giamouzis, et al., 2012; Pare et al., 2013) expounded on similar benefits. In this study, a telemedicine service has been achieved without regular plug-ins such as shockwave, flash, and java in the browsers and without the need to download and install software for multimedia contents to work each time.

II. LITERATURE REVIEW

Telemedicine is regarded as the utilization of Information and Communication Technology (ICT) for the purpose of delivering valuable healthcare services to patients at distant areas. This helps to reduce the frequencies of hospital visits and to enhance confidence in healthcare especially among the aging population and people living in remote areas (ONS, 2009).

III. TECHNOLOGIES USED FOR TELEMEDICINE

Monica et al., (2014) describes a telemedicine platform for patients with amputated limbs. The application enables prosthetic patients to enjoy certain assistance such as scheduling appointment and meeting their Doctors online. The authors further explained the techniques used in the system design, It include the LAMP stack and WebRTC technology and it does not need plug-ins such as flash to support audio-visual contents to be transmitted between caregivers and Patients. Wang (2013) describes a tele-homecare system that uses a wireless transmission technique via sensors to provide physiological inputs for remote health consultation and diagnosis. The system was used to receive measurement of people's blood pressure, electronic cardiograph (ECG) heart rate transmissions, blood and oxygen levels. The platform was designed by means of Smarty modular Web architecture and provided series of services to users of every category. The interface of the specialised application uses a complex Service Oriented Architecture (SOA) and Health Level Seven International (HL7) to deliver real-time experience. John (2015), reported four video based telemedicine technologies, it include:

- ✓ Highfive cloud-based video conferencing technologies: This technology uses a HD camera alongside a monitor, it is proprietary and uses extensive hardware.
- ✓ Logitech ConferenceCam: It connects with Cisco Jabber or skype using a high-end conference camera to a laptop
- ✓ ViewSonic VG2437Sm 24-inch LED Monitor: This technology uses LED 24-inch with built in 2-megapixel webcam monitor. Google Hangouts is pre-installed into it for video conference. It uses specific ports for microphone, headphones and built-in speakers.
- ✓ Dell Chromebox: was designed for videoconferencing meetings using Google Chrome OS and a dedicated video camera and speakerphone that sits in front of a monitor.

This technology allow users boot directly into Google Hangouts to make video chats with other partners faster. Gondi (2014) described some open source services that are linked with WebRTC technology and were developed on the bases of certain services such as video and audio chat, screen sharing capability, video recording, broadcasting, collaboration, mobile inclusion, file transfers, 3D and games features. For example, Milton (2015) describes Vsee as a highly integrated WebRTC technology that is simple to use, highly secured, low bandwidth, customisable and does not use session initiation protocol (SIP) and H.323 support. The author reported how the technology has been modified into various highly customised telemedicine solutions described in various innovative conferences. Blue Jean (Tom, 2011) is a similar technology that was developed with WebRTC to provide telemedicine services, but the technology requires plug-ins and has comparably low video quality. Skype is used all over the world to make cheap calls. It has the largest market share for video conferencing and different versions for desktop and mobile platforms. It requires users to download plug-ins and it is also characterised by high bandwidth consumption, proprietary and uses a client server model. Skype is not open source (Patrick & Alexandra, 2013). Other similar technologies include ooVoo (Oovoo LCC, 2013), this is a video conferencing technology but has a complicated user interface, Second life (Lindel Labs, 2013) and Google hangout are similar application used in video chat but require downloads of plug-in. FrisB is an application that uses only voice with no video channel. A user can freely invite other telephone users around the world to join a conversation with no text chat required. Video Conference in 3D-environment (Etienne, 2012; Gondi, 2014) operates based on WebRTC and WebGL. A user can be able to interact in a virtual world and

invite people to a room chat in real life. Others include Tokbox/Opentok, Vidyo, Tango, Zoom, Openqwaq, Cisco Jabber, WebEx, Microsoft lynx, Blue Jean (Patrik & Alexandra, 2013). Most of these applications are meant for general video conferencing, document sharing and collaboration among users but not for the specific function of telemedicine, even though some of them can be customised for this purpose. They did not really integrate the whole components we have applied in this study.

Some historical and technological innovations in telemedicine research have revealed the source of its emergence and maturity. These innovations are leading the way today and improving the future of telemedicine (Armfield, Donovan & Smith (2010). Issues relating to several dimensions of telemedicine were pointed out by Young et al., (2002). The authors described how telemedicine will have an impact on present and future technologies. They also reviewed several definitions of telemedicine. The authors describe Telemedicine as an open science whose foundation and future depends on advancing technologies to meet up the changing health requirements and contexts of societies. Young et al., (2002), Giamouzis et al., (2012) studied several telemedicine systems and pointed out that it can be used for the management of chronic ailments. (Supreet & Yashwant, 2016) analysed the comparative degree of acceptance of telemedicine research for various types of communication in their journal. While the researchers have clarified on the acceptance and utilization of telemedicine technologies, there are still mixed reactions and concerns over Patience's and caregiver's full satisfaction. Hence, researchers need to evaluate every requirement for user's maximum utilisation.

IV. TELEMEDICINE IMPLEMENTATIONS

Telehealth (Health Canada, 2008) is a related term and sometimes used interchangeably with telemedicine. It refers to various electronic based health services and also includes the actual healthcare giver and patient interactions and the delivery of information and education. It is designed to intensify awareness, treatments and other quality health practices (wootten, 1996). Video conferencing has been used for low cost teleconsultation (Grisgsby & Allen, 1997). Mobile phone technology development has triggered more research in telemedicine worldwide. Mobile phones and slow scan videos are used for transfer of medical data and video (Curry & Harrop, 1998). Telemedicine has been applied in almost every area of e-Health such as nursing care (Schlachta & Sparks,1998), therapy (Withson, et. al, 1961), training and education (Menolascino et. al, 1970), telemetry (Fuchs, 1979), televisits (Straker, et. al., 1972), and home care (Mark, 1974). Cocchi (2015) estimated a high growth rate in Telemedicine participation from 350,000 users to about 7,000,000 users before the year 2018. Research analysis also estimates an average growth of 18.5% in the global telemedicine market before 2020 (Graham, 2013), as well as monetary cost saving of more than $5 billion through millions of Telemedicine visitations (Lee, Stewart & Calugar-Pop, 2014).

V. TELEMEDICINE IN NIGERIA

Telemedicine in Nigeria is not yet established properly. It is intended to provide high quality healthcare to the most secluded parts of Nigeria (Onche, 2011). According to Onche (2011), areas where telemedicine had been implemented in Nigeria, it had been through the use of tele-conferencing technology. This has recorded significant success but not enough to cover the large population and remote settlements. Telemedicine has not gained full grounds for proper implementation due to lack of high-level stakeholder's commitment for sustenance and high cost of maintenance.

VI. RESEARCH METHOD

We applied the agile method to develop the application. Potential users were identified within and outside JUTH. The study was conducted with the involvement of the identified potential users. Qualitative and quantitative data were collected during the interactions with the participants and for the design and evaluation of the application.

The system was designed with ease of use, simplicity and usability in mind. The System development phases include the following: listening/planning, designing, coding and implementation. During the listening/planning phase, we gathered the actual requirements that are typical in determining how the real-time Telemedicine service should work and also to deliver feedback during the development. This was achieved by creating and analysing logical user stories. The design involved separating the functional and non-functional requirements to allow full control over respective interface design.

At the design stage, the telemedicine system relied on information obtained from the planning stage. The development components were set-up in a logical modular Model-View-Controller (MVC) frame before actual coding commenced. The process of re-factoring or refinements and testing was applied on modules to eliminate any error. The nature of modules interrelation and interactions was collaboratively determined. The flowchat in FIGURE 1 presents the diagrammatic flow of the system.

At the coding phase, emphasis was placed on creating high quality application. The requirements for the system were used in the design. Unit testing of the various modules was done ahead of release plans and the reduction of iteration cycles was also done using common sense approach and XP philosophies. Testing was performed and the different components were guaranteed functional before fusing them with each other. FIGURE 3 shows the various interfaces of the telemedicine system and the different user groups: the healthcare givers, personalised interfaces for patients and super administrator. The system also performs the following operations: authenticate users, implement calendar scheduling, request and acceptance modules, WebRTC Video conferencing, e- mailing, and a flexible RESTive API for sending and receiving messages, validation and pagination.

A. SOFTWARE REQUIREMENTS AND DESIGN

The Software requirements specification for the telemedicine system essentially captures series of timely pre-design tasks which were analysed before software design and development began. In order to identify the essential requirement and to create the user stories, formal and informal interviews were carried out with some staff of JUTH at various times. The discussions and interviews were required to elicit requirements or user stories. Later, the requirements were used as a working document for the design and coding. Various contributions were received from various units and individuals. These include the ethical unit, ICT, administrative staff, caregivers and patient during the listening phases. The responses were analysed and organized. All modifications made to the information were recorded and added in the bit bucket version control API.

The requirement specification was categorised into 3 different groups which include 1) Telemedicine needs 2) Operational specifications and 3) Internal design specifications. From the discussions with users, the specific tasks that must be performed were identified. The first thing was to consider a real-time interaction system, and a peer to peer network architecture as a suitable architecture for fast and none in-context communication. And also, to eliminate interception by intruders and to keep the patient information secured and in line with HIPAA and ethical standards.

The operational requirement specification describes the useful features which should be integrated in telemedicine application for example the system will have various user categories, the login credentials should differentiate the tasks which should be performed by the user category. Also, the user should be able to perform a Create, Retrieve, Update and Delete operations. The Internal design specification are tasks left for the designer to FIGURE out the best logic and strategy of the design, the platforms and technologies to use as well as browser support. The design decisions were streamlined to consider the use of Node.JS for the server side run-time environment, Express.JS was used as the server side framework for Node.JS, MongoDB for the database and JADE template engine for the front end design since these technologies are fast and support JSON. The MVC modular design and WebRTC for real-time video communication were also used. The module and naming strategies were considered critical in the internal design of the telemedicine system. The most important phase for creating high quality application was during the coding phase. At this stage, the user task and design specifications were carefully followed. Hence time frame was set, targets prioritised and followed. The flowchart (FIGURE 1) shows the three categories of users and their various operations.

The M.E.A.N architectural patterns for building the telemedicine application is based on the MVC style (FIGURE 2). A Model can be viewed as data or information store, the View as the layout of the user interfaces that renders data, and the Controller as logic that handles the control flow including any business logic needed to build the Model and pass the model data and the view for presentation to its end user. In the design of the telemedicine system, a route component was added between the controllers and the mandated user's browser in order to coordinate the interactions with the controller. One common strategy was to have a RESTful interface which feeds a single page application (SPA). REST interfaces are implemented through REST API. In the telemedicine design, an HTTP request will be routed to the appropriate Controller Action based on the URL. The Controller Action will process information then submit it in the request, and then returns the appropriate Model and View for rendering to the end user. Goran (2016), described the MVC as a software architectural pattern for implementing the UI. It has three interconnected parts, separating the internal representations of information. The architecture of this system consists of data, logic, and presentation layers similar to the database, server, and client in web application development. The architectural implementation pattern will handle the logic, visualization and data as presented in FIGURE 2. While the operational architecture in which the telemedicine application is based, is presented in FIGURE 3.

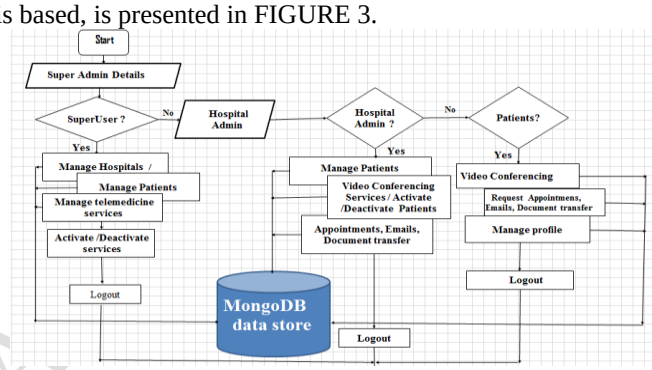

Figure 1: Flowchart of the telemedicine system

MODEL – VIEW - CONTROLLER (MVC) ARCHITECTURAL DESIGN

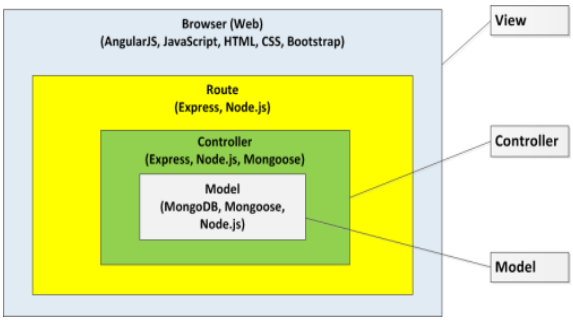

Figure 2: M.E.AN M-V-C Architectural pattern adapted from (Goran, 2016)

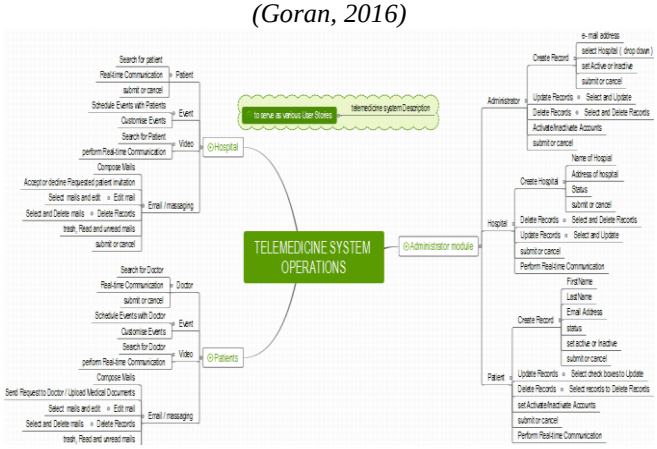

Figure 3: Operational structure of the telemedicine system

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VII. RESULTS AND DISCUSSIONS

APPLICATION SCREEN SHOTS

The application was developed and was hosted on the Heroku platform as a service (PaaS) cloud server as shown on the snippet below. A flexible deployment platform was considered because of its benefits. Heroku platform as a service (PaaS) cloud hosting was chosen because it allows developers to focus on building, running, and scaling application. It helps to reduce cost, better access to developer infrastructure and support for Quality of service. The following command were used on git to deploy the application.

$ heroku login // login into the heroku account and install the toolbelt

$ cd m – hrtc /

$git - init

$heroku git: remote –a hrtc

Git add.

Git commit –am"make it better"

Git push heroku master

The secured login page comes up as soon as the URI is entered over HTTP transport protocol in the address bar as shown in FIGURE 4, while the transport layer protocol uses *User Datagram Protocol (UDP).* The users will first of all go through the authentication process before having full interaction with the system. Every user need to be registered as either a patient or medical personnel by the super admin and will be e-mailed their secured login credentials before logging into the application. FIGURE 4, depicts the user interface that is used by the three categories of users to include Super user, hospital admin and Patients. The system allows entry based on login. If login is successful, users are allowed to carry on their related operations

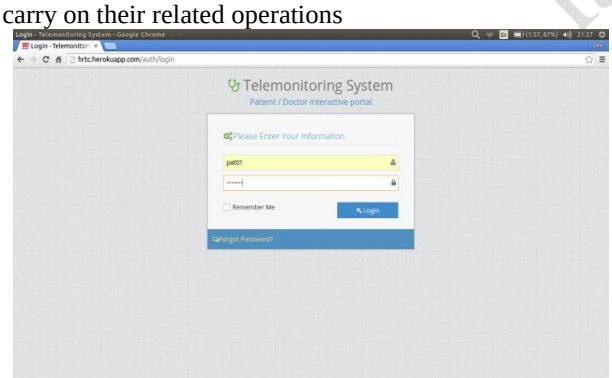

Figure 4: The Login page for the application

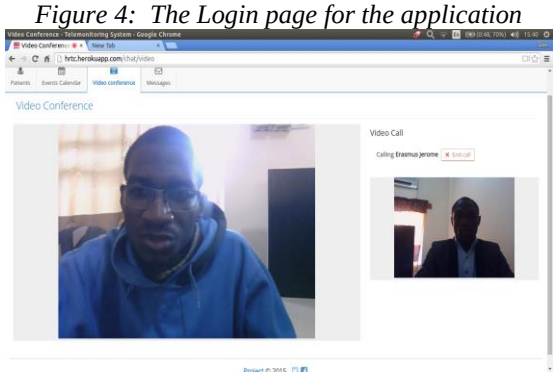

Figure 5: A sample virtual user and caregiver communication interface

FIGURE 5 shows the real-time conversation between the caregiver and the patient using Google chrome browser. The elimination of plugins in the entire running of the application has automatically eliminated all the problems that are associated with plug-ins. The solution was obtained using WebRTC and MEAN stack without installation of custom drivers plugin and downloads and also hosting the application on the Heroku platform.

USER EVALUATION

In conducting the user evaluation process, some of the users/participants were provided most of the setup tools, in cases where the tools were not readily available. They were provided with personal HP laptop computers, installed with windows XP and Ubuntu V. 14.04 Linux Operating systems. The systems were installed with Google Chrome, Mozilla Firefox and Opera web browsers that were required to run the telemedicine application. They were also provided with broadband modems required for Internet connectivity. Most of the participants stayed within the comfort of their offices or homes to interact with the application. After the complete setup of the working tools, the participants were asked to login into the system using login credentials automatically generated on registration or provided by the administrator through the telemedicine URL to enable them to participate in the evaluation. Several users were successful in logging into the system and carried out the required tasks. The users were asked to explore every activity as they wished. The mandatory activity which every user was expected to explore was the video conferencing interaction. Each participant was asked to communicate with the caregiver (We chose an arbitrary caregiver within the hospital in cases where the main caregivers were not readily available for online interactions). Also for ease, printed copies of the communication interfaces as well as elaborate explanations were printed for patients who were not capable of using the system due to low computer literacy or does not have much time to use the application. In this case, we explained the entire procedure to the participants, thereafter, the users were asked questions with regards to the application.

POST-TEST QUESTIONNAIRES AND ETHICAL CONSIDERATION

We conducted a post-test / evaluation interviews and administered post - evaluation questionnaires. The users were requested to answer the questionnaire freely after completing the consent document. Caregivers that subscribed to interviews were interviewed. Prior to administering both questionnaires and interviews, questions were prepared and structured to match the research aim and objectives. After evaluating the system, we administered 100 questionnaires and interviewed 16 healthcare givers that include 13 medical Doctors, 1 ICT expert and 2 administrative staff. The questionnaire was designed with a likert-scale that was positively rated using 5-strongly agree to 1- strongly disagree. Most of the respondents we contacted were out-patient from various out-patient departments which include General Out Patient Department (GOPD), Medical Out Patient Department

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(MOPD), and Surgical Out Patient Department (SOPD). Ethical consideration was necessary when conducting this type of study (Stenberg, 2000).

JUTH like any other academic medical institution has an ethical policy for patient's security, confidentiality and comfort. Therefore, the research was presented to JUTH ethical committee and adequately screened before an ethical approval was given for the research to be conducted. In the course of the research, Participants / respondents were provided with 1) consent letter 2) in some cases copy of the ethical approval for the respondents to acknowledge the authenticity of the research before they participated.

EVALUATION SETUP AND TASKS

During the evaluation process, the interactions were successfully carried out with participants who showed willingness after the have filled the consent forms and were capable of using the computer for the operations, and other participants who were less literate and showed interest were guided through the process. 100 Participants were successful in carrying out all tasks required during system evaluation activities. These include locating the WebRTC enabled web browsers (newer versions of Chrome, Firefox and Opera) on the provided computers, locating the address bar and entering the correct URL, identifying the telemedicine application, inputting login credentials and interacting with caregivers on the remote site or within the hospital environment through the application. All the practical application procedures were successfully carried out before the participants were allowed to answer the questionnaires.

DEMOGRAPHIC DATA OF STUDY PARTICIPANTS

The demographic data of the study participants include participants for the questionnaire and for the interview sessions.

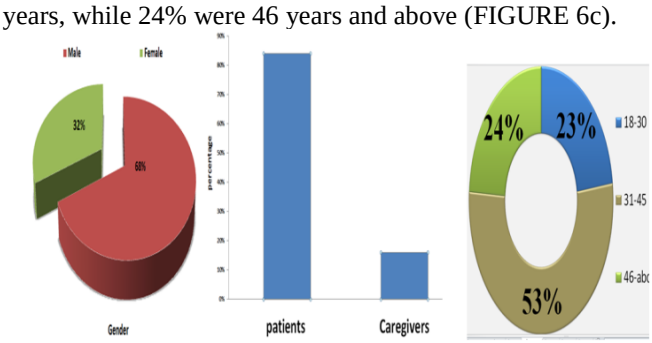
POST-TEST QUESTIONNAIRE

For the questionnaire, the sample population comprise of patients and caregivers (FIGURE 6).

GENDER: Out of a total of 100 participants, there were 68 % of males and 32% of female respondents (FIGURE 6a).

OCCUPATION: 84% of the respondents were patients while 16% were healthcare givers (FIGURE 6b).

AGES: 23% of the participants were between the ages of 18 to 30 years, 53% of the participants were between 31 to 46 years, while 24% were 46 years and above (FIGURE 6c).



a b c

Figure 6: Demographic data for Questionnaire respondent (a: Gender, b: Occupation, c: Ages in years)

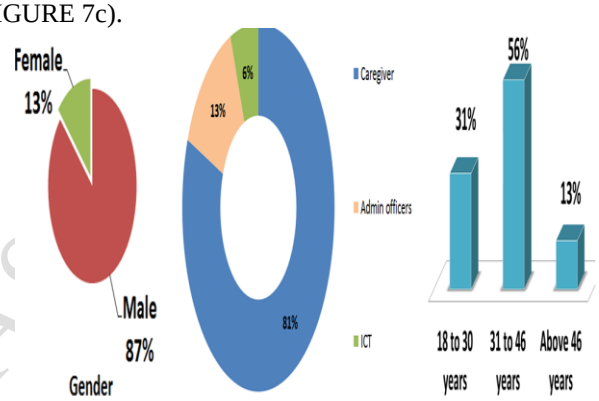
POST-TEST INTERVIEWS

The demographic data of participants during the interview consists of 16 respondents participated in the post-test interview process (FIGURE 7).

GENDER: Out of a total of 16 participants, 87 % were male, while 13% were female (FIGURE 7a).

OCCUPATION: 13 were healthcare givers, 2 were medical administrative officers while 1 was an ICT expert working as staff of JUTH hospital. This FIGURE represents 81% as healthcare practitioners, 13% administrative staff and 6% ICT staff as represented in FIGURE 7b.

AGES: 31% of the participants were between the ages of 18 to 30 years, 56% of the participants were between the ages of 31 to 46 years, while 13% were 46 years and above (FIGURE 7c).



a b c

Figure 7: Demographic data of interview participants (a: Gender 7b: Occupation 7c: Ages in years)

VIII. RESULTS

Based on the post-test questionnaire, we tried to find out from the participants if the telemedicine application can improve interaction between the patients and caregivers and vice versa. If the application will help to improve the quality of service that the patient will receive from caregivers. The result is presented in FIGURE 8.

IMPROVE CAREGIVERS/PATIENT INTERACTIONS WITH THE TELEMEDICINE SERVICE

The users were asked five questions to find out if they see the application as one that can support the improvement of interactions between the patients and caregivers. The results are presented in FIGURE 8.

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Quesionnaire Response for user interaction								
Participant Responses	All responses are based on a Likert scale (Strongly Agree to Strongly Disagree, Strongly Available to Strongly Not available Strongly Agree=5 to Strongly Disagree=1							
Number of Likert Scale Options	5							
Survey Title								
Participants response: Simple %								
Participants response: Standard Deviation (S.D)								
Participants response: MEAN								
Questionnaire total Participation	100%							
Total number of Answered questions	100							
Data Tabulation	Questions						MEAN	STANDARD DEVIATION
Q1	Do you think the Telemedicine system will reduce hospital visits?	31%	56%	12%	1%	0%	4.170	0.667
Q2	The technology can allow for easy access of the interaction site within or outside the hospital	30%	57%	11%	2%	0%	4.150	0.687
Q3	Do you think the system will be helpful in increasing information for diagnosis of health care?	31%	41%	17%	8%	3%	3.890	1.034
Q4	Do you think the system will increase Doctors / patients Real-time interaction?	25%	49%	14%	7%	5%	3.820	1.048
Q5	Having adopted the telemedicine system, do you think the technology will improve the overall cost of healthcare if fully implemented within you locality?	31%	43%	14%	8%	4%	3.890	1.063

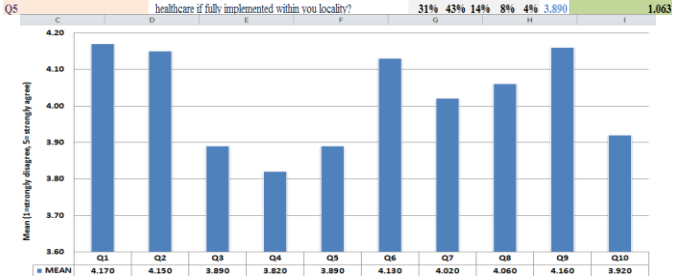

Figure 8: Improve interaction between caregivers and patients

First, the participants were asked if the telemedicine application will help to reduce hospital visits (Question 1). A total of 31% of the participants strongly agreed that the telemedicine service will help to reduce hospital visits and 56% agreed that the application will also help to reduce hospital visits. 12% of the participants gave neutral response. The result is shown in FIGURE 9. From the result, the participants accepted that the telemedicine service will help to reduce regular hospital visits, but will improve the interactions between caregivers and patients because regular interactions are possible through the application. FIGURE 8 presents the calculated mean score of 4.170/5 and the standard deviation (SD) of 0.667 for the user rating. The mean score is positive and indicates that the participants perceive the telemedicine system as a platform that will be able to reduce hospital visits. The SD shows similarity among users perception. When fully adopted, the telemedicine service will reduce cost of obtaining healthcare services in the long run.

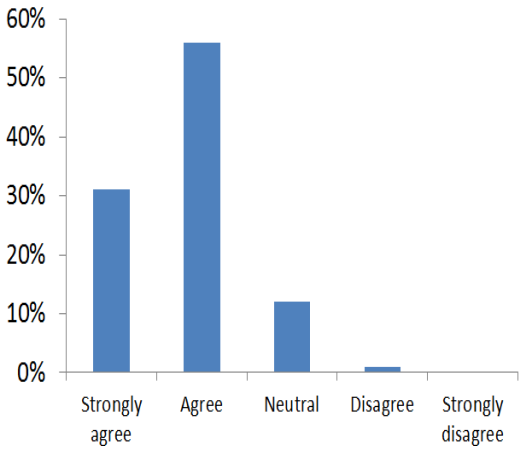

Figure 9: reduce hospital visits

The second item in the questionnaire seeks to find out if the participants see the telemedicine service as a platform that will be able to create easy access to caregivers in and outside the hospital' (Question 2). 30% of the participants strongly agreed and 57% agreed that the platform will enable easy access to caregivers. The result is presented in FIGURE 10.

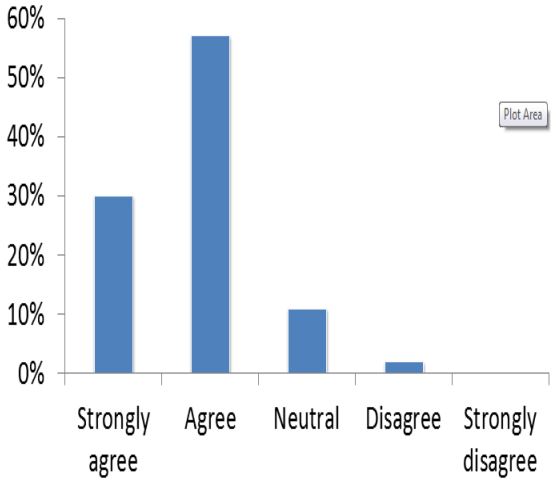

Figure 10: Easy access to caregivers

Similarly, 11% gave a neutral response, while 2% disagreed. The calculated mean score of 4.15/5 and S.D of 0.687 were obtained (see Q2 in FIGURE 8). The result shows a positive rating that the telemedicine service will enable users to have easy access and interaction with health care providers at any time. A S.D of 0.687 shows that a higher percentage of the respondents agreed with the similar opinion.

In FIGURE 8, item (Q3) tries to find out if users think that the telemedicine service will be helpful in increasing information for diagnostic services. FIGURE 11 presents the participants' responses. 31% of the participants strongly agreed that the telemedicine service will provide better information for diagnosis. Similarly, 41% agreed that the telemedicine service will be helpful in providing better information for diagnosis. 17% were neutral, while 8% disagreed. The participants' rating of this item shows the calculated mean score was 3.89/5 and the SD of 1.034 (FIGURE 8). The participants were positive that the telemedicine service will increase information needed for diagnosis.

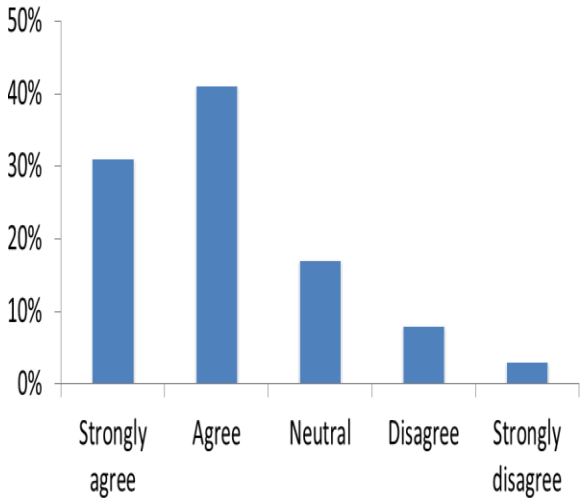

Figure 11: Information for diagnosis services

The fourth item in FIGURE 8 asked the participants to rate the telemedicine service whether it will or not be able to improve caregivers/patients real – time interaction. In this

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case, the participants were asked to use the application continuously at several different times not less than four times within a week to interact with a designated caregiver. This is because there were few number of patients who were hooked to the Internet all the time during the test. The result is presented in FIGURE 12. The result shows that 25% of the participants strongly agreed based on their experience that the telemedicine service will help increase caregivers and patient real-time interaction. Similarly, 49% of participants also agreed that the telemedicine service will increase caregivers/patients real – time interaction. 14% maintained a neutral opinion, while 7% disagreed that the telemedicine service will improving caregivers/patients real – time interaction. The participants' rating was positive (FIGURE 8 and Q4). It shows the calculated the mean score of 3.82/5 and the SD of 1.048. This result shows that the respondents were positive based on the experience they gather during interactions that the application will increase caregivers / patients real-time interactions.

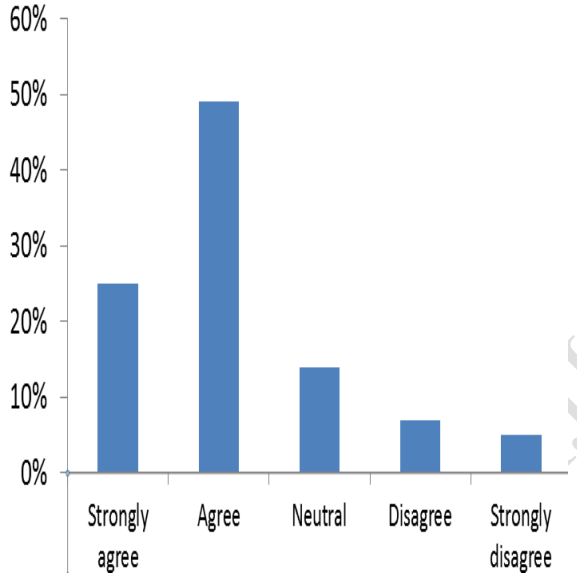

Figure 12: real-time interaction between caregivers / patient

The fifth item in FIGURE 8 seeks to determine if the participants based on their interactions with the telemedicine service will consider it as a platform capable of reducing the overall cost of health care if fully implemented in their locality. FIGURE 8 shows the result for user responses. 31% of the participants strongly agreed that the telemedicine service will help in reducing the overall cost of healthcare. Also, 43% agreed that the telemedicine service will assists in reducing the overall cost of healthcare. This is because, if the cost of visiting the hospital is reduced which is one of the problem faced by people living in remote locations, the cost of health care will be affected too. 14% of the respondents were neutral, while 8% disagree that the telemedicine service overall cost of healthcare. Based on the participants' rating for this item, a mean score of 3.89/5 and SD of 1.063 were calculated (see FIGURE 8 and Q5). This result also shows the users have the perception that the application can help in reducing the cost of healthcare in the long run.

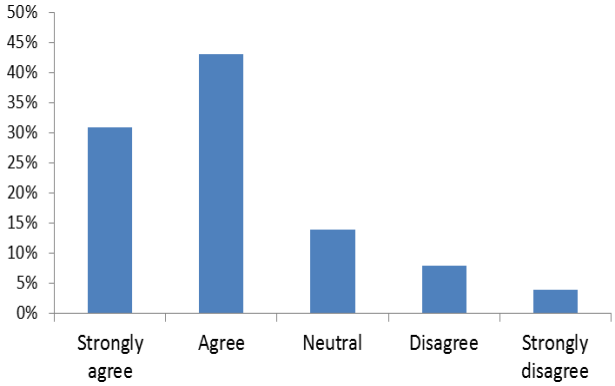

Figure 13: Reducing cost of health care

There was strong indication based on the users' perception that the telemedicine application will improve interaction among the users of the system i.e. between care givers and patients. This shows that the users have seen the importance of real – time interaction in healthcare. During the study, we found that the users were able to communicate with each other without any hindrance. Real-time interaction will improve communication between caregivers and patients.

IMPROVED QUALITY OF SERVICE DELIVERY AND PATIENT MONITORING

The participants were asked to use the telemedicine application for a period of 4 months within the *General Out Patient Department* (GOPD) and Family health unit of JUTH. The intention was to find out if the real-time telemedicine system can improve quality of care received by patients. After the period, we asked the participants to rate the system in terms of increase in service delivery, quality of care, Doctors/Patient's real-time participation, home monitoring for the aged, and increase education among healthcare givers. These criteria will positively influence the quality of service delivered to the patients.

The assessment of the technology in terms of increase quality of service delivery are presented in table 2.

Quesionnaire Response for improved quality of care								
Participant Responses	All responses are based on a Likert scale (Strongly Agree to Strongly Disagree, Strongly Available to Strongly Not a Strongly Agree=5 to Strongly Disagree=1							
Number of Likert Scale Options	5							
Survey Title								
Participants response: Simple %								
Participants response: Standard Deviation (S.D)								
Participants response: MEAN								
Questionnaire total Participation	100%							
Total number of Answered questions	100							
Data Tabulation								
Q6	Do you think the Telemedicine system will increase service delivery	28%	62%	6%	3%	1%	4.130	0.734
Q7	Do you think the Telemedicine system will increase quality of care	21%	64%	11%	4%	0%	4.020	0.696
Q8	The system will increase Doctors / patients Real-time participation?	23%	64%	10%	2%	1%	4.060	0.708
Q9	Do you think the Telemedicine system will Increase home monitoring especially for chronic illness or for the aged?	33%	54%	9%	4%	0%	4.160	0.748
Q10	Do you think the system can increase education among Healthcare givers?	27%	48%	18%	4%	3%	3.920	0.939

Table 2: Quality of service

Question 6 (Q6) in table 2 deals with increase service delivery i.e. if it will enable caregivers to increase the number of patients they are able to attend to within the period considered for the study. FIGURE 15 presents the percentage distribution of responses. 28% of the users strongly agreed

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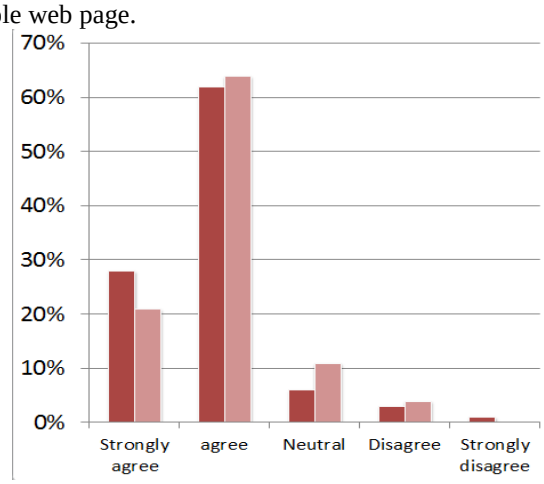
that the telemedicine service will help to increase their service delivery, while 62% also agreed that the application will help to their increase service delivery. 6% of the participant were neutral and 3% of the participant disagree that the telemedicine service will increase service. The likert-scale rating for the question shows a calculated mean score of 4.130/5 and a SD of 0.734. This result shows that the caregivers were positive that the application will increase service delivery.

During the study, we also tried to find out if the users see the technology as a platform that will enable the users to receive better quality of care from caregivers after using the system for a period of 4 months. FIGURE 15 presents the percentage distribution. The participants who strongly agreed that the application will enable increase quality of care were 21%. 64% of participants also agreed that the system will increase quality of care, and 11% of the participants remained neutral. 4% of the participants disagree that the system will help them to receive better quality of care from care givers. The calculated mean for the users' rating was 4.020/5 and the standard deviation (SD) was 0.696. This results therefore reveals that, the users agreed that the telemedicine service will be able to help the care givers to improve the quality of care they offer to their patients.

Most of the patients expressed satisfaction with the telemedicine system they used for consultation. The categories of patients that evaluated the telemedicine application include: National Health Insurance Scheme (NHIS) patients, Family medicine and GOPD patients. The responses received compared to the normal routine consultation services being offered during the evaluation period for quality of service were in terms of 1) the convenience with which the patients can interact from any location 2) First-Hand attention/service since the specialist was the actual consultant offering the service rather than less qualified medical attendants. This has the advantage of better health service, 3) the application offered better communication and care through the interactions, 4) Quick services: the caregiver was able to consult with more patients since some patients were able to communicate from home and with their entire family, 5) cost saving: the cost of the patient travelling the entire family to visit the care giver was reduced or completely eliminated since they were able to communicate through the application, and 6) better interactions and a promise of constant and continuous interaction. All these were made possible by simply loading a simple web page.



Legend: ● Increase service delivery, ● Increase quality of care

Figure 15: Improve service.

In another instance, a group users (patients) were asked to use the application and continually have real-time interactions with the caregiver over a period of two months at various time of the day. The users were then asked at the end of the period to rate the application and the interactions in terms of whether the telemedicine service will be able to improve caregivers/patients real – time interactions and participation. The analyses of the results are presented in FIGURE 16 and 17. In FIGURE 16, the percentage distribution shows that 23% strongly agreed that the telemedicine system will increase care givers and patients' real-time interactions and participation. While 64% agreed that the telemedicine system will increase care givers and patient real-time interactions and participation. 10% of the participants were neutral in their perception, while 2% disagreed that the telemedicine system will increase care givers and patients' real-time interaction and participation (see FIGURE 16). The results shows that the users agreed that the system will enable them have real-time interactions and participation. The participants' ratings show a calculated mean score of 4.060/5 and a standard deviation (SD) of 0.708. The result indicates that the users were positive that the telemedicine service will help to improve caregivers/patients real – time interactions and participation.

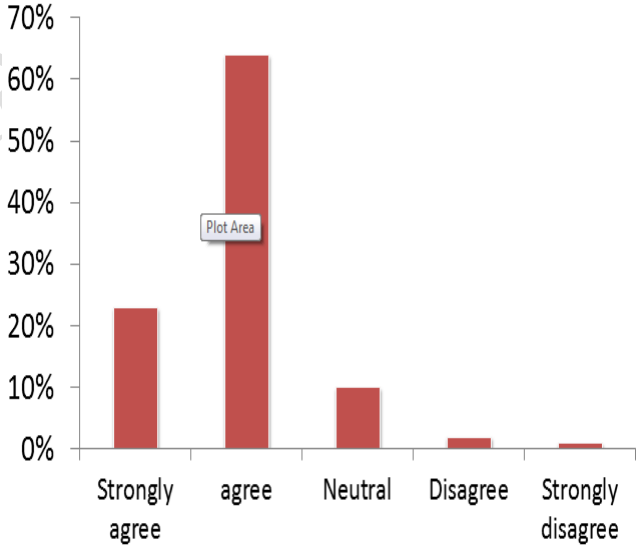


Figure 16: caregivers/patients real – time interaction and participation

After the participants have used the platform for a period of two months, the participants were asked to rate the system if it will allow for better home monitoring of patients and the aged people that normally engage in regular visits to hospital for check-ups. The percentage distribution of the result (FIGURE 17) shows that 33% of the users strongly agreed that the telemedicine system can enable increase in home monitoring of patients and the aged people. Also, 54% agreed that the telemedicine system can help the care givers improve home monitoring for patients and the aged people, while 9% of the participants were neutral in their assessment. Only 4% of the participants disagreed that the telemedicine system will increase home monitoring of patients and the aged people. The calculated mean score for the question is 4.160/5 with an SD

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of 0.748. The positive rating and standard deviation indicates that the users during the study were able to use that platform to increase home monitoring of patients. The telemedicine system has given the care givers the opportunity to increase home monitoring and patients' care.

The study participants were positive that the application has the potentials to improve quality of care. It will enable care givers to render first hand quality care to the patients. This is because the platform enables the patients to interact directly care givers, explain their health and receive medical advice without delay at their convenience.

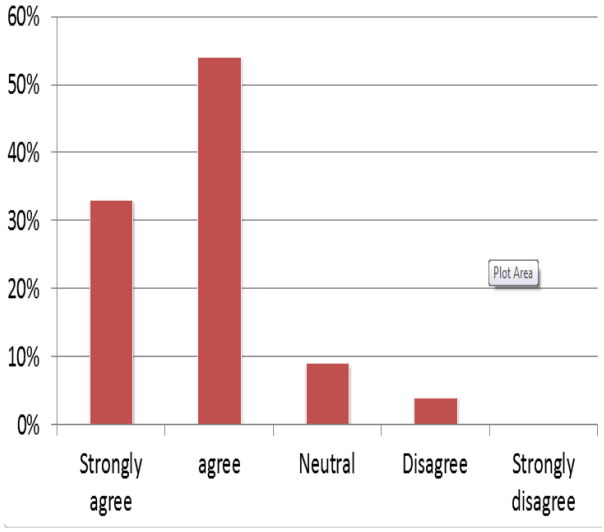

Figure 17: Increased home monitoring of patients

USER INTERFACE INTERACTIVITY, EASE OF USE, SIMPLICITY, AND USABILITY

The users were asked to assess the user interface on the qualities of the application that were considered as being part of the application design goals. These include user interface interactivity, user interface ease of use, user interface simplicity, and user interface usability. The percentage distribution of users' assessment and the ratings are presented in table 3. 37% of the participants strongly agreed that the user interface was highly interactive, and 53% of the participants agreed that the user interface was highly interactive. 7% of the users were neutral and 2% disagreed that the user interface was very interactive. The calculated mean for user assessment of the user interface gave a mean score of 4.230 and a standard deviation of 0.750. The users were positive that the user was very interactive. The participants' assessment for user interface ease of use is also presented in table 3. The percentage distribution shows that 36% of the users strongly agreed that the user interface of the telemedicine system were easy to use, while 57% of agreed that the user interface was easy to use. 4% of the participants were neutral, while 2% of the participants strongly disagreed that the user interface was easy to use. The mean score rating of 4.250 and SD of 0.716 were obtained. The users were highly positive that the user interface was easy to use. This enables the users to carry out all the tasks that were given to them during the evaluation session.

A user interface that is simple to use and understand is able to attract the users to use the application, and increase their experience. The users were also asked to rate the user interface in terms of its simplicity and ease of understanding. The percentage distribution of responses (see table 3) indicates that 37% of the participants strongly agreed that the user interface was simple. 54% of the participants agreed that the user interface was simple to use, and 7% of the participants were neutral. 1% of the users disagreed that the user interface of the telemedicine application was simple to use. The user rating for the simplicity of the user interface gave a mean score of 4.240, and a standard deviation (SD) of 0.712. The result shows that the users accepted that the user interface was simple. The standard deviation shows a common opinion among the participants that the user interface was simple to use. The users say the simplicity of the user interface made it possible for them to understand and interact with the interface.

User response to interactivity of the interfaces, ease of use, simplicity, and usability								
Participant Responses	All responses are based on a Likert scale (Strongly Agree to Strongly Disagree, Strongly Agree=5 to Strongly Disagree=1							
Number of Likert Scale O	5							
Survey Title								
Participants response: Simple %								
Participants response: Standard Deviation (S.D)								
Participants response: MEAN								
Questionnaire total Partic	100%							
Total number of Answere	100							
		Strongly agree	agree	Neutral	Disagree	Strongly disagree	MEAN	S.D
Q21	User Interface	37%	53%	7%	2%	1%	4.230	0.750
Q22	Ease of use	36%	57%	4%	2%	1%	4.250	0.716
Q25	Simplicity	37%	54%	7%	1%	1%	4.240	0.712
Q27	Usability	31%	60%	6%	2%	1%	4.180	0.716

Table 3: simplicity of the telemedicine system

Lastly, the usability of the user interface and system was also considered. Table 3 also presents the percentage distribution and the rating for usability criterion. 31% of the users strongly agreed that the telemedicine system and the user interface was usable, and 60% also agreed that the interface did not stand as an obstacle during their interaction with the telemedicine application. 6% of the participants were neutral, while 2% of strongly disagreed that the user interface and telemedicine system was usable. A mean score of 4.180 and a standard deviation (SD) of 0.716 were obtained for the user ratings. This is a positive acceptance from the users that they were able to carry out interactions between caregivers and patients successfully, improve relationship and better service through the telemedicine technology as a result of its' usability.

IMPROVED REAL-TIME INTERACTION

The quantitative data gathered during the user evaluation were further analysed using the Pearson product moment correlation to determine if the telemedicine platform can significantly improve real-time interaction between the caregivers and the patients. The result is presented in Table 4. It shows the Pearson Product Moment Correlation of the relationship between the telemedicine service and improved Real-time interaction between caregivers and patients. With R-value of 0.425 and a probability value (0.000) less than 0.05 significance level, it shows that there is significant relationship between the telemedicine service and improved Real-time interaction between caregivers and patients. This means that the telemedicine service can significantly improve Real-time interaction. This is because the users can perform functions such as; patients making enquiry about their health status and obtaining information that can aid in their diagnosis and treatment. The care givers can give advice to patients. This

will reduce the frequency of hospital visits in search of medical services. This will eliminate the difficulty patients experience as a result of bad road network and reduce cost of going to the hospital for medical consultation and time wastage.

IMPROVED QUALITY OF SERVICE

Analysis of quantitative data for improved quality of service through the application using the Pearson Product Moment Correlation is presented in table 5. With R-values of 0.599 and a probability value (0.000) less than 0.05 significance level, it reveals that there is significant relationship between the telemedicine service and improved quality of service. Thus, the telemedicine service can significantly improve the quality of service in the hospital by allowing easy access for patients within or outside the hospital. It will also increase caregivers /Patients participation in health care delivery.

Correlations

		Telemedicine Service	Real Time Interaction
Telemedicine Service	Pearson Correlation	1	.425**
	Sig. (2-tailed)		.000
	N	98	98
Real-Time Interaction	Pearson Correlation	.425**	1
	Sig. (2-tailed)	.000	
	N	98	100

***. Correlation is significant at the 0.01 level (2-tailed).*

Table 4: improved real-time Interaction

Correlations

		Telemedicine Service	Service Quality
Telemedicine Service	Pearson Correlation	1	.599**
	Sig. (2-tailed)		.000
	N	98	98
Service Quality	Pearson Correlation	.599**	1
	Sig. (2-tailed)	.000	
	N	98	100

***. Correlation is significant at the 0.01 level (2-tailed)*

Table 5: Improvement of quality of service

IX. CONCLUSION

The telemedicine application will go a long way in improving the interactions between health caregivers and patients. It will enable the patients to receive the best advice for diagnosis and medical education. The system can be utilised in minor healthcare centres for interaction and for learning among health caregivers. Other benefits to earn include minimised cost of travel for consultation especially for the aged and increase in first-hand quality care as a result of physicians attending directly to patients regularly online through the Internet. It also offer timely benefits through home monitoring of patients. During the study, the caregivers were able to attend to patients and the issue of time wasting on queues was reduced. The application was designed with simplicity and ease of use as criteria. This is to enable users in remote locations and with less computer literacy to understand and use the system for their benefit.

FURTHER RESEARCH

The application can be extended further with more functionality and adapted to the mobile phone platform and evaluated so that more users can be covered.

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