 

# A Multi-Agent Based Virtual Personal Assistant for E-Health Service

Emmanuel Azom Edim and Adannaya Simeon Ivo
Dept. of Maths/Stats., and computer Science, University of Calabar, Nigeria.
* E-mail of the corresponding author: edimemma@gmail.com

**Abstract**
The application of Information and Communication Technologies (ICT) in the health sector is increasingly changing today's health care. A communication agent for a multi-agent system-based virtual personal assistant is an attempt towards improving health care service delivery. We have developed a Multi Agent System and user interface for management of diabetes patients where the patients and medical specialist can interact easily without necessarily visiting the clinic. The application will enable the users to have regular interactions with each other, reduce the cost of going to the clinic, saves patients and medical personnel time. In order to design the application and user interface, we adopted a user centered approach and conducted interviews with the potential users. We also reviewed existing materials for data. Qualitative and quantitative data were collected during the development process. The application and user interface were evaluated by the potential users (patients and medical personnel). The user evaluation of the system shows that the participants were pleased with the application and the user interface. They interacted with the user interface with ease and they encountered little or no difficulty.
**Keywords:** multi-agent, e-health, virtual personal assistant, information and communication technology

## 1. Introduction

Agent-Oriented Programming (AOP) is a new concept that is still receiving attention in software development circle. This concept brings artificial intelligence theories into the major realm of distributed systems (Fabio et. al. 2007). AOP models an application as a collection of components called agents whose characteristics include autonomy, proactive and an ability to communicate. Autonomous means that the agents can independently perform complex and long-term tasks. Agents that are proactive can enterprisingly perform a task without an explicit motivation from any user. Communicative means that agents can carry out interactions with other entities to help in achieving goals for themselves and others.

Agent technology has been the subject of extensive research and discussion within the research community for several years. In recent years, it has witness significant degree of exploitation in commercial applications. Multi-agent systems have been applied increasingly in wide range of applications, ranging from small personal assistance systems to open, complex, mission-critical industrial systems (Fabio et al. 2007). Multi-agent System provide a set of environments with functionality that allows for agent inter-operation. Agents are registered in an environment that provides their necessities and enable the agents to interact with other agents. Within the environment, the Virtual Personal Assistant will enable the human actors to interact with the different agents.. The use of a Virtual Personal Assistant (VPA) is meant to provide a mediator between the users and the active agents. The application of agent based technology in health care service is to enable the health care provider to interact with the patient (health care receiver) in different locations, while the software agents also perform internal tasks on their own for the benefit of the health care giver and the receiver.

With the increasing network connection speeds, the decreasing cost of health care services e-health provides a platform for supervision of patients and decision-making and also provides the capacity to adequately increase the availability of self-care (Leventhal et al. 2004). Self-care enables individuals, families, and communities perform health care related activities with the intention of enhancing their health care. These activities enable the people to be able to prevent disease, limit illness, and restore their health and above all improve their lifestyle, medical devotion , and their health in the future (Bhuyan 2004).

ICT and agent technology are applicable in the management of diabetes disease. In such applications, mathematical models are used to model blood glucose regulation. This will enhance the identification of problems and treatment generation. Treatment can be generated by first recommending insulin therapy, diet recommendation and regulation, and physical exercise therapy. Multi Agent System (MAS) technology can enhance e-health solutions for personalized assistance to multiple distributed actors, which include patients, physicians, and other workers within the health sector (Xiao et al. 2006; Tonino et al. 2002; Lindenberg et al. 2003). The solutions will in turn improve relationships among health care givers and their clients, proactively detect dangerous trends in the patient's health, and stimulate a behavioral change in the patient.

The objective in this study also includes the design and deployment of an e-health system in the medical center of Akanu Ibiam federal polytechnic as a case study. This medical center offer health care services to staff and students of the institution and the uwana community as part of the institution's community development service. We have designed an agent architecture and a user interface, consisting of multiple distributed agents and a Virtual Personal Assistant that supervises patients' self-care, with chronic illness (diabetes). The system was developed with the involvement of medical personnel, and the users' evaluation of the system indicates that they are satisfied with the application and are interested in using the application not only for diabetic patients but also for patients with other chronic diseases.

## 2. Literature Review

MAS present a network of loosely tied problem solvers. These problem solvers interact to solve problems that are normally beyond the capabilities of the individual or the experience of each problem solver (Durfee & Lesser 1999). These actors are often called agents, and are autonomous and sometimes heterogeneous. MASs posses characteristics that include each agent having limited viewpoints because they have incomplete information or capabilities for problem solving. They also lack system global control, and have data systems that are not centralized as well as computational methods that are asynchronous in nature (Katia 2008). MASs has the ability to solve problems that may be too complex for centralized agents to solve due to lack resources. MASs has the ability to enable multiple legacy systems to interconnect and interoperate and provide problem solutions to a group of autonomous interacting components-agents (Katia 2008). This can be seen in a calendar scheduling agent for different users (Garrido & Sycara 1996; Dent et al. 1992), and air-traffic control (Kinny et al. 1992), as well as in multi-agents trading goods on the internet. MAS provides solutions using spatially distributed information sources such as sensor networks (Corkill & Lesser 1993), seismic monitoring (Mason and Johnson 1999), and information gathering from the internet (Sycara et al. 1996). They also provide solutions in environments where the expertise are distributed such as in concurrent engineering (Lewis & Sycara 1993), health care, and manufacturing. Finally, MAS enhances performance along the dimensions of computational efficiency, reliability, extensibility, robustness, maintainability, responsiveness, flexibility and reuse. Agents have ability to recover if components fail; their capabilities are alterable and can tolerate uncertainty. Agents are also easy to maintain due to their modular nature, and can handle anomalies effectively and locally. Agents are equally adaptive to current problems in order to provide a solution and are reusable in different agent teams to provide solutions to different problems.

The Virtual Personal Assistants enable the human actors to interact with the different agents in the environment. The interaction can take place through the performance of three main activities such as data entry, formulate policies and make recommendations. The care giver (medical personnel) will enter data regarding patient information such as demographic data, medical history, and clinical diabetes information. The patient on the other side keeps track of self-care tasks in a personal electronic diabetes diary such as current mood, exercises performed, meals consumed, medication taken, and blood glucose measurement results. This data is entered by the patient and the medical specialist through their Virtual Personal Assistants (VPAs) into the database. The Virtual Personal Assistant usually provides policies or suggestions either in the short term or long term. The policies or suggestions are dependent on the data or information available in the patient's record. The VPA is very essential in monitoring the patient health status such as in diabetes care. It will usually formulate its policies based on the results obtained from the patient's electronic records.

A Virtual Personal Assistant (VPA) often plays the role of a mediator between the human actors and the active agents in the smart environment (Lindenberg et al. 2003; Grill et al. 2005). The agents have the ability to communicate among themselves and share information through sensors within the smart environment. The multiple agents apart from getting information through sensors, they also acquire information through their behavior and as they communicate. The VPA interacts with the user and share data with the agents. Agent-based technology presents a platform for conceptualizing and developing exciting software systems. Agent-based applications are intelligent systems that operate in distributed and open environments like the Internet. In the past most agent-based systems consisted of single agents. Due to the rapid changes in demands and advances in technology, multiple agent-based systems are now used to implement increasingly complex applications for solving complex problems. Systems that consist of multiple agents communicate in a peer-to peer fashion.

The duties of a Personal Assistant Agent (PAA) is to work with the user environment and application and provide solutions to e complex tasks, monitor events and make decisions which the user would have made (Nikos 2003). The PAA intelligence is able to adapt under different environmental factors and also able to customize user requirements. Another capability of a PAA is its ability to handle and meet up with the enormous demands of customized services at anywhere, anyhow and anytime. The user's personalized services can also be made in advanced. In some cases, when adaptive behavior mechanism is integrated into the system, it will enable the system to handle and provide solutions to user's request or implicit behaviour. The learning capabilities and adaptive nature of the PAA system are a pointer to the level of intelligence of the system. The intelligence of the system can be used to determine the reliability of the PAA's decisions and plan. The users will be able to use the

 

PAAs decisions as a reference and also utilize those decisions as inputs to acquire more detailed and correct information regarding each plan and the total cost of their activities.

## 3. Methodology

In carrying out the study, we applied user-centered approach in collecting data for the design of the system. Qualitative and quantitative data were collected from the staff of Akanu Ibiam Federal Polytechnic Medical Center, Uwana. Interviews were conducted with the medical doctors, nurses and lab scientists/technologists and patients. The data collected at this stage include the fasting blood sugar and interpretations, normal human glucose level, management and treatment of diabetes, user interface elements such as menu, icons and other elements and interaction activities. Information on the level of ICT availability and usage among the staff in the medical centre were also collected. We were able to interview 20 staff in the medical center. It was difficult for most of the staff to grant us the opportunity to interview them, some of them even told us to come back at a later date. And during the returned visit, we could not find them in their offices or they were too busy to attend to us.

All the interview sessions were held in the medical center. We interviewed five (5) doctors, nine (9) nurses and six (6) lab scientists/technologists. Prior to the interview, we prepared structured questions to serve as a guide for the different group of staff. The interviews were requirement gathering process for the e-Health Virtual Personal Assistant prototype design. Data were collected through field notes for analysis. Each interview session took 30 minutes to 1 hour. The data collected was used for the development of the prototype e-Health Virtual Personal Assistant application.

The prototype of the application was evaluated with participants in the medical center. Evaluation sessions were conducted through single user evaluation process. Each of the evaluation participants was given tasks to perform and then make assessment of the user interface and the application. The tasks include creating a user account and enter the blood sugar level data after testing with the glucometer in the morning. The medical specialist actors used a default login detail and give prescription based on the patients' status.

## 4. Results and Discussion

We conducted a study to understand the users' level of acquaintance with some ICT services, data was collected and analyzed. We also evaluated the prototype application to determine users' view and usability of the application. During the interactions, data was also collected and analyzed.

### *4.1 Availability and Usage of ICT in the Medical Center*

The mobile communication network services are fully available in the medical center. Internet services through the mobile communication networks are also available for those that use internet enabled mobile devices. The use of laptops and mobile communication network modem to access internet in the medical center is not very popular. There is the absence of local area network in the medical center and having access to the internet through a corporate Internet facility is not yet possible (except for the ICT center in the school). The school is establishing hotspots (wireless network) in the whole premises and the work is on progress as at the time of this study. Some of the staff in the medical center especially the medical doctors directly connect to the internet using their USB modem.

A study was conducted to ascertain the level of use of internet to access information, the use of e-mail and e-health application among staff in the medical center. Figure 1 presents the result. Among the staff we interviewed, 52% said they use the internet on regular basis to access information pertaining to their work. 60% of these internet users visit the ICT center to access the internet whilst 40% use their laptops and modem or mobile phones for browsing. 48% do not use the internet at all. Among the respondents who use e-Health information services on the Internet or e-health application (15%), they do so using their laptops and modem or mobile phones. These respondents also would like e-Health Virtual Personal Assistant application to be in place. Those who are not familiar with e-health application (85% of the respondents) because they have not been using it equally would like e-Health VPA to be in place so as to at least reduce crowd in the medical center. 54% of the respondents use e-mail for communication. Out of this number, 55% frequently visit the cyber café/ICT center to access their email service, while 45% use laptop and modem or mobile phones to access their e-mail service. The medical center has not been fully connected to the internet. Few units within the school such as ICT center, OTM lab, Computer science lab have Internet facilities and connection.

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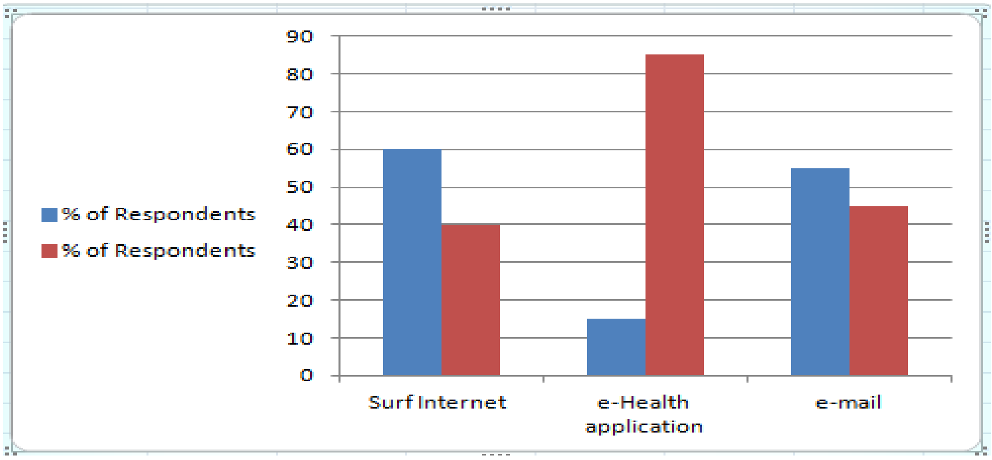


Figure 1. ICT Usage

*4.2 The Application Prototype*

The e-Health Virtual Personal Assistant will enable the users to create user account, enter their glucometer reading to determine their status and also get prescription/advice from their medical consultant based on their status. The prototype user interface screenshots are presented and discussed next.

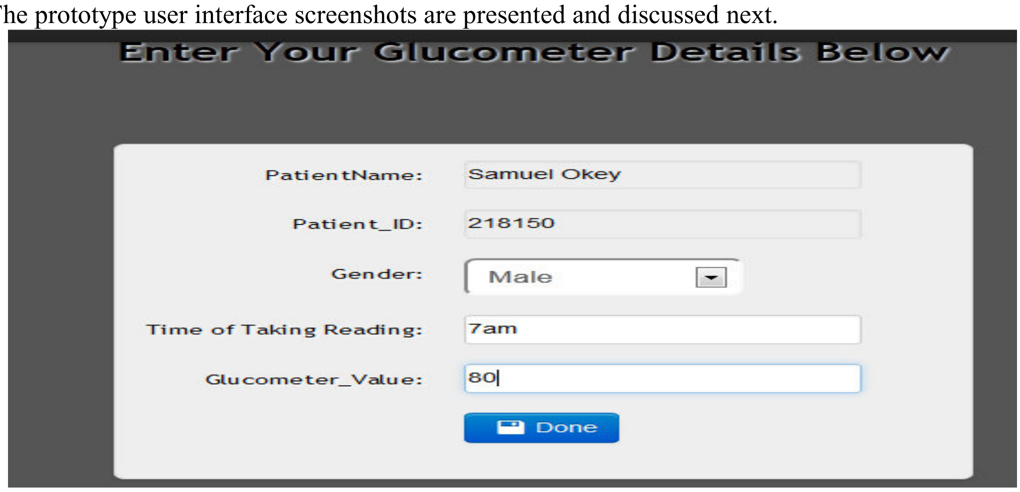


Figure 2. A user interface for recording fasting blood sugar

Figure 2 shows the user interface for entering the fasting blood sugar in the morning. The users are expected to carry out the blood sugar test in the morning and then log into the application and enter the reading for their medical consultant to monitor on regular basis.


Figure 3. The interface shows the response from the application

Figure 3 shows the system response indicating that the blood sugar level entered by the user is ok. If the status is not ok, the system Will advice the user on the next step to take. On the other hand, the consultant on checking the patient's status can write medical prescription for the patient. The patient can in turn access the prescription for further action. And so the patient can receive treatment without necessary visiting the clinic.

Figure 4 shows the medical specialist user interface where prescription/advice can be given to patients based on their glucometer value. On selecting a patient ID and clicking the OK button, the patient name and glucometer reading are synchronized and thus shown on their respective fields; while the medical specialist gives the prescription based on the blood sugar level value.

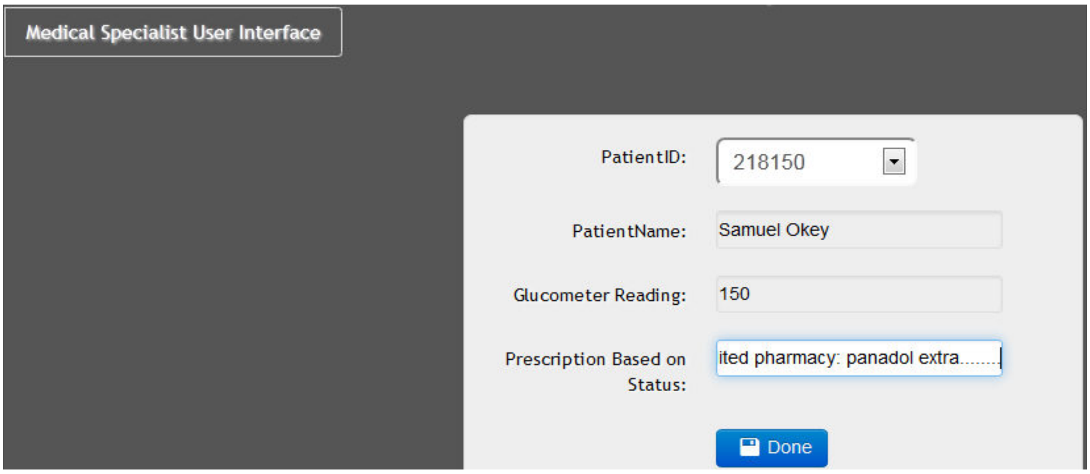

Figure 4. The medical specialist user interface

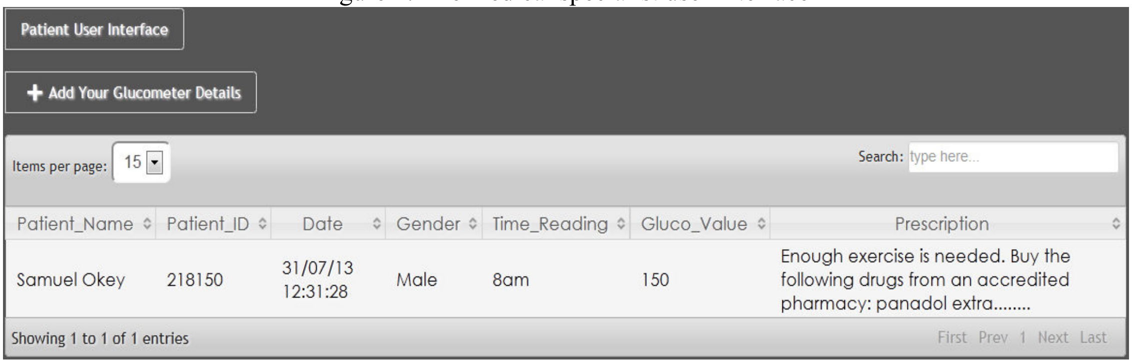

Figure 5: Patient's interface after the medical specialist has made prescription

After the medical consultant had made prescription given advice based on the blood sugar level, the patient will in turn view the advice or prescription (Figure 5) for the next action to take. The e-Health Virtual Personal Assistant user interfaces are interactive and user friendly. The users, being educated may not require any training for them to be able to use the application. Apart from the advice given by the medical specialist, the system agents also make reactions to the inputs from the users, most especially that of the patients by offering advice.

*4.3 Design Evaluation*

Evaluation of a software system with the intended users of the application has the potential of revealing errors that may not be noticed by experts during the design process. The e-Health VPA was evaluated with the intended users. Three different tasks were selected for the evaluation process. The tasks include creating a user account (medical consultant and patient), entering blood sugar reading and accessing the doctor's advice or prescription (patient), accessing the patient's daily reading and making prescription or advice to a patient (medical consultant)consultant. The results are presented next.

*4.3.1 Tasks Completion*

The tasks completion rate was very high among the two user groups. Figure 6 shows the task completion rate among the users who participated in the evaluation process. 98% of the participants were able to complete the three tasks. We observed that moving from one task to the other was not difficult for the participants. 50% of the participants were not regular users of the computer or Internet. 2% of the participants failed to complete at least one task out of the three tasks. The participants verbally expressed their satisfaction and feel that interface was not difficult to understand. They also said that navigation from one screen to another was easy. The participants perceived the user interfaces and the interactions as being very easy to perform.


Figure 6. Tasks Completion Rate

The result shows that the users were able to use the e-Health VPA with ease and were able to complete the tasks selected for the evaluation. Those who could not complete all the tasks said it was not because of its difficulty, but because they were slow in entering data as well as in moving the mouse to the intended location on the screen. They said they did not find the interactions too difficult; rather the user interface was simple enough for them to understand.

*4.3.2 Tasks Completion Time*

The participants completed each task under considerable time. The tasks completion time is shown in table 1 for the medical specialists group. The first task recorded a mean time of 45.36 seconds and a standard deviation of 5.05. This indicates that there was no much difference in the level of learning and understanding of the application and user interfaces among the participants. In the second task, participants used 20.25 seconds as mean time and a standard deviation of 4.15. The third task recorded 60.05 seconds as mean time and a standard deviation of 6.03. The results also show that the interactions were not difficult to carry out. The standard deviation shows very close completion time among all the participants; i.e. learning the user interfaces and interactions were uniform. These users were not given any prior training before the test. Owing to the simplicity of the application, a little introduction was enough to enable the participants to interact with it.

Table 1. Tasks Completion Time (Medical Specialists)

| Task for Medical specialist (n = 10) | Mean Time (seconds) | Standard Deviation |
|---|---|---|
| 1. Create a user account | 45.36 | 5.05 |
| 2. Access patient's daily status | 20.25 | 4.15 |
| 3. Write prescription | 60.05 | 6.03 |

Table 2 also shows the results of tasks completion time among the selected patients. The first task involved creating a user account. The participants recorded an average time of 50.25 seconds and a standard deviation of 9.25. In the second and third tasks, participants used 46.15 seconds (SD = 6.22) and 30.10 seconds (SD = 5.12) respectively to complete the tasks. The results show that the participants did not find the interactions difficult to understand. The application and user interface were interactive enough to enable the users to perform the tasks with ease. The variations in the length of time used among the participants shows that the difference in the level of understanding and use of the application among the participants was minimal. Different people irrespective of their level of education will be able to use the application and user interface.

Table 2: Tasks Completion Time (Patients)

| Task for Patients (n = 10) | Mean Time (Seconds) | Standard Deviation |
|---|---|---|
| 1. Create a user account | 50.25 | 9.25 |
| 2. Record daily blood sugar reading | 46.15 | 6.22 |
| 3. Access medical prescription | 30.10 | 5.12 |

*4.3.3 Tasks Completion Errors*

The task performance was highly impressive among all the participants. A greater percentage of the participants completed the tasks without encountering any difficulty and didn't need assistance to do so. This was because the user interface and interactions were easy to understand. The percentage of the participants who encountered errors as they perform each task was minimal. Figure 7 shows the tasks performance errors in each task. 90% of the participants completed the first task without having any challenge. 10% of the participants had at least a single error or difficulty as they performed the first task. 85% and 89% of the participants completed task 2 and 3 respectively without having any difficulty or committing any error. 15% and 10% performed and completed task 2 and 3 respectively with at least a single error. The result indicates the ease of use and interactive nature of the application.

 

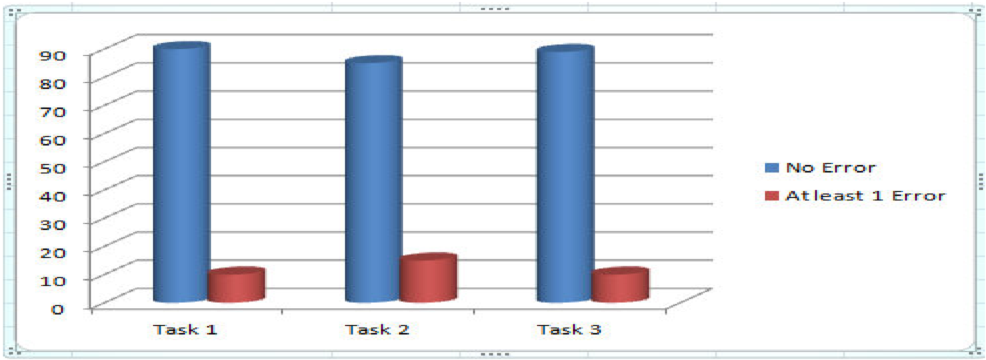

Figure 7: Tasks Completion Errors

The post test interview reveals that participants were positive about using the e-Health VPA to know if they are diabetic or not and to give prescription based on the patients' status. They also feel that the interactions are simple and easy to perform. The user interface elements (fields) and activities were easy to understand and so they will not encounter problems when using the application.

Table 3 presents the results of the post test Likert-scale questionnaire completed by the evaluation participants. The results indicate that the participants were satisfied with the system. All the questions were positively rated with a mean score range of 3.57 – 4.45. The participants feel that the user interface is easy to use (mean score = 4.01, SD = 0.63), and the system is very easy to understand (mean score = 3.69, SD = 0.86). They also see the application as one that will help them to save cost and time (4.45), and help to facilitate health management (3.75). The users believe that they do not need training before they can use the application (mean score = 3.57, SD = 1.10). The standard deviation values show that the opinion of the participants for all the questions was closely related. There is close similarity in their interaction and perception about the application.

Table 3. Application and User interface Evaluation Data and Analysis

| **Application and user interface evaluation (Likert-scale questions: 5 strongly agree – 1 strongly disagree) (n = 20)** | | |
|---|---|---|
| **Question** | **Mean Score** | **Standard Deviation** |
| 1. I am satisfied with the application and interface | **4.20** | **0.23** |
| 2. The user interface is easy to use | **4.01** | **0.63** |
| 3. The user interface is easy to understand | **3.69** | **0.86** |
| 4. I do not need training to be able to use the application | **3.57** | **1.10** |
| 5. There is enough information on the user interface | **4.00** | **0.66** |
| 6. The application will help to save time and cost | **4.45** | **0.87** |
| 7. The application will facilitate health management | **3.75** | **0.71** |

## 5. Conclusion

In the developed countries where ICT has been deployed fully, there are several benefits and efficiency investments for individuals and organizations in the health sector (Andrew & Dubow 2006). ICT in developing countries such as Africa is still a challenge to ICT service designers; there is still a lot to be done to raise ICT awareness and application of its services in work places especially in the health sector so as to benefit both the urban and rural citizens.

e-Health Virtual Personal Assistant for Diabetic patients will help to improve efficiency, minimize transportation cost, time spent in medical center, reduce patients' anxiety and increase productivity on the part of the medical specialists. The application was designed and evaluated with the involvement of the target users at Akanu Ibiam Federal Polytechnic Medical Center. The users' evaluation study conducted shows that the intended users of the e-Health VPA are satisfied with the user interface and interactions provided in the application. The medical specialists were able to use the application to access the patients information and make prescription for the patients. The patients at the other end, had access to the prescription made by the medical specialists.

The authors hope that in future they will not only use the application for Diabetic patients but also for patients suffering from other chronic diseases. This will require just little modification.

We are working further to migrate the VPA application to the mobile platform so that the users can also interact with in anywhere and anytime.

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