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Digital Framework Strategy for Patient Medication Adherence and Improvement in Medical Healthcare Centre Offa, Kwara State

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The prospect behind digital transformation strategies makes the healthcare systems more safe, affordable, and accessible with remarkable opportunities. The reasons why patients decided to have negative medication adherence became a critical challenge in the healthcare system. This study presents a Digital Framework Strategy DSF for patient medication adherence to improve patient health during the treatment regime. A case study of the Federal Polytechnic Medical centre and clinical activities of Offa General Hospital examines the existing treatment of chronic diseases. The cloud-based server revolves around Convolution Neural Network (CNN) feature to perform a real-time collection of data and analytics of patient information. When thoroughly combined, the CNN of the neural network has a model of the application, which will form part of the desired output. This output presents a level of patient medication adherence within the parameters—the data around the enclosed sources. The approach data was acquired with the patient wearing a sensor and smartphone devices. The model throughputs presented detailed analytics of individual patient adherence behaviors. The result of CNN performance revealed 96.99% accuracy of medication adherence level on a

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tested dataset collation, and the essence of digital framework analytics helped the healthcare workers (HCW) and healthcare providers to make prompt decisions on patients' medical conditions.

Keywords: Digital transformation; medication adherence; healthcare provider; chronic diseases.

1. INTRODUCTION

Digital Framework Strategy (DFS) is gaining global recognition due to digitalization and advanced technology [1]. Over the past two to three years, healthcare organizations in the private and public sectors have had a big data analytics framework to analyze a lot of data. The big data system is a short and critical developing research scope covering a wide range of industrial innovations and exerts researchers in the medical domain with an extraordinary potential [2-5].

Generally, patients tend to have improved medical outcomes from chronic ailments when they strictly follow medication schedules set by medical experts. Improving patient health conditions is becoming a significant concern when dealing with chronic diseases like HIV and AIDS, Cardiovascular disease, Tuberculosis (TB), and relative cases of pandemics. The issue of rural settings is overwhelming due to social factors that contribute to medication adherence of patience living in such a domain. Health experts find it difficult to monitor patients' medication adherence related to rural settings and are unable to create a technological intervention that could lead to encouraging them towards good adherence. In the light of these findings, existing tracking and monitoring strategies like Direct Observation Therapy (DOT), Video Observation Therapy (VOT), and Indirect Monitoring Technological (IMT) for Medication Adherence and Improvement (MAI) have not embraced a big data analytic framework [5-9]. The weakness of the existing medication monitoring method failed. Because it does not include critical human and ergonomic factors, for instance, motivation, encouragement, negotiation, and determinant elements that can revolve around the daily lifestyle of a patient in the design of a medication adherence monitoring scheme which limits the chance of health recovery [10], [11]. These existing methods have limited their patients' self-sufficiency. They have not created any adherence improvement as a central core of their design that is supportive of the patient in the end.

In resource-limited settings, the responsiveness of positive adherence behavior is significantly low due to social-economic problems. The factors vary from illiteracy, low income, poverty, poor infrastructure, and Insufficient good medical facilities. In this scenario, the researcher observed the difficulties of healthcare providers in effectively monitoring patients' medication adherence in Offa town and encouraging them towards good adherence behavior. In light of these findings, existing Medication Adherence and Improvement MAI strategies have not been embraced into the digital framework. Strategies DTS for medication adherence involves cascading two or more devices, a cross-platform integration framework to execute heterogeneous activities, and multitasking from remote terminals [6,12].

Many factors lead to the negative impact of Medication Adherence and Improvement of MAI in a patient's life [13]. A patient can decide to have negative adherence behavior if there is no consistent timing or unconditional intent to deviate from medical agreement. It could occur due to environmental stigma, unfriendly cross-platform for medication adherence, close relative negligence, emotional illness, and working conditions [14]. The existing MAI poses limitations and constraints that result in a patient's unhealthy lifestyle and does not include Artificial Intelligence (AI) to support the patient's health recovery [15-19]. The research DTS framework, which presented low-cost hybrid technology, creates a synergy workforce amongst stakeholders who have symmetrical working alignment and provide flexible medication adherence and improved life of patience in Offa Medical Centres.

The effect helps health providers and other health agencies to make good decisions in the life of affiliate patients with the different observed levels of medication adherence [3,20].

The reasons existing technology failed to measure consistent positive results in behavioral patient patients in the long run. Is there any tendency for every patient to comply with mobile health considering the availability of applied? If a phone and email could replace DOT, then the perspective on the wireless communication model could be a defined solution in the treatment of patients. This work is concerned with the relationship between patients, relatives, government, health workers, and the technology approach.

Several studies have been conducted on applied big data analytics in the healthcare system and others. In contrast, these studies offer importance to highlight foresight on the chances that exist in the application of big data analytics in the treatment of chronic diseases and the scope cantered on patient medication adherence and improvement [21-24]. However, dealing with prevailing factors hinders medication adherence and the way back from the existing adherence monitoring methods that do not feature a big data analytic framework approach. Yet reality has proven that the big data analytics framework dealing with chronic disease is inefficient in the resource setting [25].

However, The proposed study makes use of a big data analytic framework to monitor patient medication adherence in real-time and determine personalized treatment of patient adherence behavior via AI [23,24,26].

This study aims to develop a framework that can improve medication adherence by patients with chronic diseases in low-resource settings.

This research is to identify resource-limited settings attributes associated with the big data analytic framework. Emback on the design of the mechanism-based data-driven attributes that can identify the difference in patients' behavior toward medication adherence.

2. LITERATURE REVIEW

The digital frame research field is yet to be fully defined, and most of the research is case driven and multi-disciplinary [24]. Some data framework studies, especially in medicine and biology, have failed to provide conceptual contexts to which they are applied. With the rising interest in big data analytics, the impression to understand the problems to be solved with predictable scientific methods of inquiry. Numerous measuring adherence monitoring methods have been revolving for many centuries with different approaches. The existing ones are categorized into direct and indirect monitoring methods [26].

2.1 Direct Measure of Medication Adherence

The use of direct monitoring involves direct contact with patients to know if taken the drugs administered at a time. The other way through laboratory tests is to examine the patient body fluids in the laboratory, blood or urine, and evaluate the presence of a biological marker given with the drug and direct observation of the patient's medication-taking behavior [27,28].

2.2 Indirect Measure of Medication Adherence

The indirect monitoring methods use technology devices to engage the activities that support the patient during the treatment journey and the trigger signal if the patient takes medicines or not in real-time. Technologies like sensors involve acquiring information. Employing detection and converting it into readable signals, these technology devices are device-facilitated. These exist in three types: sensor-based, vision-based, proximity-based, and fusion-based systems [29]. The sensor-based methods include smart pill containers, wearable sensors, and ingestible biosensors that can aid in monitoring activities regarding pre-set conditions. The intelligent pill containers exist in the nine-stage sub-system of the programmable system that enables medical caretakers or clients to determine the pill amount through the cap opening and bottom pick up to track adherence, timing to take pills, and the service times for every day.

Daramola [30-32] has proven that the prototype of this nature includes Wisepills, Mem- scap, GlowCap, Evrimed, and Amiko, respectively [31,32] is used to monitor patient adherence in the literature. Hence, Wearable sensor technologies gather physiological and movement data, thus medically enabling patient status monitoring. Sensors are implemented and deployed according to the clinical application of interest in the major concern related to motion relationship with twisting, tracking hand-to-mouth, pouring the pill into the hand, and pill swallowing. neck-worn sensors and wrist-worn sensors [22]. This kind of device, in the form smartwatch, has been incorporated to track mediation adherence. A signal-based smartwatch sensor that detects accelerometer hand gesture data and use to convey the data collected to a central cloud database using AI-based technology like neural networks [15,19,21].

2.3 Tag Dispatch System

"Google developed the tag dispatch system for the Android platform. The system coordinates the reading of NDEF data from an NFC tag. When an Android device scans an NFC tag, the tag delivery system allows an accurate device. It then determines which applications are interested in receiving such a message rather than asking the app user to select an appropriate application from an application selector from the target device" [33]. "The app gets or receives an NFC event without interfering with or conflicting with other NFC apps on the host device; It is essential to have full knowledge of how the NFC broadcasting system on Android prioritizes. The target device selects which applications are ready to receive the scanned NFC tag or NDEF message as presented in Fig. 1. The conflict is presented to the user as an application choice to decide whether to send the scanned NFC to an app" [34]. In order to identify which activity to handle the NFC tag, two systems are required to push the intent dispatch system and then picture the activity of the dispatch system.

The intent dispatch system is used to find the best activity to handle the NFC tag. To do this, review each activity's intent filters and supported data types. The selected activity is displayed when multiple activities have the same intent filters and data types. The tag delivery system defines three types of intents:

- NDEF_DISCOVERED
- TECH_DISCOVERED
- TAG_DISCOVERED

"The foreground dispatch system allows an activity to have a high priority over other activities registered to handle the same intent. In addition, the intent dispatch system can be overridden when scanning an NFC tag" [35]. "Foreground dispatch is used while the application runs without shutting down if another application has a similar intent dispatch facility. When the application runs, it can recognize an NFC tag and process the intent through other apps on the phone. The phone does not provide the user with an app selection" [25].

3. METHODOLOGY

A Big Data Analytics Framework for Medication Adherence and Improvement (BIDAFMAI) presented with technical derivative components. Implementation of a big data analytics framework for medication adherence and improvement will enable healthcare organizations and associate stakeholders to be highly dedicated and accountable for the following;

- Concurrently improving motivation bond between the patients and the supporters.
- Holistically improving patients' medication adherence behaviors in a continuous process.
- Managing and maintaining a high level of medication adherence among patients
- Enabling reliable treatment outcomes concerning acceptable medication adherence behaviors.

The need for developing a Mobile Application called DTS is required in the case study to provide interfaces for participants and create a statutory profile in categories. The app modules allow intercommunication using hierarchy modules and enable participants to send or receive information via structured data; this will track the activities of patients, patient supporters, and other health care providers concerning server requests. The DTS implementation involves the use of integrated software and pairable hardware devices. The devices "smartwatch and phone" must be changed regularly to ensure their effectiveness for the research study.

DTS in the case study in Fig. 2; the composite tools and resources include email, WhatsApp, the DTS app, and SMS. All connected with aid IoT enable all participants (health care providers, patient supporters, patients, stakeholders) to create a workflow in the line of duties. In most cases, all stakeholders gained statutory of receiver/sender, consolidate action by driving data from remote server for decision making. Treatment strategies depend on the level of adherence observed by the healthcare providers. Therefore, all these are based on a modular architecture that will take care of the research problems and seek a way to suit different contexts in the case study of medication adherence monitoring and improvement.

The proposed work on the development of medication adherence applications is divided into different screens, as presented in Fig. 3 gives an overview of the composition of the Digital framework for improved medication adherence. Each screen must be implemented according to the design specification and tested before running the next screen. The various screens of the proposed application will follow the state diagram shown in Fig. 2, which is subject to change from time to time.

This description used in Fig. 3 is a composition of digital framework strategy adoption in the study area. These include Bluetooth technology, smartwatch, smartphone, cloud database, and backend analytic services.

Smartphone involves patient enrolled in the program and healthcare provider accredited to participate in the treatment of medication adherence. The essence of the smartphone allows the healthcare provider to remotely monitor patients and share information about patients with other stakeholders assigned to collaborate in monitoring patient adherence over time.

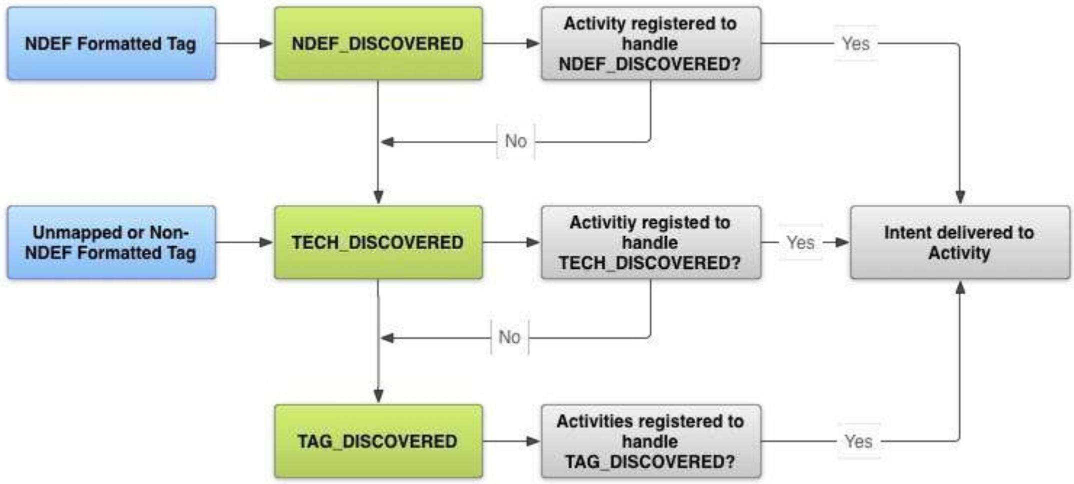

Fig. 1. Present Tag dispatch system

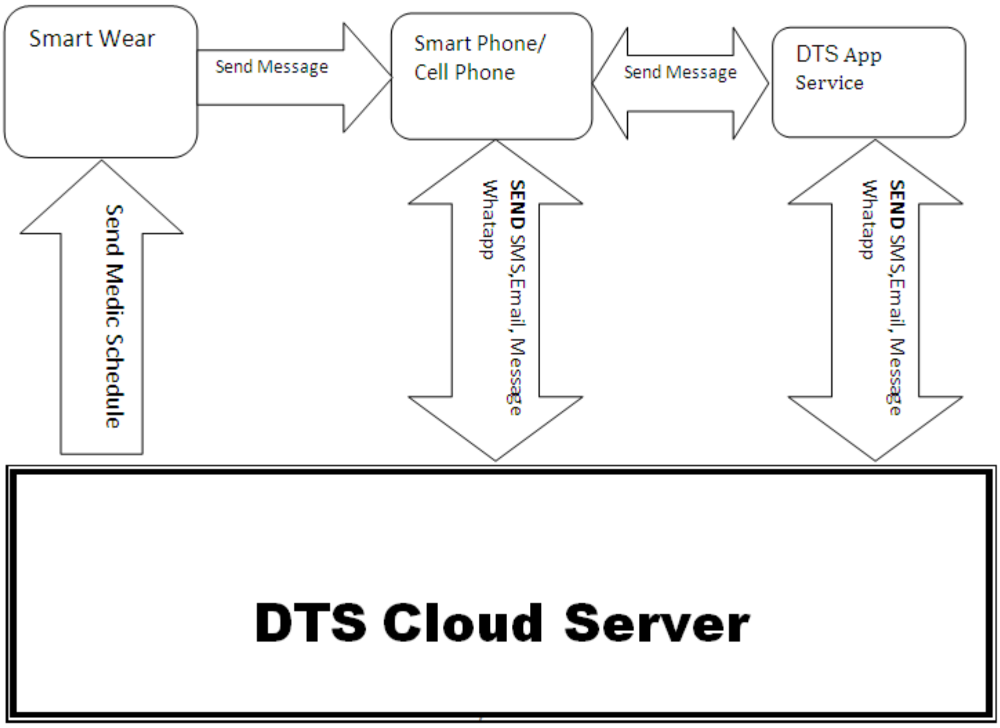

Fig. 2. An overview of the research entity of DTS work-flow for improving medication adherence

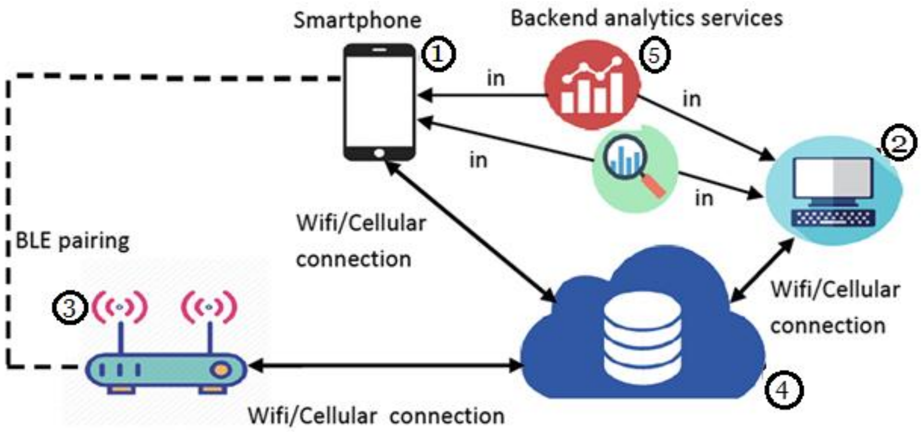

Fig. 3. An overview of the composition of the Digital framework for improved medication adherence

Backend analytic service is a small tool for a healthcare provider that enables data analytics service to be done. The path analytics include medication adherence of personalized treatment of patients over time. The fact remains that a lot of data are sent to the backend server from smartphones and the analytics tool is used to collate the report of the patient medication adherence on scheduled (weekly, monthly, and yearly) in periodical order.

Cloud Database is a centralized repository in the study that stores data collected and retrieved during each session of the mobile app service. The cloud database takes the patient details, caregiver detail, healthcare worker information, transactions (date, time, adherence values), and reminder schedule. All instances of medication adjustment and renegotiation between patients and healthcare providers are stored for future analytics. The future data from the data collected are used to precede patient adherence in the analytics view for decision making.

Internet of a thing (IoT) is an existing facility in the study area used to provide internet access within the Federal polytechnic Offa campus. The usage of IoT goes beyond campus since the cloud database is positioned in the cloud. IoT enables all participants enrolled in the medication adherence system to participate remotely from the localized region fully.

3.1 Near Field Communication (NFC)

Near Field Communication (NFC) is a short-range wireless communication standard between devices such as smartphones and tablets. Based on Radio-Frequency Identification, referred to as the standard for the development. RFID technology can recognize by its use in passports or bus cards in Sweden (SL Access Card). For many years, NFC technology has been built and used in mobile phones, and the long-term promise is to replace all electronic cards with NFC-enabled devices. NFC allows the user to send and receive data securely and efficiently without going through multiple steps to set up the connection. This communication system can define a method for establishing peer-to-peer (P2P) communication between NFC-enabled devices, with at least one device transmitting and the other receiving the signal. NFC enables the communication between devices through magnetic field induction when devices are so close to each other. Communication between NFC-enabled devices is established when they are within 4 cm of each other since NFC operates in the licensed 13.56 MHz HF ISM band.

3.2 NFC and Security

“One of the most significant advantages in terms of security when using NFC is that the range is quite limited. Even if all security and other protective measures have been violated, the individual that has initiated the breach must be close to doing that, and it requires that both devices have their NFC functionality enabled” [36].

“But still, new users of this technology may not know how dangerous it is with these security breaches, especially for payment purposes where users store their credit card information on their smartphones” [15].

4. RESULTS

The development process has resulted in an application that can be used to communicate with an intelligent pillbox by using NFC. The application provides a way for healthcare providers to "tap and go" model, where all they require is to touch the pillbox to start and perform a brief communication where information can be added or retrieved based on the user's need.

The application has been developed based on the requirements defined by MIT App, as shown in Fig. 4. These requirements have been met throughout the development process of each function and have been evaluated through tests with the help of healthcare professionals. The application contains seven screens, as mentioned in the previous chapter. There each screen will provide different information. A welcome screen, login screen, and two screens will allow the user to add information about the patient, medication, alarm, and x-alarm, and three screens will be used to retrieve information from the pillbox. The application is designed to be launched by clicking on the app icon found in the phone app drawer.

4.1 Adding and Retrieving Information

The user must first enable NFC in the phone settings to retrieve information about the patient, medication, or missed pills. When you place the phone on the pill box, a brief message will appear on the screen, informing the user that the NFC tag module has been successfully scanned and is awaiting user input to retrieve information. Depending on the information the user wants to recover. The retrieved data will be placed either in text boxes or calendars. The user cannot change the retrieved information after retrieval. Adding information about the patient, medication, and setting the alarm, X-Alarm and time are accomplished by providing this information via text fields and time selections. After providing this information, the user has to place the phone on the pill box and then click a button to add this information to the pill box. A message will inform the user that the information has been added successfully. Otherwise, indicate when the app is connected to the pillbox and when the NFC tag was recognized. Fig. 5 shows the connectivity between the pill box and the mobile application.

4.2 Application UI Structure

"Application UI structure consists of several elements widely used in today's application design. Fig. 8 shows the structure of the forgotten pill screen and the design elements used during the development of this screen. As mentioned, there are two main ways of navigating when using the application. The first way is to use tabs marked in red. Each tab displays different information, and each tab has been assigned an icon that reflects the content link. Clicking the button retrieves information about forgotten pills from the pill box and displays them on the calendar. The user can swipe left or right on the calendar to switch between different months. Clicking on a tag with a missed pill shows detailed information about when a pill was missed and the ID of the alert that started reporting a missed pill to the NFC tag" [16]. And design, from prototype to final implementation. These changes are due to some complications and knowledge limitations in NFC and Android development when designing the first and second iterations of the prototype.

A front end of the android app develop on the MIT app where indicate how the app interacted with the pill to prompt the user if medication is taken. The B area shown indicates a close button when the patient brings the mobile app close to the pill box as shown in C. The D reveals details of the UI layer on the MIT app with corresponded feature block code shown in Figs. 7 and 8 respectively.

These changes in the internal structures of the application indicate when the user forgets pills with red dots instead of red circles on the calendar. The time selection is analog and digital, not just one of the two. The time picker is shown when an alarm is set. Otherwise, it is not shown. The side navigation menu contains more options. Some screens were skipped, and others were merged into one in the design layer. The buttons added to the bottom of each screen show the option to get or add information to the pillbox.

Despite all these changes the final implementation has some design elements that are common with both iterations.

4.3 Evaluation

The application is made available to the MIT App, which could further improve and evaluate the application with the help of healthcare organizations and hospitals in Sweden beyond the scope of this work. However, the evaluation of the application based on device communication and interface with the smart pill box was carried out and passed through a field trial. The field trial was conducted in collaboration with healthcare expect to affirm the knowledge of the research work.

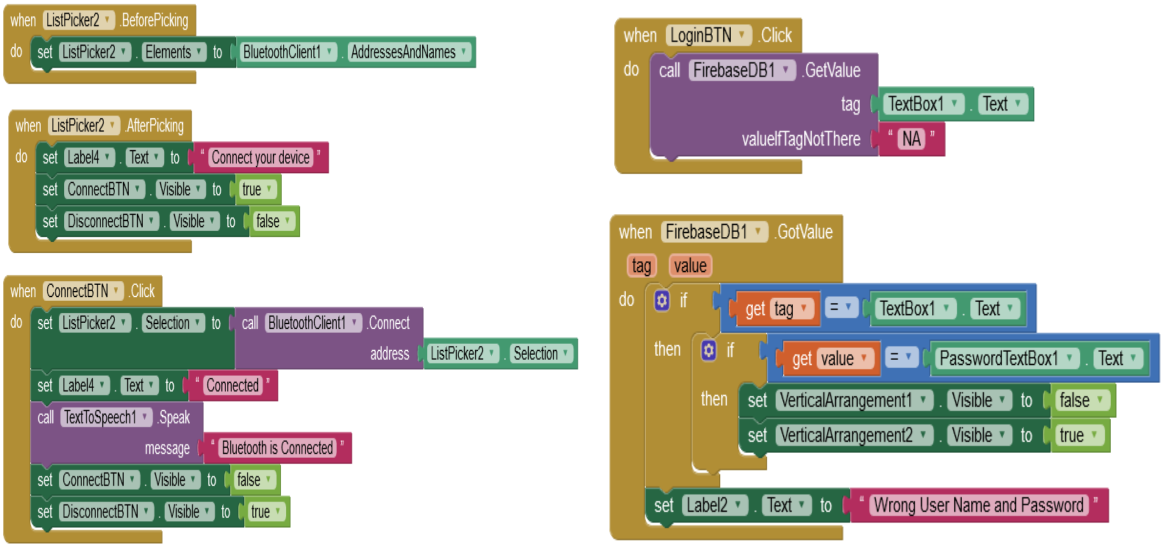

Fig. 4. User the login method with the feature of bluetooth

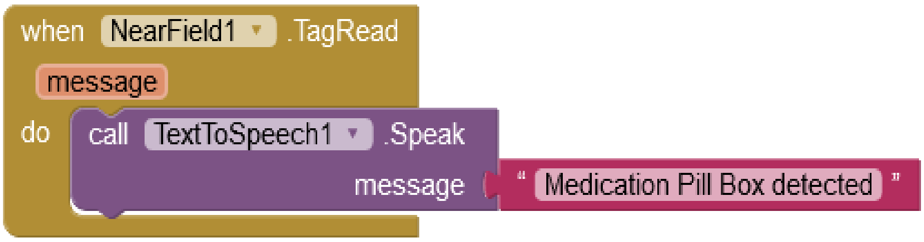

Fig. 5. Near field communication connection API

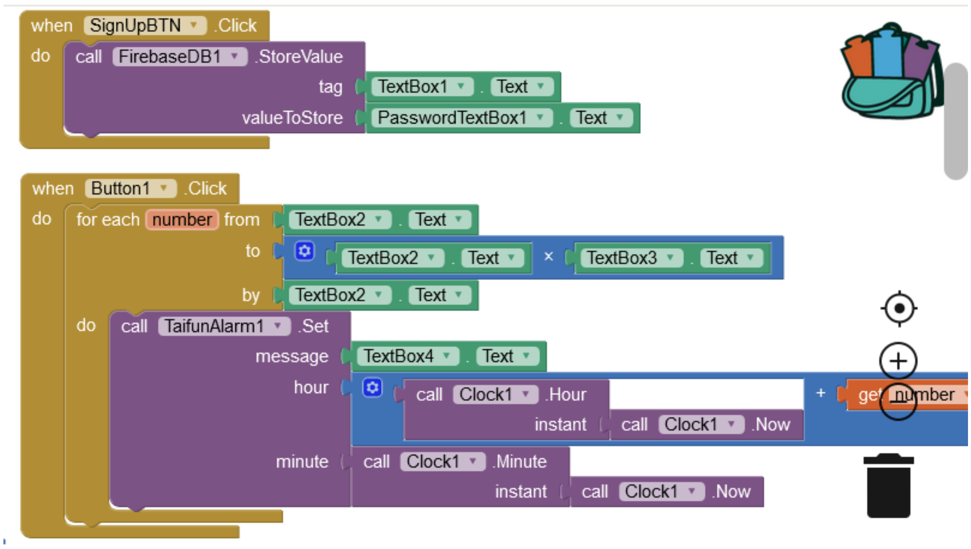

Fig. 6. Button click response connection string

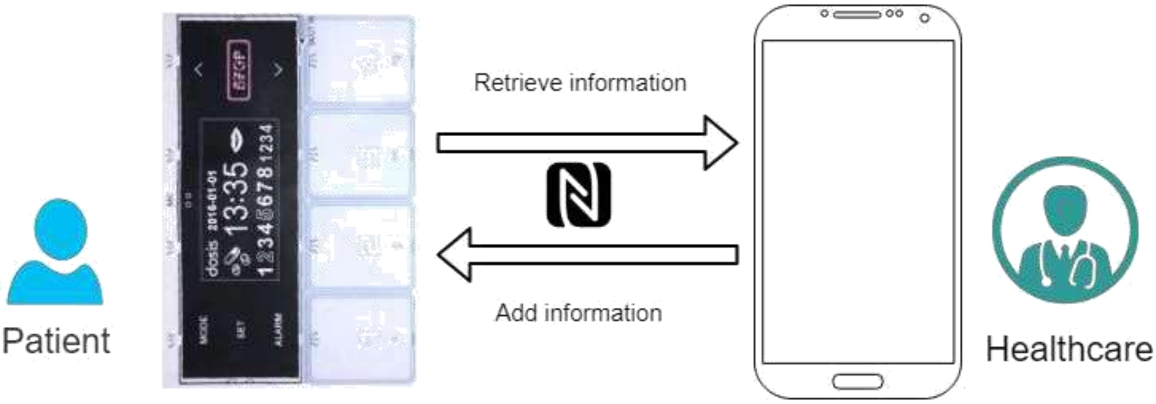

Fig. 7. Retrieve information from a pillbox

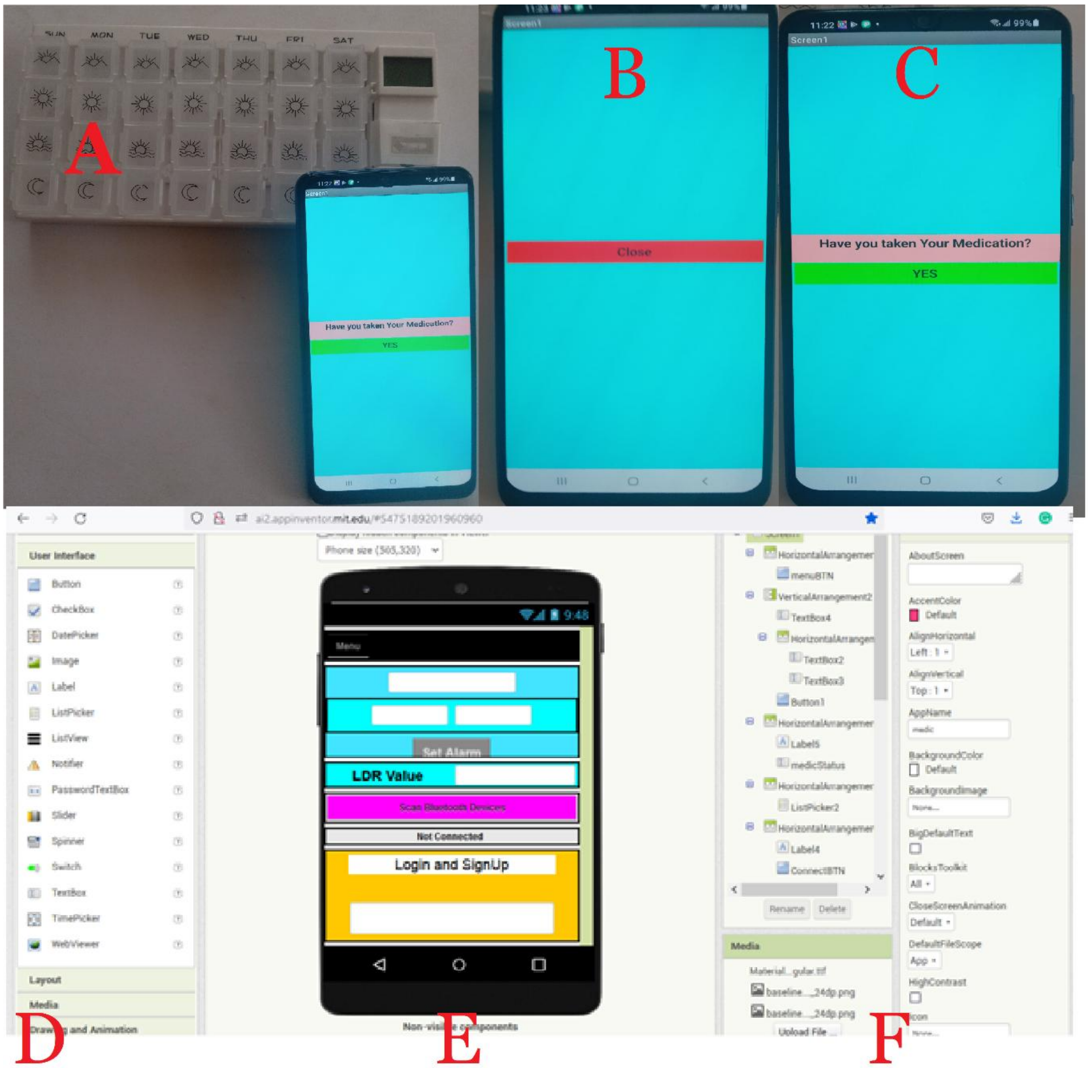

Fig. 8. User interface with pillbox featuring connection string of NFC embedded with a smartphone

Table 1. Use case mapping of affordances to specific actors

1	**Digital framework of the medication adherence system**	**Receiver/Beneficiary** **Patient:** the app will create motivation, encouragement, negotiation, and flexibility in the scheduling of medication plan **HCW:** HCW will timely update on the patient's progress on medication adherence
2	**Core Monitoring of Medication adherence**	**Initiator;** the patient refers to the initiator and initiates action between smartphone and pillbox through a cloud-based Adherence monitoring service. The Receiver or Beneficiary are the stakeholders or HCW, and family/ friends. Hence, they will timely update on patient's medication adherence
3	**Data-driven decision-making in the MA**	**Action HCW: T**he HWC will initiate action by analyzing gathered data from placed sensors and observed patterns. MA by Health Sector is to take decisions based on generally regarded patterns on adherence behavior for various patients. **Government:** Create plans and policies at regional and national levels. The MA path is hidden on the receiver/receiver Patients: improved healthcare HCW (doctors, nurses, etc.): decision support for improved service delivery Healthcare sector: data to improve healthcare services Government: data for planning and development Society: healthier society, improved health care
4		**Initiator** **HCW** develops person-specific methods and strategies to help a patient based on observed adherence behavior **Receiver/Beneficiary** **Patient:** the patient receives the right attention and care that is necessary **HCW:** the HWC to the improved success rate in healthcare
5	**Medication Adherence behavior data archiving and curation**	**Initiator** The DFS an automated process of storing relevant data for future use **Receiver/Beneficiary** The health sector is to is t data-driven process improvement in the health sector Government: the stored data is used for policy development. Statistics

To provide an understanding of what the application is trying to achieve in communicating with a smart pill box. A brief introduction to the app was presented. The overall assessment was that there is an identifiable problem in patient medication compliance that needs to be improved with the help of healthcare professionals. Some real cases for the treatment of chronic diseases were introduced to underline the need for a mobile application to retrieve information about the patient and their medication.

The proposed artifact provides the application for healthcare providers to access patient information and monitor patients' medication intake using the pill box. The features of the native app enable healthcare providers to support patients during their treatment, enabling them to improve their medication adherence. The application also reminds patients to take their pills by setting alarms for each cartridge and x alarms in case the patient forgets to take medications.

5. DISCUSSION

The expected outcome of DTS will solve medication adherence monitoring and improvement in the treatments of patients' medication during the execution phases. The adherence to patient treatment will be measured using a peer smartwatch, smartphone, and NFC (Near Field Communication) tag on the drug casing. The composition of this pairable device consists of software and hardware modules.

The essence of these modules will enable communication of the multitask holders and help in the continuous monitoring and decision making. The stage in the phases of implementation indicated, would bring about the application of AI in the mindset of programming languages (android application option) and database structure. Java application is one of the suitable programming languages for the implementation phases of a mobile application. SMS API is required to perform messaging protocols, then XML to create the front and back end of the application interface. The Firebase Database with features a cloud-hosted NoSQL *Database; this* stores stakeholder information and handle all server requests. Sequential processes of achieving this include;

1. Phase Test different phases of the design and evaluation of prototype application.
2. Modeling, simulation modules, and integration of application
3. Preparing user requirements and system requirement documents
4. Promoting within the content social, economic, and technological benefits

The significance of the study is to provide the solution to hold promise flexible and low-cost innovation to deliver positive response patient medication adherence monitoring system. A necessary context to optimize data set for decision making for medical practice, therefore, DTS to become a healthcare tool to remove barriers affecting patient treatment.

5.1 Background of the Chronic Diseases in the Life of Patient

Mr. Tope is a 48-year-old patient with chronic tuberculosis who works at Federal Polytechnic Offa. He lives with his wife and four children in a mining community/town of Offa in Kwara State. Mr. Tope has been registered for TB treatment at the local Medical Healthcare Center Offa hospital for six months and is said to take his medication twice a day, six hours apart. Mr. Tope has agreed with health workers to take his medication every morning at 7 am and during the lunch break at 1 pm while at work and to follow the same schedule on days off. The medication plan was agreed upon with the health workers, the presence of Mr. Tope's wife (Mrs. Tope), and Ade, a close friend, and associate of Mr. Tope at work. Mrs. Tope and Ade were enrolled as co-monitors and patient attendants to help Mr. Tope keep to the agreed schedule. A challenge with Mr. Tope is that lunch breaks at work vary depending on the hours worked. For example, there are times when Mr. Tope and his colleagues need to be at the mine for long periods, which would require a mid-day shift.

6. CONCLUSION

This study presents the concept of a digital framework strategy for medication adherence and improvement in the context of chronic diseases based on the Medical Health Center Offa case study. Unlike existing approaches to medication adherence monitoring, which primarily focus on tracking and measuring medication adherence, DFS seeks to integrate both medication adherence and improving patient medication adherence. The multi-stakeholder collaboration approach was designed and implemented to achieve this research aim and objectives. With the aid of sensors, paring devices were used to track patient medication intake. However, DSF is no longer in the conceptual phase. The necessities for its implementation, as well as the plausibility of its use for medication adherence monitoring and improvement in resource-poor settings, were also discussed. This is followed by an evaluation regarding the applicability of the framework from the participants' perspective and its effectiveness in monitoring medication adherence and jeopardizing the improvement of medication adherence.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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