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Drishti: A sense-plan-act extension to open mHealth framework using FHIR

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***Abstract*—Mobile Health (mHealth) is vital in promoting a collaborative healthcare model. Disparate mHealth Apps that do not talk to each other make complex behavioural interventions difficult. Open mHealth is a schema and framework for facilitating health information exchange for mHealth apps. We propose an extension to open mHealth for behavioural interventions. We call our proposed extension; Drishti (yogic gaze). It applies the sense-plan-act paradigm from robotics. We offer an open-source implementation of Drishti, and we evaluate it using a design science research framework.**

***Index Terms*—mHealth, FHIR, Interoperability**

I. Introduction

Behavioural interventions are critical in the prevention and control of most chronic diseases [1]. Behaviour Intervention Technologies (BITs) include several mediums such as web, virtual reality, social media and mobile [2]. Mobile health (mHealth) is a new concept of using mobile communication devices, in association with the internet and social media to provide smart health interventions tailored to the individual user [3]. The ubiquitous cell phone has the potential to be the future telemedicine and telemonitoring platform. mHealth apps can monitor and display physiological parameters such as blood pressure, and behavioural parameters such as smoking patterns, and share data with care providers. mHealth applications can also deliver behavioural interventions in the form of alerts and tailored messages.

Designing a system for health monitoring involves reliable sensors, secure transmission of data and providing privacy and security. Treatment of many chronic diseases benefits from continuous monitoring of parameters such as blood pressure, pulse rate, blood sugar, ECG, and respiration [4]. mHealth applications are capable of recording physiological data passively by sensors or by patient self-reported data. In addition to physiological parameters, sensors can also stream data related to the individual's environment, which is crucial in planning complex interventions [5].

The number of mHealth apps has grown exponentially over the last few years. However, a siloed approach has led to plenty of mutually incompatible apps serving niche needs, leading to calls for a coordinated approach for an open mHealth architecture [6] for data collation. We explore the theoretical dimensions and practical challenges of this approach and extend it to BITs. Drishti (yogic gaze) is an open-source software stack that implements the extended open mHealth framework.

The rest of the paper is structured as follows. First, we explore the potential strengths and challenges of mHealth BITs. This is followed by a systematic investigation of theories and models that support an overarching mHealth architecture. Next, we review the relevant technologies followed by a description of Drishti, its components, and its advantages. Finally, we conclude by stating its limitations and how others can improve Drishti collaboratively.

II. Strengths and challenges of mHealth BITs

mHealth and wearable devices can continuously monitor a variety of patient characteristics such as symptoms, side-effects, and physiological parameters such as blood sugar and blood pressure. mHealth makes it possible to collect and share these health data with care providers. In turn, care providers can deliver interventions through the device in the form of alerts and reminders. Alerts can also be auto-generated by machine learning and artificial intelligence systems.

Health Risk Behaviours are deleterious action patterns that increase the risk of diseases or recovery times. They are prevalent and often co-occur, with most individuals having more than one risky behaviour. Educational and informational interventions may be able to improve many unfavourable behaviours, while at the same time having a considerable public health impact [7]. Strategies adopted with mHealth interventions to facilitate behavioural change include goal-setting, social support, social comparison, prompts, cues, and rewards. Most of these interventions resemble recommendations from social cognitive theory [8].

An effective framework to integrate mHealth and wearable device data generation may have sufficient velocity, veracity and volume to belong to the realm of big data. This can be mined using machine learning techniques to provide useful insights. Big data can also be used to test existing theories and to propose novel theories [9]. Therefore, an overarching mHealth architecture could have an enormous impact on BITs.

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III. BIT THEORIES AND ARCHITECTURE

Clinical specialties use randomized controlled trials (RCTs) as the standardized method to determine the efficacy of BIT in behaviour change. However, RCTs do not provide answers to the 'why' or 'how' that is needed for designers to develop and refine BITs [10]. The biggest hurdle in mHealth application design is the lack of models for researchers to communicate with designers. The BIT model is proposed to define both the conceptual and technological architecture to bridge the gap between clinicians and designers [11]. The technological aspect of the BIT model is comprised of profilers to collect data, intervention planner, intervention repository and user interface or actor [11] to deliver interventions. The BIT model has successfully been used for app design [12].

An ideal BIT framework in mHealth should passively collect data, infer patient state, have robust models that can determine tailored interventions, and should deliver interventions to users in a non-intrusive manner [2]. It should support collaboration between clinical and development teams [13], and assist building and maintaining machine learning models that do not become obsolete. It should also support low-fidelity prototyping [14] and agile development [15]. Drishti offers one such framework based on BIT model.

Traditionally, different mHealth applications perform related tasks in the BIT model. An Open mHealth Architecture built around popular data standards and existing communication protocols have been proposed to overcome the siloed approach. In this model, each component has standard interfaces that allow information exchange [6]. Open mHealth facilitates innovative uses for healthcare data than the original application initially intended. For example, activity data and blood sugar data can be combined to provide intervention. The open mHealth model proposes reusable health data and knowledge services. Drishti framework integrates the BIT model with the open mHealth model and proposes FHIR as the interface standard.

IV. DRISHTI FRAMEWORK

The BIT model divides the functions of any BIT implementation into four components: profilers to collect data, intervention planner, intervention repository and actors serving alerts and messages back to the user [11]. However, the BIT model does not provide any particular direction or standards for app designers to implement. We propose a pragmatic extension of the paradigm by recommending a modular architecture for BITs, with each module implementing the four core functionalities, and communication between the modules ensured by FHIR (See Figure. 1).

The profiler can be implemented by standalone sensors or modules in the app running on the mobile device. The open mHealth community has created an open-source tool called shimmer to pull health data from popular third-party APIs like Fitbit and Googlefit [16]. Open mHealth shims (a library that transparently handles API calls) are adapters for third-party data providers offering RESTful operations to retrieve data [16]. We use the shimmer application as the profiler

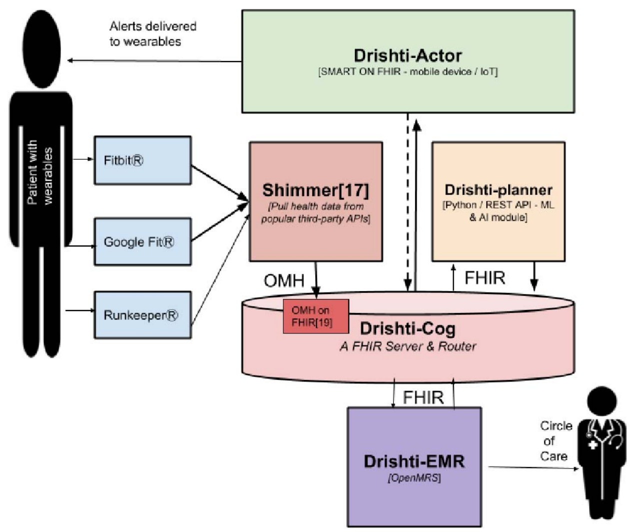

Fig. 1. Drishti Framework.

in the Drishti implementation. Shimmer can fetch data on physiological characteristics such as blood sugar and blood pressure, and other data such as location and movement from various APIs.

Drishti-cog is a module that integrates calls to various shims. It converts data returned by the shims to the Fast Healthcare Interoperability Resources (FHIR) format and saves it as a FHIR bundle. Drishti-cog is implemented using HAPI FHIR server [17] and open mHealth's OMH-on-FHIR module [18].

Drishti-plan is a planner module that uses this data to prepare interventions. The planner module may reside in the cloud or on the mobile device itself. The plan may also be created by the provider in an EMR. The Drishti-act component in the mobile device deliver interventions in the form of alerts, reminders, and messages while sending the delivery status to the Drishti-cog. The actor can be Internet of things (IoT) devices that can deliver any intervention. Drishti-EMR is the integration module with an electronic health record. FHIR is the data format that is used by all the modules for data exchange and persistence.

A. *FHIR Resources*

Fast Healthcare Interoperability Resources (FHIR) is a new approach by the HL7 architects to simplify the HL7 V3 standard to encourage adoption [19]. FHIR is rooted in the utilization of the popular open web standard called REST. FHIR defines key entities involved in healthcare information exchange as *resources*. The resources have clear boundaries, differ from each other and should be detailed enough to support the clinical data exchange that is involved. FHIR is an evolving standard, and at present more than 50 resource types have been described. Resources center on supporting 80% of the common use cases rather than the 20% of exceptions

(80/20 rule). FHIR is fast emerging as the most popular data exchange standard between health information systems.

Two of the existing resources can be leveraged to provide the data model for Drishti. Observation is a resource that can represent any clinical observations such as vital signs, device measurements, and laboratory data [20]. The CarePlan resource can represent information on how clinicians intend to deliver care [21]. The Observation resource can be used by the profiler to exchange data; The Care Plan resource model can be leveraged by the planner module to represent detailed intervention plans, that can be pushed as alerts and messages to the user. If any of the resources in its native form is found inadequate for Drishti, the resource model can be extended to support them.

B. OpenMRS EMR Platform

Healthcare providers need the consolidated data in the EMR for efficient care delivery. In the reference implementation, OpenMRS is used as the EMR with an integration app called Drishti-EMR. OpenMRS is an open-source electronic medical record (EMR) system developed especially for developing countries [22]. OpenMRS provides the modular building blocks for health information systems in the form of APIs built on top of a robust data model.

C. Current State of the Drishti framework

The Drishti implementation is available as an open-source project on GitHub [23]. The Drishti-cog is a java application built using the HAPI FHIR library [24]. The Drishti-planner is a python application supporting REST API. The Drishti-Act is a SMART-ON-FHIR [25] application using Vue framework. The EMR module uses hGraph to provide a visual summary of a patient's health status to the clinician [26]. The project is work in progress, and the open-source community is invited to collaborate and guide this project.

D. Hypothetical use case

Exercise is known to improve outcomes in patients with clinical depression [27]. Clinicians can use the Drishti framework to monitor the activity of patients using devices and apps that the patients may be using already. The clinicians in the circle of care can actively monitor the patient and push messages to the patient's mobile device to encourage regular exercise. Intelligent systems can generate alerts for patients and clinicians based on the data collected in Drishti-cog.

V. Design Evaluation

We use Hevner's design science research guidelines [28] for the evaluation of Drishti instantiation (design as an artifact). The Drishti framework proposes a solution to the problem of disparate healthcare apps not talking to each other (research problem) by using FHIR as the data standard to ensure interoperability. The conceptual separation of profiler, planner and actor facilitates communication between software designers and clinicians (problem relevance). Design evaluation is based on structural, functional and integration testing. Our research contributions are the integration of BIT model with open mHealth model (design theory) and the software stack built using FHIR (design artifact). We search the existing systems and standards for reuse whenever possible to ensure research rigour. Finally, we communicate our results to both clinical and technical experts.

VI. Discussion

Several technology companies have implemented proprietary solutions for mHealth data storage and retrievals such as Apple HealthKit [29] and Google Fit [30]. Most of these solutions are cloud storage applications using proprietary data models, and none of them are open-source. However, many of these solutions offer developers easy tools for developing applications that interface well within their ecosystems. Open mHealth is a non-profit startup that offers a variety of mHealth data integration services for storing, processing, sharing and visualizing data in the mHealth domain [31].

With the ever-increasing volume of data collected and streamed by mobile devices, we are now at a stage where we can contemplate individual level big data. Privacy and security remain a major concern for mHealth technologies, especially those involving sensitive domains such as mental health. Some behaviour intervention apps may come under the purview of the Health Insurance Portability and Accountability Act (HIPAA). Such apps are affected by policies related to medical licensure, privacy and security protection, and malpractice liability [32].

Patient self-monitoring introduces a host of human factors and ergonomics (HFE) problems, for both patients and clinicians, that can affect the quality of care and patient safety. Some of these concerns are related to critical home care tasks of information access, communication, and diverse monitoring devices. An overarching mHealth architecture reduces the HFE problem by effective health information exchange [33].

The incessant use of mHealth interventions can lead to detrimental cognitive consequences such as alert fatigue. The term alert fatigue describes how busy clinicians and mHealth users become desensitized to messages and alerts, and as a result ignore or fail to respond appropriately to such signals [34]. Alert fatigue can be avoided by innovative strategies such as just-in-time adaptive intervention (JITAI) that strives to provide the right support, at the right time, by tailoring interventions to the individuals context [35]. JITAIs should be able to rapidly adapt to the individual's internal state as well as the external and environmental state. Drishti makes a consolidated view of the patients' data possible. Drishti also enables alerts and messages that integrate several sources of information reducing alert fatigue.

Drishti, guided by the BIT model will help clinicians and developers to work together more efficiently. In addition to interoperability, it also helps modules to be shared across applications, plan complex interventions with input from a variety of sensors, and maintain clinical knowledge separate from the other software components. The integration with a full-fledged EMR system (OpenMRS) provides a host of related clinical data management functions.

Drishti framework is not suitable for data types such as images and ECG recordings. Drishti gives broad guidelines on implementation but it does not make any recommendations on data privacy, security or patient safety. FHIR resources are designed for data exchange between systems, rather than as a database storage format. However, since the framework stores disparate data, FHIR may still be a good choice as a data persistence format [36].

Drishti is a model-based mHealth architecture and a reference application for demonstrating its implementation. It is intended to leverage existing standards such as FHIR for information exchange. A modular structure that segregates functionalities as the profiler, planner, and actor helps improve collaboration between clinicians and developers. The clinical knowledge can be abstracted away from the technical infrastructure and shared by multiple systems. The reference application is open-source [23] and can be collaboratively extended.

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