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Design and architect an Informatics solution to improve health outcomes for elderly patients suffering from loneliness-induced health issues.

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TABLE OF CONTENTS

INTRODUCTION 4

BACKGROUND 4

BUSINESS NEED 8

PURPOSE 8

HYPOTHESIS 9

HIGH LEVEL REQUIREMENTS 10

MAJOR DELIVERABLES 10

ENTERPRISE ARCHITECTURE 11

SOLUTION 12

- Physician's EHR system 13
- OHAA system and activity trackers 14
- OHAA system 14

THE OPEN GROUP ARCHITECTURE FRAMEWORK (TOGAF) 15

- BUSINESS ARCHITECTURE 16
  - Business Process Model 16
  - Business Process Template 17
- DATA ARCHITECTURE 20
  - Data Management 20
  - Datasources 21
  - Data Quality 22
  - Data Migration 23
  - Data Governance 23
- TECHNOLOGY ARCHITECTURE 24
  - IT Infrastructure 25
- APPLICATION ARCHITECTURE 31
  - OHAA and Activity tracker(FitBit) 32
  - OHAA Web Interface 34

EXECUTIVE SUMMARY 41

INTRODUCTION

Studies have shown that in the United States, roughly 33% of people older than 65 live alone, and that percentage increases to 50% among those older than 85. The effect of loneliness on the elderly population is becoming a public health crisis. According to the PEW research center there were around 74.9 million baby boomers (ages 51-69) in 2015. Since aging and loneliness are correlated, the likelihood of loneliness becoming a public health threat is elevated.

Quantitative data from studies have shown an increase in mortality rates based on the effects of loneliness, social isolation, or living alone. The recent US census data shows that more than quarter of the population lives alone, more than half of the population is unmarried and, since the previous census, marriage rates and the number of children per household have declined. Among the aging population, chronic loneliness has been shown to increase the levels of cortisol, a stress hormone, and higher vascular resistance, leading to a rise in blood pressure and decreased blood flow to vital organs.

BACKGROUND

Loneliness can be defined as a subjective negative feeling associated with a perceived lack of a wider social network (social loneliness) or the absence of a specific desired companion (emotional loneliness). The elderly population experiencing social isolation and loneliness are faced with numerous physical, psychological and social role changes that challenge their sense of self, and capacity to live happily. Many people experience loneliness and depression in old age, either as a result of living alone or due

to lack of close family ties and reduced connections with their culture of origin[1]. Among people older than 60 the prevalence of loneliness ranges from 10 % to 46 %.

According to an AARP national survey, 42.6 million adults 45 and over are estimated to be suffering from chronic loneliness. According to the survey, over 55% of the respondents who reported being in poor health and having chronic conditions like diabetes, hypertension, cardiovascular/heart disease or high cholesterol were lonely as compared to 25% who reported being in excellent health. Of diabetic respondents, 42% expressed feeling lonely. Among the respondents, the highest rates of loneliness were experienced by those with chronic pain conditions (47%) and those who were obese (43%). 45% of respondents with sleep disorders were lonely and senior adults with 3 to 5 hours of sleep had a higher probability to being lonely [2]. Figure A, shows the correlation between chronic conditions and the percentage of the surveyed population experiencing loneliness. It is noticeable that conditions like chronic pain, anxiety, and mood disorder, among others, increase the effects of loneliness[2].

[1] Loneliness, depression and sociability in old age
Archana Singh and Nishi Misra1 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3016701/

[2] Loneliness among older adults 45+ Knowledge networks and Insigh Policy Research
https://www.aarp.org/content/dam/aarp/research/surveys_statistics/general/2012/loneliness-2010.doi.10.26419%252Fres.00064.001.pdf

Table 1. Medical Condition by Loneliness		
Diagnosed with:	**Lonely**	**Not Lonely**
Cancer	24%	76%
Arthritis / Rheumatism	35%	65%
Cardiovascular / Heart disease	38%	62%
Hypertension	35%	65%
Gastrointestinal diseases	37%	63%
High cholesterol	35%	65%
Diabetes	42%	58%
Obesity	43%	57%
Other medical condition	42%	57%
Sleep disorder	45%	54%
Other chronic pain condition	47%	53%
Anxiety	56%	44%
Other mood disorder	59%	41%
Depression	60%	40%
Drug / Alcohol abuse	63%	37%

Note: Rows may not sum to 100 percent due to rounding error.

Figure A

(https://www.aarp.org/content/dam/aarp/research/surveys_statistics/general/2012/loneliness-2010.doi.10.26419%252Fres.00064.001.pdf)

Studies with controlled confounding factors such as demographics and objective isolation have shown that loneliness increases the odds of an early death by 26% as well as an increase in the early onset of cardiovascular diseases, cancer, accidents, suicide and diabetes among the elderly population[3].

To mitigate these negative outcomes, several findings have pointed out the positive effects of interventions like increased social and physical activities to alleviate the feeling of loneliness and social isolation among the elderly population[4]. Improved

[3] Loneliness and Social Isolation as Risk Factors for Mortality A Meta-Analytic Review - Julianne Holt-Lunstad, Timothy B. Smith, Mark Baker, et al
http://journals.sagepub.com/doi/full/10.1177/1745691614568352
Relationship Between Loneliness, Psychiatric Disorders and Physical Health ? A Review on the Psychological Aspects of Loneliness - Raheel Mushtaq,corresponding author1 Sheikh Shoib,2 Tabindah Shah,3 and Sahil Mushtaq4
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4225959/ .

[4] Loneliness, isolation and the health of older adults: do we need a new research agenda?

physical activity as part of a healthy lifestyle has also been shown to play an important role in preventing the chronic diseases in this age group. The CDC physical activity guidelines recommend that adults need to engage in 150 minutes of aerobic activity and 2 days of muscle strengthening activity per week. Despite these recommendations, it has been observed that inactivity increases with age. Less than half of adults aged 65–74 years and about one-third of adults aged 75 years and older meet the CDC's physical activity recommendations[5]. Current research has focused on understanding the potential effects of the use of activity trackers among older adults and their influence on change in behaviors like increased physical activity and improved clinical outcomes. The results indicated improvements in overall well-being and confidence among the participants, coupled with weight loss and improvements in clinical outcomes like decreased LDL levels[6]. As demonstrated by these studies, incorporating physical activity into daily life and tracking the activity through fitness technology can have a profound impact among the elderly and nudge them out of their sedentary lifestyles[7]. It was also noted that objective measurement of fitness activity provided factual data on everyday activities like running errands, walking from the parking lot to a store or office, and playing with a grandchild. These activities are typically otherwise forgotten or overlooked by respondents in a survey. In addition, fitness trackers tend to play an important role in sustaining behavioral changes among older adults. Health patterns like Energy Expenditure (EE), distance walked, elevation, heart rate, diet, sleep quantity,

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Nicole Valtorta1 and Barbara Hanratty2 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3536512/

[5]Health behaviors of adults: United States, 2008-2010.
Schoenborn CA, Adams PF, Peregoy JA. https://www.ncbi.nlm.nih.gov/pubmed/25116426/

[6]Can a Free Wearable Activity Tracker Change Behavior? The Impact of Trackers on Adults in a Physician-Led Wellness Group - Monitoring Editor: Gunther Eysenbach Reviewed by Daryl Mangosing, Christophe Giraud-Carrier, and Michael Chary https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5156822/

[7]Behavior Change with Fitness Technology in Sedentary Adults: A Review of the Evidence for Increasing Physical Activity Alycia N. Sullivan, and Margie E. Lachman https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5225122/

and quality can be tracked among older adults and provide substantial insight to physicians and health care providers about various lifestyle patterns that could either be current contributors or potential contributors to chronic conditions among the elderly population[7].

BUSINESS NEED

Facilitating an information system that would aid physicians to work closely with their elderly patients would be a novel informatics solution to address this problem. By integrating clinical data as well as activity tracking data among the elderly, the Online Healthy Aging Assistance (OHAA) tracking system would provide primary care physicians with a comprehensive understanding of patient health, enabling them to mitigate the onset of loneliness and improve health outcomes. This system could significantly improve the quality of life for the elderly as well as reduce the mortality rate associated with loneliness.

PURPOSE

This thesis aims to design and architect an Informatics solution - the OHAA tracking system, a cloud-based solution that will integrate with Electronic Health Record (EHR) systems and activity tracking apps, like the FitBit, to improve health outcomes for elderly patients who are predisposed to loneliness-induced health issues.

HYPOTHESIS

The use of a web-based tracking system will assist health professionals to proactively track social isolation and make the process of extracting relevant data about a patient's current mental state more efficient. This will, in turn, drive reporting, analysis and decision support while addressing adverse health outcomes among seniors.

Specific Aims

- **Aim 1:** Identify and describe the need for an informatics solution to improve patient-centric health outcomes and mortality rates for patients over 65 who are predisposed to loneliness-induced health issues.
- **Aim 2:** Describe the impact and benefits of an informatics solution for primary care providers to improve health outcomes for patients over 65 through early intervention and detection.
- **Aim 3:** Develop a process flow to demonstrate the workflow and data exchange between the OHAA system, EHR system and activity tracking apps.
- **Aim 4:** Design a blueprint of the informatics solution with artifacts like the Business Architecture, Information Architecture and the Technical Architecture to demonstrate the interoperability between the OHAA system, the EHR system and activity tracking apps (like FitBit). Data from activity trackers like the FitBit will provide health providers with enhanced **predictive analysis capabilities.** Through enhanced reporting on the detailed health indicators tracked by the device, physicians will be equipped to better identify trends in the health statuses of their patients as well as accurately predict potential health outcomes. By

linking key data elements from the patient's EHR as well as the activity tracker, physicians will have the ability to identify contributing factors to behavioral patterns and their effects on the health of their elderly patients.

HIGH LEVEL REQUIREMENTS

Listed below are requirements that the project's product, service or result must meet in order for the project objectives to be satisfied:

- Ability to interface and push relevant EHR data for older adults identified with loneliness by the physician into the OHAA system.
- Ability to pull data from the activity trackers (namely the FitBit) into the OHAA system.
- Ability to aggregate data and perform reporting to determine the correlation between health indicators and loneliness.

MAJOR DELIVERABLES

Some of the major deliverables that the project's product, service or result must meet in order for the project objectives to be satisfied are listed below:

- Engagement - Obtain engagement from stakeholders at the participating physician offices.
- Data use agreement - Sign off on data use agreement from medical health professionals, participating patients and the OHAA system owner.
- Data sources - Identify various data sources that feed into the OHAA system.

- Interoperability- Identify technology as well as interface API between OHAA system and EHR systems. Identify technology and API between OHAA and activity trackers.
- Analysis of data collected - Analyze and aggregate the data collected from OHAA system and EHR. Analyze and identify key indicators in the data to assist with predicting possible health outcomes .
- Reporting - Provide reports to participating health providers.

ENTERPRISE ARCHITECTURE

Enterprise Architecture is mainly focused on the performing enterprise analysis, design, planning, and implementation, with the main goal of successful development and execution of strategy. Through the application of architecture principles and practices the organization is guided through the business, information, process, and technology changes required to execute their strategies. Various facets of the enterprise architecture guidelines are used to identify, motivate, and achieve these changes[8].

8 A Common Perspective on Enterprise Architecture Developed and Endorsed - The Federation of Enterprise Architecture Professional Organizations.

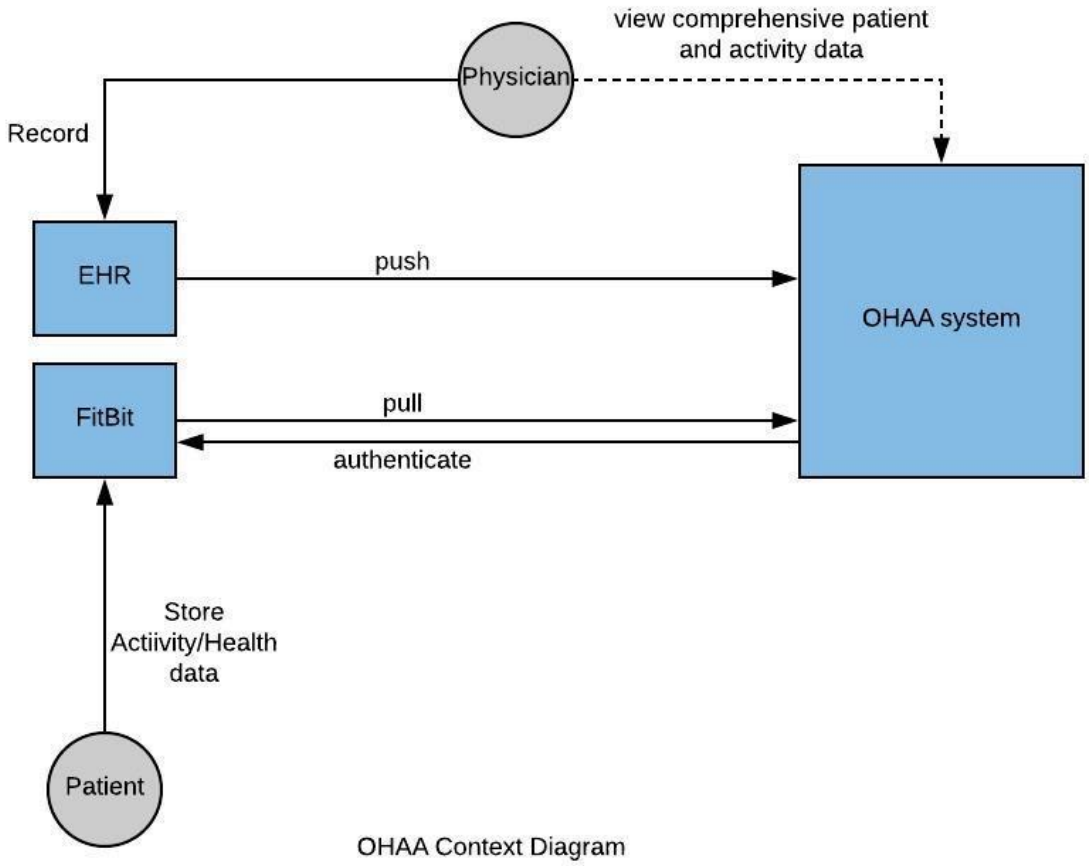


Figure B

SOLUTION

The proposed solution to support this public health issue is to create a cloud based web application called the Online Healthy Aging Assistance (OHAA) tracking system for use by primary healthcare providers. The integration of the OHAA system with the

physician's existing Electronic Health Record (EHR) system as well as an activity tracking app like the FitBit would facilitate tracking current patient health through the association of patient data with lifestyle patterns like exercise level, sleep, heart rate etc. Based on the harmonization of the clinical data with the activity tracking data, physicians would be able to improve health outcomes for elderly patients who are predisposed to loneliness-induced health issues. Through key data points and analysis of the data captured in the OHAA system, physicians would be able to provide the necessary intervention and treatment to improve health outcomes among the elderly and reduce the mortality rate associated with loneliness.

The reporting tools within the OHAA system, will enable physicians to make better decisions about a patient's care through the use of predictive analysis. The novel idea for physicians to be able to detect and track the effects of social isolation among patients, determined by their medical records as well as their lifestyle activities, can potentially improve the health outcomes among the aging population.

PHYSICIAN'S EHR SYSTEM

During a health visit, each patient will be administered a short questionnaire similar to the one published by UCLA - *The UCLA loneliness Scale*[9], by their primary care provider to determine their current mental state. This questionnaire will comprise of 3 to

[9] http://fetzer.org/sites/default/files/images/stories/pdf/selfmeasures/Self_Measures_for_Loneliness_and_Interpersonal_Problems_UCLA_LONELINESS.pdf

5 qualitative questions to assist the physician with gathering details on the living situation, patient mental health (alertness) as well as the number, type, and duration of social interactions. Based on the responses, the physician can determine if the patient is experiencing loneliness and flag the patient in the EHR system, syncing that patient's data with the OHAA system using standard data exchange platform like the HL7 on FHIR.

OHAA SYSTEM AND ACTIVITY TRACKERS

Based on the determination/degree of loneliness identified by the primary care provider, patients will be encouraged to purchase and use an activity tracker, mainly the Fitbit. The data points from the activity tracker, such as heart rate, distance traveled, stress levels, breathing rate, and sleep patterns will be pushed to the OHAA system using standard data exchange APIs like the Rest API using the FitBit Web API.

OHAA SYSTEM

The OHAA system will present a comprehensive view of an individual's social isolation/loneliness, its effect on personal well-being, and will help physicians make informed decisions on treating the effects of loneliness on chronic illnesses like heart disease, hypertension, cancer, mental status and diabetes.

THE OPEN GROUP ARCHITECTURE FRAMEWORK (TOGAF)

Applying the principles of the **TOGAF framework** to design an enterprise architecture would meet the business needs of the OHAA system. The 4 components of the TOGAF model- **the Business Architecture, Data Architecture, Application Architecture and Technology Architecture** would define the OHAA system. The ISO/IEC 42010:2007 defines "architecture" as: **"The fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution."**[10]

According to the **TOGAF model**, the definition of architecture varies based on the context

1. ***A formal description of a system, or a detailed plan of the system at a component level to guide its implementation[11].***
2. ***The structure of components, their inter-relationships, and the principles and guidelines governing their design and evolution over time[9].***

The TOGAF model takes a Process Centric approach. Based on the TOGAF model, the Enterprise architecture consists of four components.

ARCHITECTURE TYPE	DESCRIPTION
Business Architecture	The business strategy, governance, organization and key business processes.
Data Architecture	The structure of an organization's logical and physical data assets and data management resources.

10 ISO/IEC/IEEE 42010 http://www.iso-architecture.org/ieee-1471/defining-architecture.html

11 http://pubs.opengroup.org/architecture/togaf9-doc/arch/chap02.html

Application Architecture	A blueprint for the individual applications to be deployed, their interactions and their relationships to the core business processes of the organization.
Technology Architecture	The logical software and hardware capabilities that are required to support the deployment of business, data and application services. This includes IT infrastructure, middleware, networks, communications, processing and standards.

BUSINESS ARCHITECTURE

Business Process Model

The business processes that have a major impact on meeting the objectives of the OHAA system are listed below.

- Connect with the EHR system of the Provider - The OHAA system will interface with the EHR system of the affiliated provider offices to access the patient medical information as well as the patient visit information.
- Connect with activity tracking devices - The OHAA system will interface with the activity tracking system, namely the FitBit, to extract activity related information.
- Enhance the EHR to record questionnaire information - The physician's current EHR will be updated to record answers to the questionnaire.
- Analyze OHAA data - The data within the OHAA system will be analyzed.
- Reporting / Dashboard modules within OHAA system - The OHAA system will have a reporting /dashboarding module.

Business Process Template

The "**Connect with EHR system of the Provider**" table below as well as the figure C shows the various steps in the business process between the OHAA system and the EHR system.

Connect with EHR system of the Provider	
Item	**Details**
Trigger Event	When the primary care provider saves the patient visit information.
Result	Patient medical data as well as visit information of patients flagged in the EHR system with showing signs of loneliness during the medical appointment will be pushed to the OHAA system.
Business Process steps	1. Patient visit with the Primary care provider. 2. Provider records the questionnaire data, health vitals, and observations during the patient visit.
Shared Data	The patient data and visit information are stored in the EHR database. The patient visit data and patient medical data are pushed to the OHAA database as well.
Predecessor	Completed patient authorizations and approval from the patients encouraged by the physician to wear an activity tracker, namely the FitBit.
Successor	The patient visit information is recorded.
Constraints	
Failures	Patient denies the authorization of sharing data with the OHAA system.

Performance Measures	Number of patient visits and completeness of questionnaires. Validate required information are captured accurately.

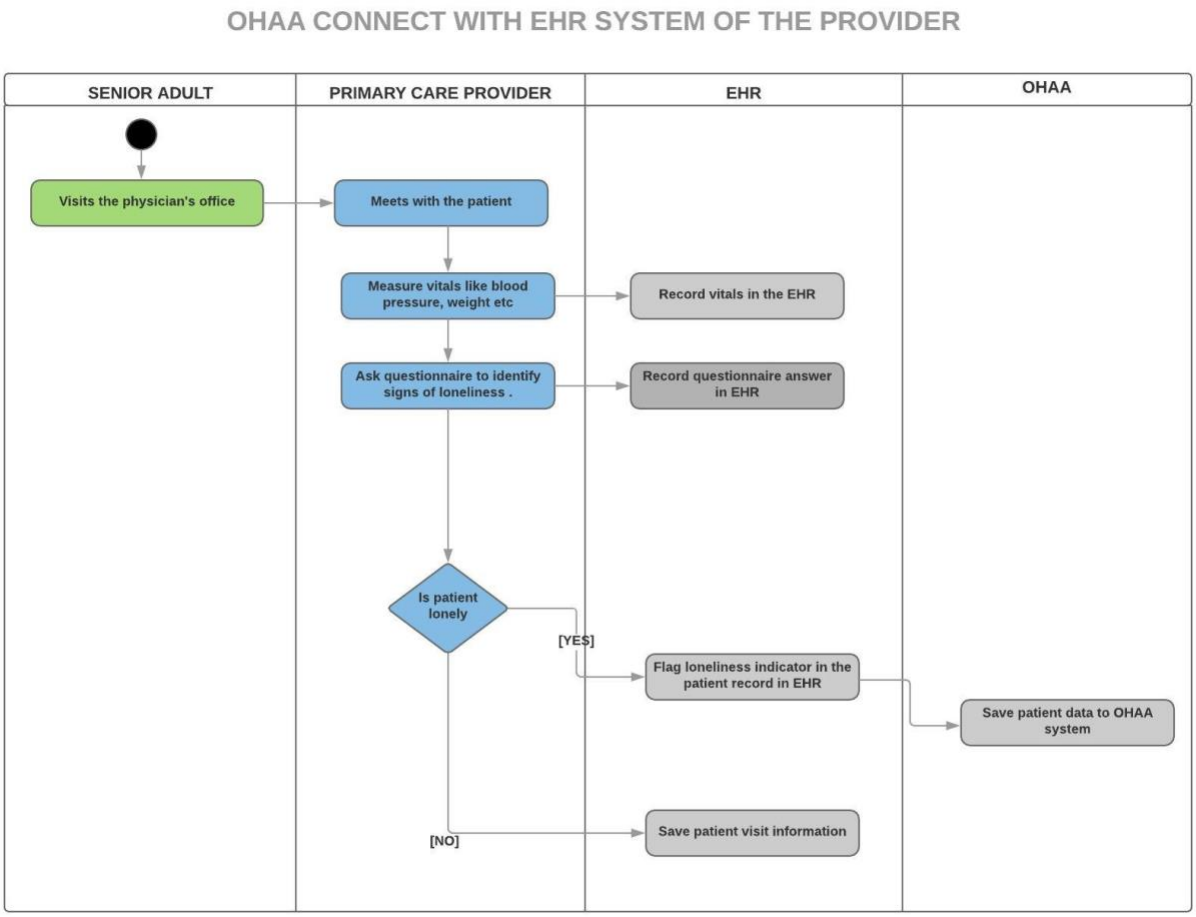


Figure C

The "**Connect with activity tracking system**" table below as well as figure D shows the various steps in the business process. It identifies the Predecessors, Successors and Failures that are key elements in a business process flow.

Connect with activity tracking system	
Item	**Details**
Trigger Event	Pull activity tracking data into the OHAA system.
Result	Relevant activity tracking data is stored in the OHAA system.
Business Process steps	1. Physician indicates in the patient record that patient is showing signs of loneliness. 2. The physician encourages the patient to use an activity tracker like FitBit app. 3. Patient fills out the authorization form approving the data pull of their activity data into the OHAA system**.** A unique authorization token id is generated for each patient after the approval. 4. The data from the activity trackers is pulled by the OHAA system.
Shared Data	Patient visit data and patient questionnaire data.
Predecessor	Patient visit data indicates signs of loneliness
Successor	Patient wears activity tracker
Constraints	Patient can choose to wear or not wear activity tracker.
Failures	A failure to establish successful communication in the interfaces between OHAA and EHR and OHAA and device trackers.
Performance Measures	Successful pull of data using the Application programming interfaces(API) form EHR and device trackers into the OHAA system.

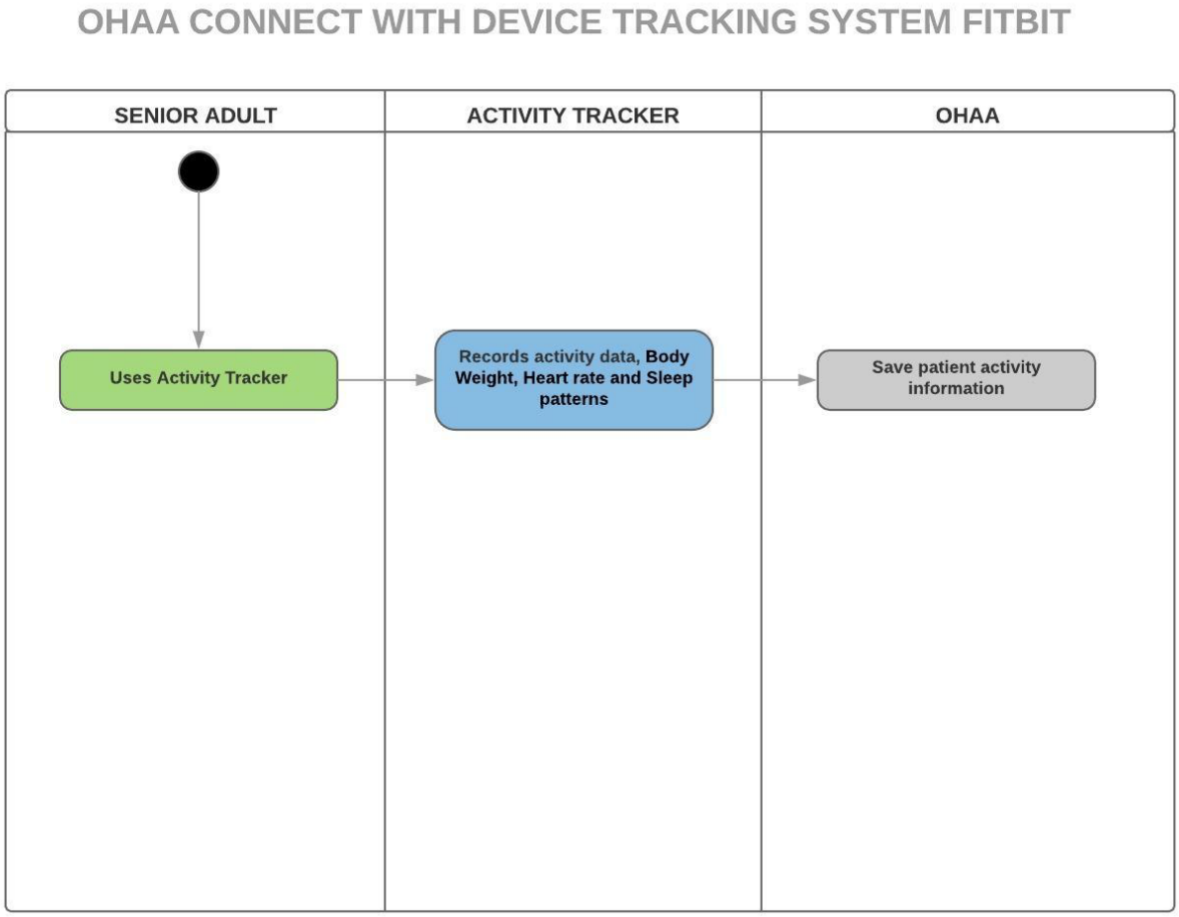


Figure D

DATA ARCHITECTURE

Data Management

Within the OHAA system, the Electronic Health record will serve as the system of record or reference for the enterprise master data. Key master data sets like patient demographic data within the EHR system will be referenced by the OHAA system for

linking activity tracking data with each patient's health records i.e - the longitudinal measures of patient health and the associated comorbidity. The data exchange between EHR and OHAA system will comply with the technical standards and specifications to meet the goals identified by the HITECH Act. Standardized healthcare vocabularies such as ICD 10, SNOMED, LOINC as well as HL7 data exchange standards on the FHIR platform will be adopted and implemented.

To ensure security of the PHII data using the HIPAA guidelines, the National Institute of Standards and Technology (NIST)-adopted encryption standards will be implemented. Interoperability between the OHAA system and the EHR will be implemented with the HL7 FHIR standards platform. The HTTP post transport strategy using RESTful services on the HL7 FHIR data exchange platform will ensure the security and reliability of the data transport between the EHR and OHAA system. This ensures that the TLS version 1.2 / Secure Socket Layer SSL version 3.0 protocols are applied[12].

Datasources

The EHR and the FitBit activity tracking data will serve as the data sources for the OHAA system. The data pull from the activity tracker into the OHAA system will be enabled through the use of Services through open and accessible application programming interfaces (APIs). Using the FitBit Web API, the activity data points will be pulled into the OHAA system. The token ID generated for each patient using the FitBit is stored along with the medical record number(MRN) of the patient in the patient data.

[12] https://www.hln.com/knowledge/interoperability-standards/

The data does not under any form of transformation because it will be returned as a JSON object.

The EHR system will push patient demographic data, patient medical history, and patient visit data into the OHAA datastore using the HL7 FHIR platform. This data will be a representation of each patient's current medical record as well as their medical history. The activity tracking data pulled from FitBit will be specifically focused on the following indicators

- Activity
- Body Weight
- Heart rate
- Sleep patterns

The data harmonization will enable linkage of EHR data and activity tracker data for each patient, thereby providing a robust view of a patient's current health condition with relation to the current state of loneliness.

Data Quality

Maintaining data quality is critical and necessary for primary care providers to ensure better decision making and to improve health outcomes among their elderly patients. A comprehensive data management strategy addresses accuracy, integrity, completeness, validity, and consistency of the data. Data cleansing will improve the data quality through strategies to reduce data duplication. Through the use of Master

data management and metadata management, reporting capabilities can be enhanced and improved to meet the business needs of the stakeholders. Some of the data cleansing tools that can be evaluated for this purpose are listed below

- Drake.
- OpenRefine.
- DataWrangler.
- DataCleaner.
- Winpure Data Cleaning Tool[13].

For reporting and visualization, the data within OHAA would be loaded on Amazon's fully managed datawarehouse, Amazon Redshift. The ETL (**E**xtract, **T**ransform and Load) process would be handled using Amazon's AWS Database Migration service.

Data Migration

There won't be any data migration of legacy data because this is a new system integrating with an existing EHR and device tracking system.

Data Governance

With respect to the data within the OHAA system, the availability and the usability of the data will be managed by a centralized data governance group. The members of this group will be identified and selected based on the input from each participating primary care physician offices. This will ensure equal opportunity for participation and

13 https://www.datasciencecentral.com/profiles/blogs/5-data-cleansing-tools

involvement of the various entities using the system. This group will stipulate strict guidelines and procedures tailored around data integrity as well as security at an enterprise level and will outline a plan for the execution of these procedures. The data governance council will ensure the presence of resources necessary for enabling data standardization, data transformations through ETL processes as well as master data management. AWS will be configured in a HIPAA compliant manner.

The data for the OHAA system will be stored on the cloud using the Amazon relational data store (RDS) services. AWS RDS includes automated backups, database snapshots and automatic host replacement which will ensure high availability. The administrative tasks like patching will be applied on a regular basis while routine nightly backups will be performed as part of the AWS RDS services. To ensure patient privacy and database isolation of the various datasets associated with each primary care provider, the database instances will run in Amazon Virtual Private Cloud (Amazon VPC). The data at rest and the data in motion will be encrypted as part of the AWS RDS services.

TECHNOLOGY ARCHITECTURE

The technology architecture is shown in Figure E.

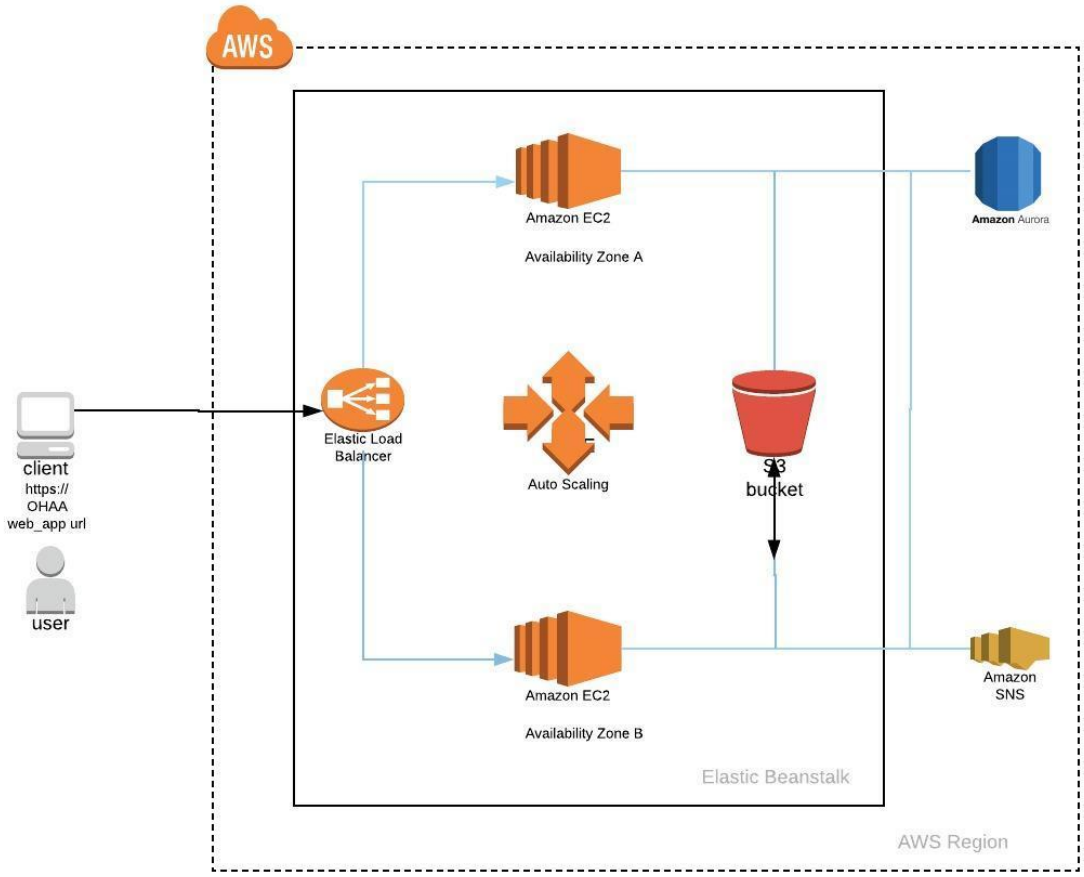


Figure E

(https://aws.amazon.com/getting-started/projects/deploy-nodejs-web-app/)

IT Infrastructure

The OHAA system will be a cloud solution provided through Amazon Web Services. Capabilities that would be provided would be captured through the following elements:

Application Server

Application server provides middleware services for security and maintenance, along with data access between the front-end browser and the back-end databases. Amazon EC2 will provide the application server services with its cloud integration through Amazon web services. The Amazon EC2 instances will be used as the platform for Enterprise web hosting. Using AWS EC2 instances will provide the high scalability, availability as well as elastic web scaling using the EC2 auto scaling feature.

Build Server

Jenkins build servers will be hosted on AWS EC2 using CI as shown in figure F. New versions of the OHAA system will be built and deployed using Jenkins. The continuous integration and build automation will build and deploy new versions of the application.

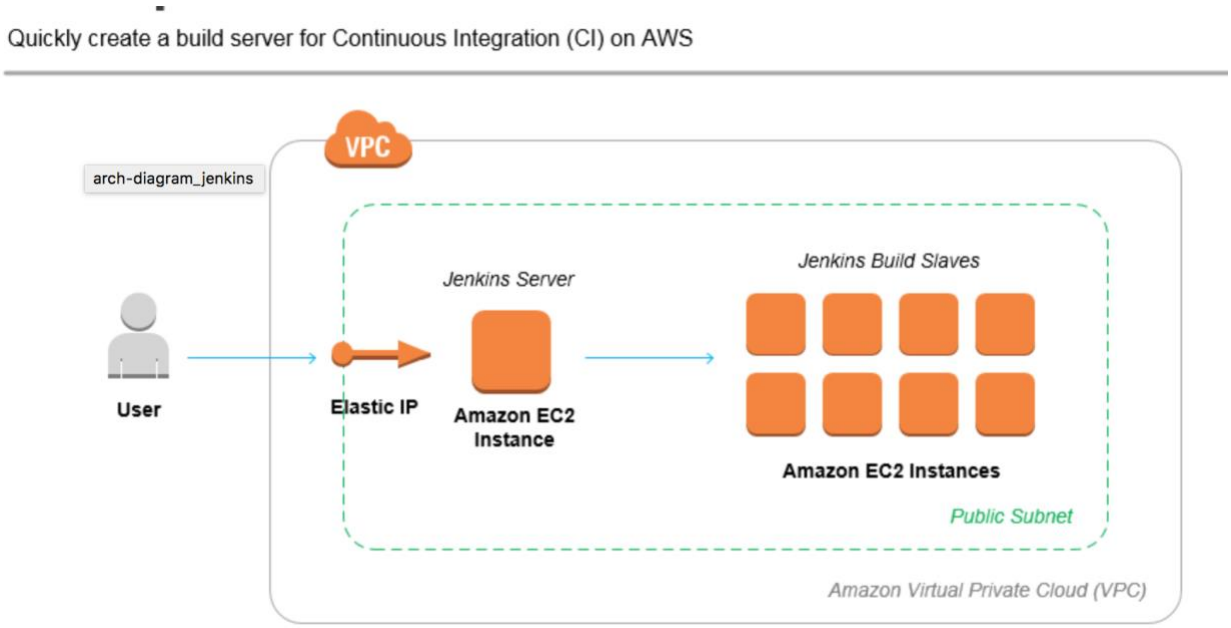


Figure F

https://aws.amazon.com/getting-started/projects/setup-jenkins-build-server/

Database Management System

The database management system would be used through Amazon Aurora. Amazon Aurora provides a data management system which enables developers to store data in blocks of variable size, identified by unique key values and uses MySQL coding. Data can be loaded at rates of billions of records per day. Hosting for the database would be maintained by a professional operations staff as part of the service through Amazon Web Services which will also provide backup and recovery, and routine software upgrades.

Data warehouse

As mentioned earlier, in order to report on the information captured within the OHAA system, a data warehouse or a reporting database would be required. Using Amazon Redshift would provide the ability to run complex analytic queries against structured data.

Server and Storage Space

Amazon S3 will be used for data storage. The S3, cloud service is designed to deliver highly variable compute and storage resources on demand. With the use of the cloud service, resources can be dynamically scaled up or down as required. The cloud service that Amazon provides would be used for service for backup and archiving, disaster recovery, storage tiering, and migration.

Data Visualization

Data visualization tools like Tableau, would provide an accurate picture of the various data points representing the health effects of loneliness on patient health. The data would be loaded on Amazon's fully managed data warehouse, Amazon Redshift. Visual analytics, interactive dashboards and insightful visualizations, would equip physicians and healthcare providers to predict health outcomes by comparing patient medical information and activity tracking data. The data visualizations would be embedded as a separate module within the application.

Security and Authentication

The authentication and authorization between the activity tracker, FitBit, and the OHAA system will be enabled using FitBit's OAuth 2.0. The OAuth 2.0 framework requires the OHAA application to obtain an Access Token when the Fitbit user authorizes your app to access their data. The Access Token is then used for making HTTP request to the Fitbit API.

Security Framework

The OHAA system will be hosted on the Amazon Virtual Private Cloud (VPC) through Amazon Web Services (AWS). This solution will provide the logically isolated sections for the various provider offices participating. This architecture will ensure physician's offices have autonomous control over their data and also supports the data sharing capability with minimal impact to the underlying infrastructure. This significantly reduces both capital and operational expense outlays. Amazon Web Services also maintains

compliance to HIPAA privacy and security standards through Federal Risk and Authorization Management Program (FedRAMP) and National Institute of Standards and Technology (NIST) 800-53, a higher security standard that maps to the HIPAA security rule. AWS enables covered entities and their business associates subject to HIPAA to securely process, store, and transmit PHI.

The elements that will be part of the security framework are:

Login

To gain access to the OHAA system, the user is identified/ authorized through a multi-factor authentication framework; using a combination of their unique Network Id/password and a secure token. Admin safeguards like filling an access form and getting it approved by the security officer is in place.

Access to the OHAA System

The OHAA system uses the HTTPS protocol to protect the information sent over the network and the Internet. The user connects using a url that is HTTPS secure to access the OHAA system via the internet. With IPSEC-V4/TLS being used the connection between the various points of communication between the systems in the network path is encrypted. VPN adds an additional layer of encryption by protecting all the information being exchanged.

Access Controls

File system access controls, implemented via security policies and/or a permissions table, will be in place to ensure that individuals within each state accessing the

resources like the file system, documents, images etc. on the servers can be authorized before gaining access. A log is maintained of all the activity of each user that accesses the network/servers. File access controls in place will ensure who gains access to network resources.

Internal Networks

The firewalls will provide a layer of security starting from the point of entry and throughout the different layers of the system. Based on providing a "Defense in Depth" strategy, the external network and the network perimeter will be monitored using auditing. Penetration testing, vulnerability analysis will be performed routinely to reduce the risk of an attack. There will be Network Routing Tables in place so that only certain IP addresses have the security rights to access the VPC servers.

Servers

The Business Associate Agreement (BAA), the Data use agreement and service level agreements (SLAs) with AWS will cover the requirements for the application servers, backup servers, web servers and the database servers to be routinely patched with the latest security patches. The data at rest will be encrypted.

Monitoring

Application as well as database monitoring is in place to make sure the activities of individuals accessing the data can be tracked based on the agreements with AWS. Intrusion detection systems will be used to monitor the various components of the IFD

· Host- based intrusion systems

· Application protocol based intrusion systems

· Network based intrusion detection systems

Within the physician's office, network analyzers /packet sniffers will intercept traffic on the network to check if the data was intended to be received or not. Port Scanners like NMap will be used for security testing.

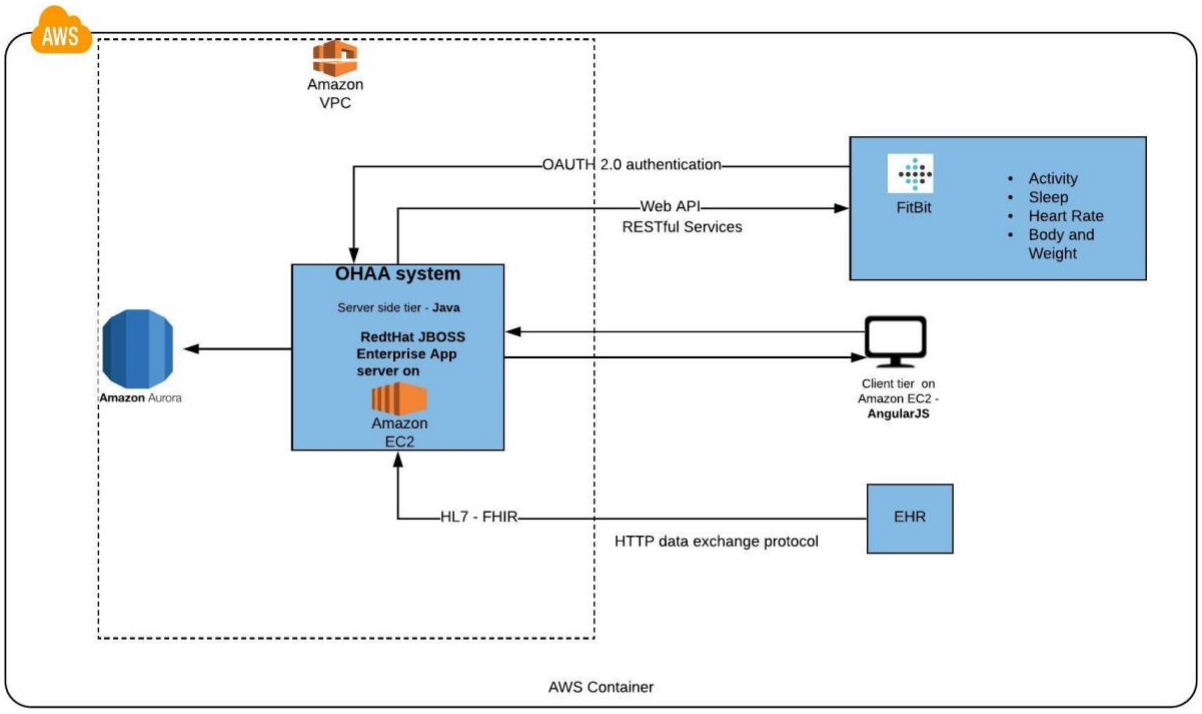
Logging

Audit logging (a standard feature supported by AWS) will be in place to track the data being accessed by the users of the system. The database and application will have audit logging. Auditing and Expiration of passwords will also be performed to make sure strong passwords are used.

APPLICATION ARCHITECTURE

The data exchange between the OHAA system and the activity trackers namely FitBit will be enabled using REST API also called RESTFul Web Services - Figure G. The RESTful API takes advantage of the HTTP protocols defined by the RFC 2616 protocol, using the GET to retrieve response data, PUT to update resource data and POST to create the resources [6]. The REST calls are stateless and that makes them most favorable for a cloud solution. The stateless features improve scalability based on the load as well as complexity free redeployment because requests can be processed by

any instance. Another favorable feature of the REST API for cloud solutions is the ease and simplicity of how the URL is decoded when the REST service binds to a service through the API.



OHAA Application Architecture

Figure G

OHAA and Activity tracker(FitBit)

The OHAA system will pull FitBit data using FitBit's Web API. The FitBit Web API uses the OAuth 2.0 authentication protocol. Using the OAuth 2.0 framework, the OHAA application receives an access token once the FitBit user authorizes the access to their

activity data. The Access Token is a unique identifier that is generated for each individual FitBit user. It is used for making HTTP request to the Fitbit API. **The access token will be stored in the OHAA as part of the patient identification information.** Using the FitBit Web API, data can be collected for specific categories as listed below[14]

- Activity
- Sleep
- Heart Rate
- Body and Weight

The data from the device trackers will be persisted in the OHAA database maintained on Amazon Aurora. The data stored will be secure with AWS Identity and Access Management (IAM). The Aurora DB instances will have a *DB cluster*. The DB cluster will consist of two DB instances, and a cluster volume to manage the data for the 2 DB instances[15]. ***"The cluster volume is a virtual database storage volume that spans multiple Availability Zones, with each Availability Zone having a copy of the DB cluster data"***[13]. The Aurora DB cluster will be made of two types of DB instances, as shown in Figure H:

- **Primary instance** – This instance will support the online transaction Processing (OLTP) to the cluster volume. A Primary instance is part of each Aurora DB cluster.
- **Aurora Replica** – This instance solely supports the read operations. The read workload is distributed between the replicas, located across various availability zones for increased availability.

14 https://dev.fitbit.com/build/reference/web-api/sleep/

15 https://docs.aws.amazon.com/AmazonRDS/latest/UserGuide/Aurora.CreateInstance.html

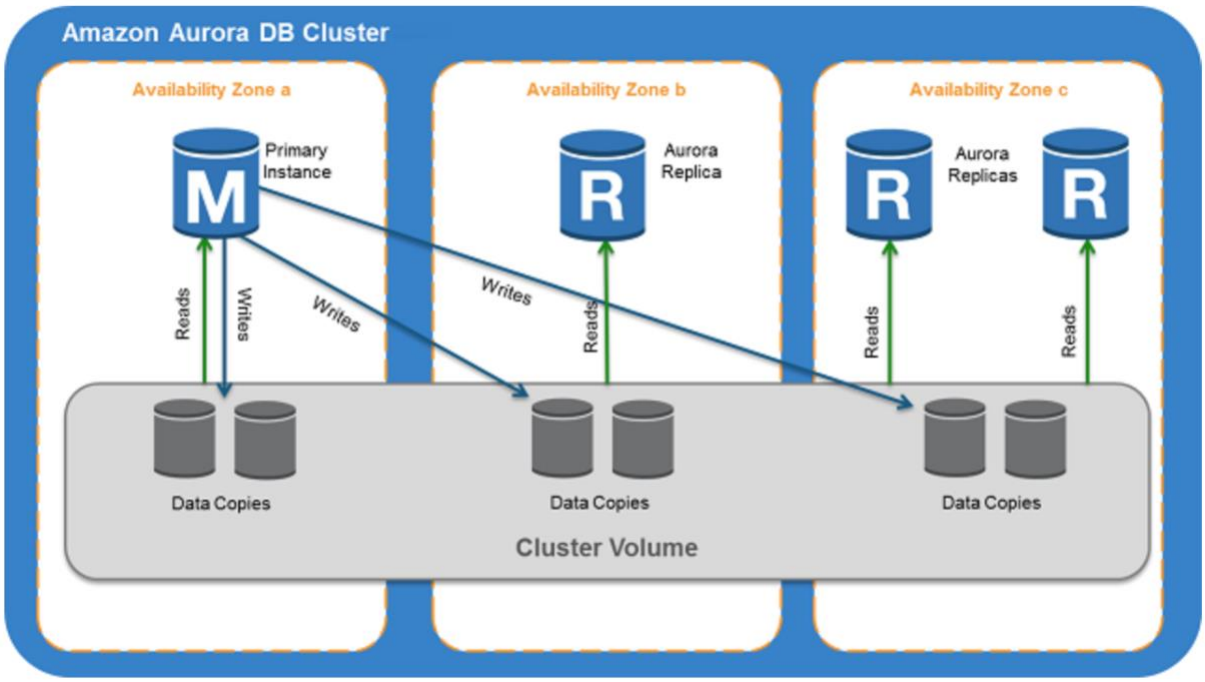


Figure H

(https://docs.aws.amazon.com/AmazonRDS/latest/UserGuide/Aurora.Overview.html)

OHAA Web Interface

The OHAA web interface will be built with open source, JavaScript framework - Angular.js. AngularJS uses the Model-View-Controller(MVC) architectural pattern. In the MVC pattern, the application is divided into 3 distinct layers the Model, the View and the controller as shown in Figure I. The Model component is responsible for handling the data, the View renders the data to the user and the controller handles the interaction and routing of the control within the application based on user input/interaction. The

view component of the AngularJS framework accesses the model component, the data is synchronized automatically between the view and the model by two-way data binding. Any changes to the model, is immediately mirrored in the view and vice versa. The AngularJS framework, interacts with the server side components using the REST API. The data is transformed to a JSON object before it is rendered to the HTML page in the view.

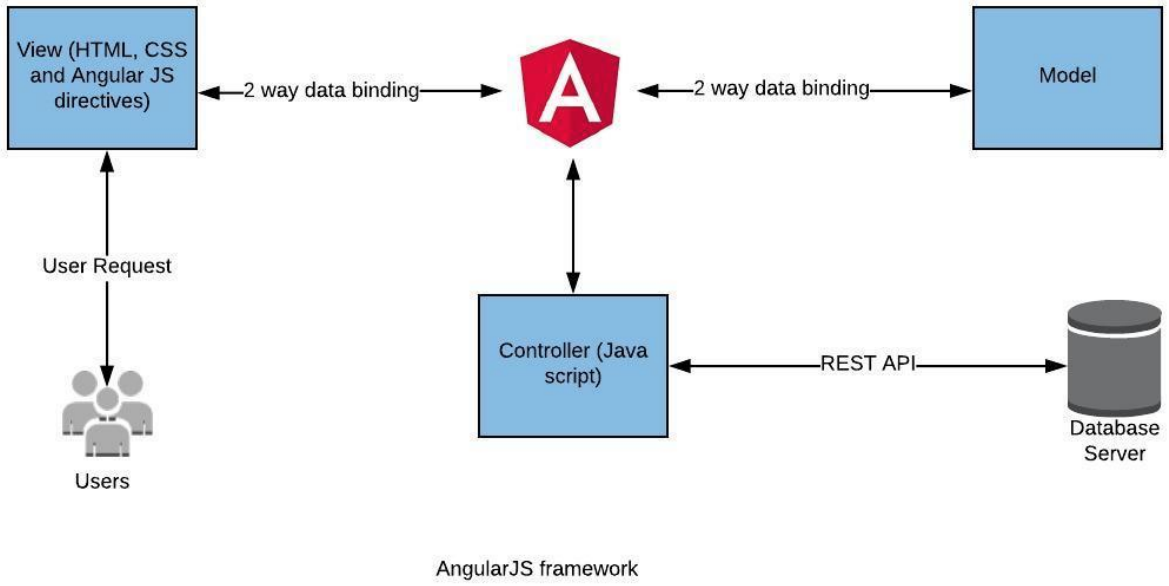


Figure I

The implementation of an informatics solution - OHAA system, will allow physicians to proactively identify the most appropriate care for their patients in the age group > 65 yrs. old experiencing chronic health conditions primarily induced by loneliness. It will assist primary care physicians with improving health outcomes and reducing the mortality rate associated with the elderly population. The strengths of implementing a system similar

to the OHAA is its ability to correlate medical history with activity tracking data and utilize it for predictive analysis.

Since the FitBit is one of the most widely used activity trackers, the OHAA system will have the ability to capture a larger percentage of the elderly population. Many patients may already own a FitBit device, making it easier for the integration of activity tracker data into the informatics solution being considered. The open platform provided by FitBit through the use of Application programming interfaces (API), would allow for easier integration with external systems. Data sharing would be improved with a direct impact on increased work efficiency. Interoperability between the OHAA and EHR, OHAA and the FitBit, would be seamless because of the use of standard data exchange platforms built on stable data exchange protocols like HL7 FHIR and Rest API respectively. Another, advantage to using a cloud solution would be the ability to control security at a granular level through the use of VPC (Virtual Private cloud).

The OHAA system is designed to mainly integrate with large EHR systems like Cerner and Epic, which would assist with covering a majority of the healthcare providers and physician practices using practice centric modules like Cerner's practice management solutions. The initial implementation with the FitBit would provide a solid foundation for designing the integration and data exchange modules within the OHAA system. The architecture recommendation for the OHAA system, would have several benefits - increased scalability, improved adaptability and enabled interoperability. The main advantage would be the physician driven nature of this informatics solution. There would be a higher compliance rate among physicians because of the possible

improvements in health outcomes and mortality rates among their patients. This would encourage and improve physician - patient relationships, leading to better communication and health care decisions. The welfare of the patient would be the main focal point especially among the elderly population.

In addressing the limitations of this solution, one of the main limitations would be the possibility that this thesis does not address the aging population who don't visit the doctor's office. This could have a possible effect on this informatics solution's primary goal to improve health outcomes among this population identified as lonely. Because of the behavioral implications of loneliness, social interactions among this age group could be minimal, thereby impacting the positive effects of early intervention by physicians to improve health outcomes. The affordability factor associated with the FitBit, would play a critical role in adoption of technology among the elderly. Even though, the FitBit itself may not be expensive, it's reliability on the smartphone could be a deterrent among the senior population. In addition, reluctance from the elderly community to adopt technology through the use of the activity trackers could be a constraining factor. Another limitation with the OHAA system, is its integration is mainly focused on larger or most commonly adopted EHR systems. This could exclude its adoption by smaller physician practices using other lesser known EHR systems.

This thesis has not addressed the cost model for this implementation. With AWS as the cloud provider, the cost would need to be strictly contained to ensure physician offices are not burdened with additional costs. The cost for compute and storage on the AWS platform could vary based on the usage and this would need to be monitored. The cost

would be high for using a dashboarding tool like Tableau which is the industry leader for visualization. With the scope of this thesis mainly focused on the integration with the activity tracker, primarily the FitBit, integrating with other activity trackers in the market would require more time and research.

Initially, the data visualization would be made available mainly to the primary care provider who would share their observations with the patient during the patient visit. This feature could later be implemented through a patient portal to provide the patients with a status of their health progress, and improvements in their health outcomes. Additional features, like adding a health coach as a service would enhance the patient's ability to get guidance/planning around nutritional meal plans or exercise regimens etc. The accuracy of the data collected by the activity trackers could be an issue. Several factors like, inconsistent usage of the activity trackers by the patients (not wearing on them all the time) or faulty device or software issues/glitches could contribute to data inaccuracies. Some research has shown that activity trackers like the FitBit, record reliable data for heart rate but the data collected on metrics around calories burnt are faulty. The inaccurate information would have a direct impact on the physician's diagnosis as well as lead to the creation of flawed predictive models.

Currently, this project is in the initial stages of a conceptual design. The next steps would be to begin vetting this concept with stakeholders like the CDC, large EHR organizations like Cerner, and Primary Care Providers. This would be followed by funding discussions and approvals from the major stakeholders like the CDC and large EHR organizations. It would be beneficial to develop a proof of concept (POC) with a

small population to evaluate the data points to be collected, conduct an analysis on that data and dashboard for proof of relevance and efficacy/outcome.

In its future state, the OHAA system could integrate with the CDC's Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is a national surveillance system, collecting state data related to chronic health conditions and health related risk behaviors through telephonic surveys[16]. Integration with BRFSS would provide public health with a snapshot of the health of the elderly populations as the adult interviews are conducted by the BRFSS continuously and annually - the BRFSS completes approximately 400,000 adult interviews. This partnership with the CDC would also help offset some of the costs associated with implementing the OHAA system. As per the CDC, *"**By collecting behavioral health risk data at the state and local level, BRFSS has become a powerful tool for targeting and building health promotion activities. As a result, BRFSS users have increasingly demanded more data and asked for more questions on the survey. Currently, there is a wide sponsorship of the BRFSS survey, including most divisions in the CDC National Center for Chronic Disease Prevention and Health Promotion; other CDC centers; and federal agencies, such as the Health Resources and Services Administration, Administration on Aging, Department of Veterans Affairs, and Substance Abuse and Mental Health Services Administration[14]."***

A cost model providing cheaper options for dashboarding leveraging tools like Sisense, Tibco Spotfire, Viur or opensource tools like Freeboard, Dashbuilder could be offered.

The OHAA system would need to have a robust and scalable open API, so that other

16 Behavioral Risk Factor Surveillance system https://www.cdc.gov/brfss/index.html

APIs can seamlessly integrate with the system and share data. A central data governance group would need to define stringent rules and policies around obtaining and verifying patient consent, to share their data across various devices.

Once funding is approved, requirements gathering and adoption of a SDLC process would be recommended. The stages, as listed below in the Software Development Life Cycle(SDLC) would move this thesis project from concept to completion -

- Planning
- Defining
- Designing
- Building
- Testing
- Deployment

Team members of the project team would need to be identified. The project team members would mainly be comprised of a lead developer, business analyst, data scientist, subject matter experts like primary care providers, patient advocates and the CDC.

The main key stakeholders would be Primary care physicians and Geriatric specialty health providers, the CDC, large EHRs, AARP, other advocacy groups such as senior care facilities.

EXECUTIVE SUMMARY

PROBLEM

Studies have shown that in the United States, roughly 33% of people older than 65 live alone, and that percentage increases to 50% among those older than 85. The effect of loneliness on the elderly population is becoming a public health crisis. Studies with controlled confounding factors such as demographics and objective isolation have shown that loneliness increases the odds of an early death by 26% as well as increases the early onset of cardiovascular diseases, cancer, accidents, suicide and diabetes among the elderly population.

BACKGROUND

Loneliness can be defined as a subjective negative feeling associated with a perceived lack of a wider social network (social loneliness) or the absence of a specific desired companion (emotional loneliness). This population is faced with numerous physical, psychological and social role changes that challenge their sense of self and capacity to live happily. Many people experience loneliness and depression in old age, either as a result of living alone or due to lack of close family ties and reduced connections with their culture of origin (1). By integrating clinical data as well as device tracking data among the elderly, the OHAA system would provide primary care physicians with a comprehensive understanding of patient health, enabling them to mitigate the onset of loneliness and improve health outcomes.

PURPOSE

This thesis aims to design and architect an Informatics solution titled Online Healthy Aging Assistance (OHAA) tracking system, a cloud-based solution that will integrate with Electronic Health Records (EHR) systems and activity tracking apps (like the FitBit or iOS Health app) to improve health outcomes for elderly patients who are predisposed to loneliness-induced health issues. I am hypothesizing that using a web-based tracking system will assist health professionals to proactively track social isolation and minimize efforts when trying to extract relevant data about the patient's current mental state, which can then drive reporting, analysis and decision support to address adverse health outcomes among seniors.

Specific Aims

- Aim 1: Identify and describe the need for an informatics solution to improve person-centric health outcomes for patients over 65 who are predisposed to loneliness-induced health issues.

- Aim 2: Describe the impact and benefits of an informatics solution for primary care providers to improve health outcomes for patients over 65 through early intervention and detection.
- Aim 3: Develop a process flow to demonstrate the workflow and data exchange between the OHAA system, EHR system and activity tracking apps.
- Aim 4: Based on the requirements gathered from the stakeholders, design a blueprint of the informatics solution with artifacts like the Business Architecture, Information Architecture and the Technical architecture to demonstrate the interoperability between the OHAA system, the EHR system and activity tracking apps (like FitBit or the iOS Health app).

APPROACH

An initial literature review to understand the importance of the current effects of loneliness among the elderly population will be essential to this thesis. The literature review will help understand past studies on loneliness in the world of informatics. The next step would be to conduct interviews with potential stakeholders such as primary care providers, Gerontology health professionals, social workers at Wesley Woods and other mental health providers.

The following will be assessed in the interviews:

- The idea of an OHAA system that is integrated with a provider's EHR and activity tracking apps.
- Indicators used to identify loneliness.

Additionally, interviews will be conducted with a solutions architect to understand the architectural building blocks of an interoperable informatics system.

Qualitative analysis and EHR

Patient health information like medications, treatment plans, and laboratory tests are typically captured in an EHR system. Additionally, during a health visit, each patient will be administered a short questionnaire by their primary care provider to determine their current mental state.

This questionnaire will comprise of 3-5 qualitative questions to assist the physician with gathering details on the living situation, patient mental health (alertness) as well as the number, type, and duration of social interactions.

Based on responses, the physician can determine if the patient is experiencing loneliness. This determination will be stored in the patient's medical records and synced with the OHAA system using standard data exchange platform like web services.

OHAA system and activity tracking

Based on the determination/degree of loneliness identified by the primary care provider, patients would also be supplied with and encouraged to use activity trackers (like a Fitbit or the iOS Health app). The data points from the activity tracker, namely heart rate, distance traveled, stress levels, breathing rate, and sleep patterns will also be integrated with the OHAA using standard data exchange APIs like the Rest API.

OHAA system

The OHAA system will present a comprehensive view of an individual's social isolation, its effect on personal well-being, and help physicians make informed treatment decisions on the effects of loneliness to chronic illnesses like heart disease, hypertension, cancer, mental status and diabetes.

Based on the requirements gathered from the stakeholder engagements, the Business Architecture, Technical Architecture and Information Architecture would define the OHAA system. This solution would provide reporting tools necessary for physicians to make better decisions about a patient's care through the use of predictive analysis. The novel idea for physicians to be able to detect and track the effects of social isolation among patients, determined by their medical records as well as their lifestyle activities, can potentially improve the health outcomes among the aging population.