SeizSmart

A mobile application for detecting, tracking, and reporting seizures in real-time.

Prototype Design Presentation

CS 410 Spring 2019

Team Silver

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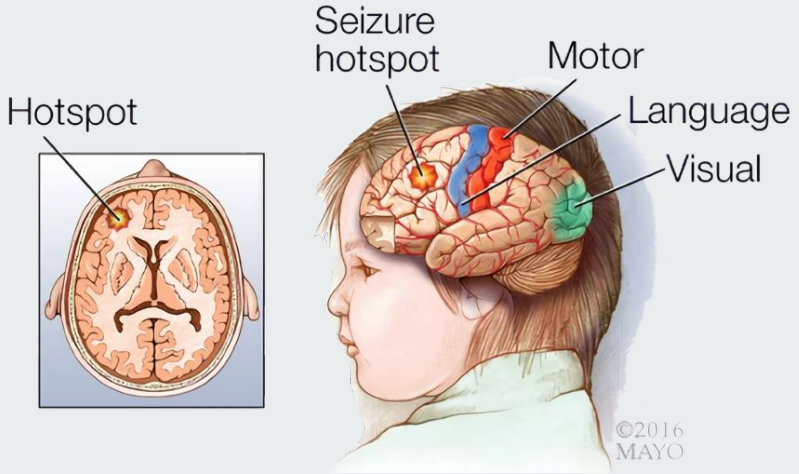

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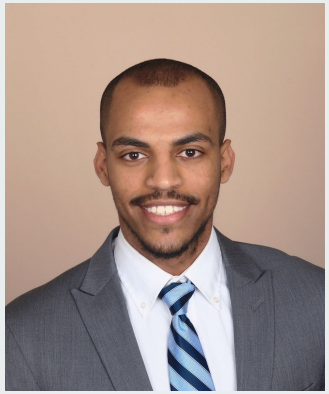
The Team



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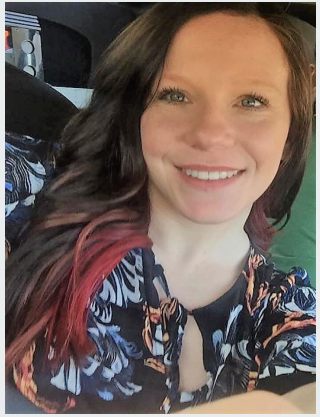
UI/UX Developer - Smartphone

Peter Scheible
UI/UX Developer - Smartwatch



Danielle Luckraft
Webmaster / Developer

Jeffrey McAteer
Infrastructure & ML Engineer

Alpha Din Gabisi
Database Engineer

Mentors

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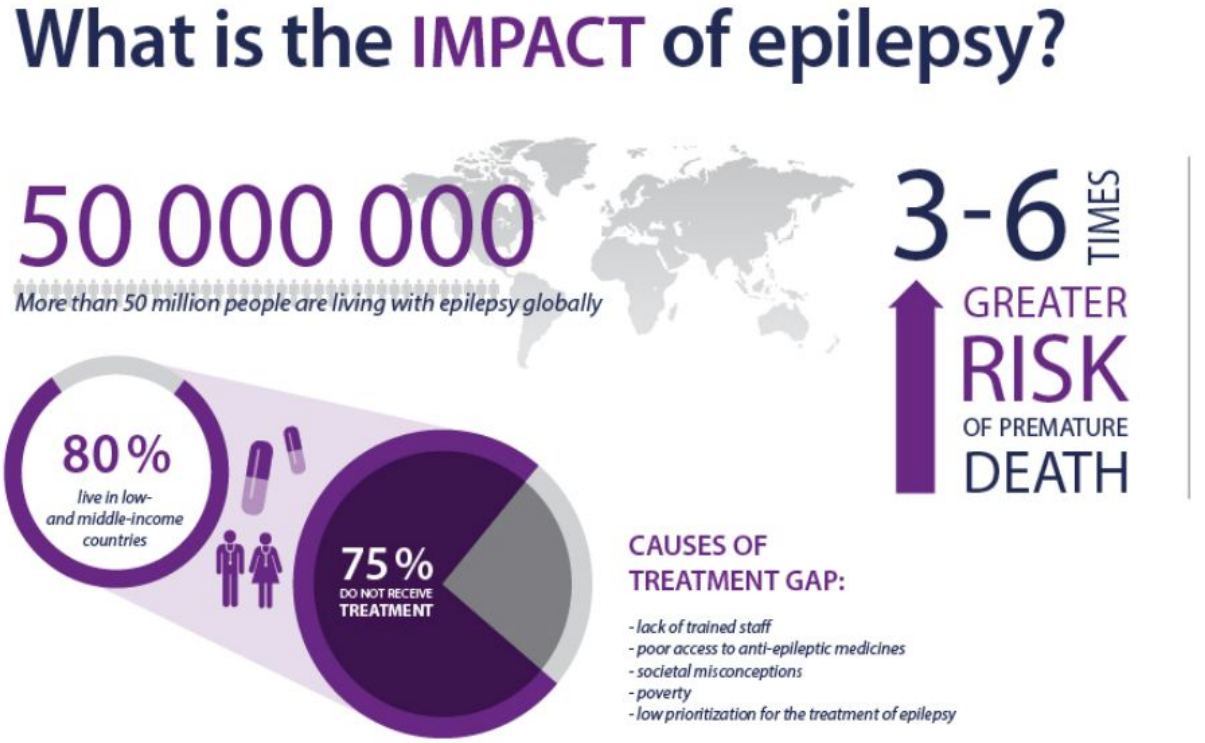
Jesse Gordon

Terminology

- Patient
  - An individual who experiences generalized seizures. May also be referred to as the end user.
- Emergency Contact
  - Anyone who cares for a patient; Usually family members.
- Seizure Profile
  - Personalized for each patient, describes information regarding the individual's typical seizure, such as physical indicators, or their typical threshold for specific biometrics during a seizure. The seizure profile is used to provide more accurate seizure detection.

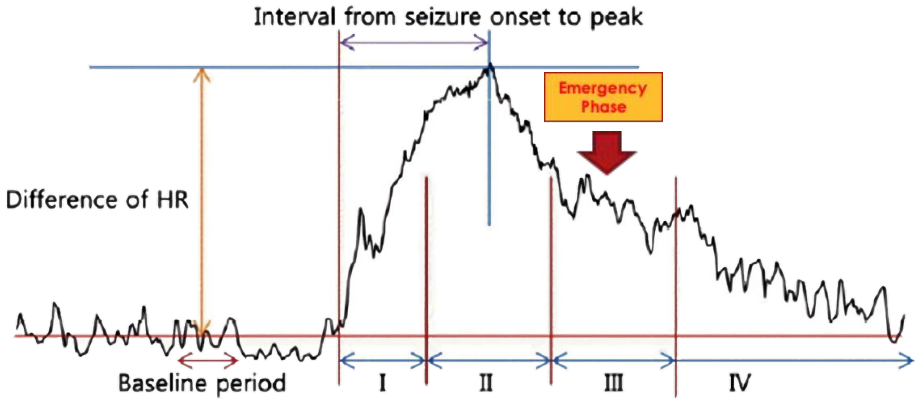
Background - Epilepsy

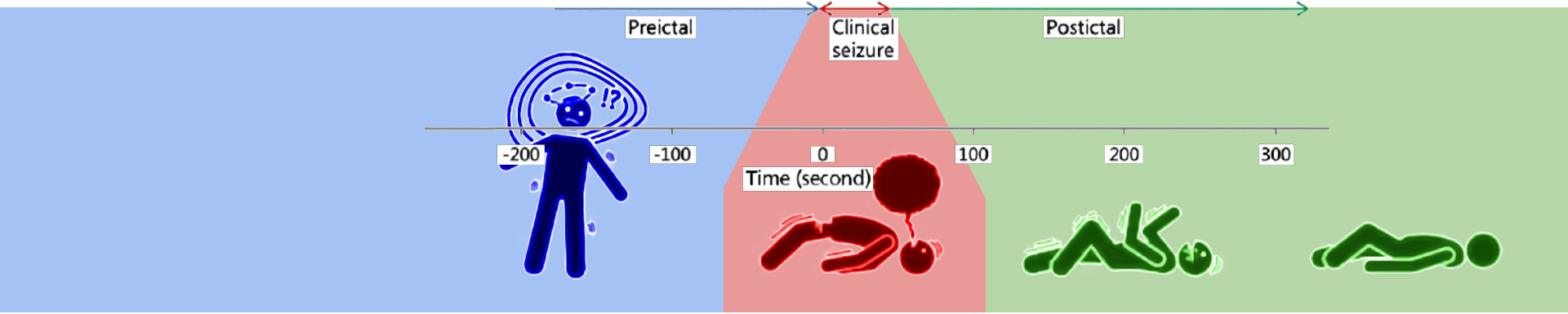
- Epilepsy is the 4th most common neurological disease in the world.
- Cases of epilepsy in the US have increased over the past five years.
- Cases in the US are predicted to increase further by 2020.



Characteristics of Generalized Seizures

- Rapid change in heart rate
- Rapid convulsions in limbs and face
- Loss of consciousness



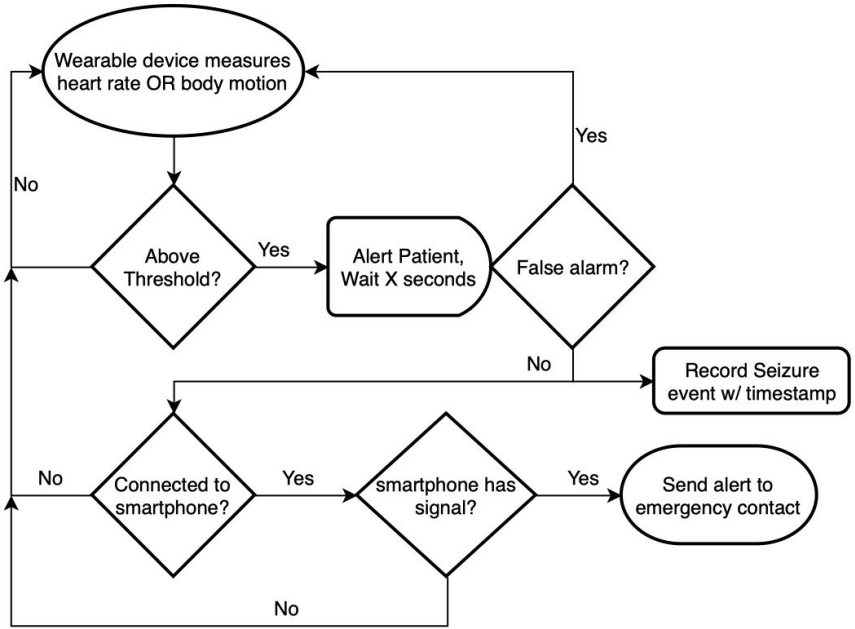


Problem Statement

- Epileptic seizures are difficult to detect in a timely and accurate fashion and undetected seizures can result in injury or even death.
- Current smartwatch detection technology does not provide the ability to automatically detect the onset of a seizure **based on a combination of heart rate behavior and repetitive body movements**.
- Available devices do not provide capabilities that **tune detection variables to match individual patient seizure characteristics**.
- Existing solutions to detect seizures use smartwatch technology which must be in the **proximity of a smartphone in order to notify emergency contacts**.

Current Process Flow

- Most existing solutions detect seizures based on body motion.
- Some detect seizures based on users heart rate.
- The process flow for both are identical.
- No existing system detects based on a combination of both metrics.



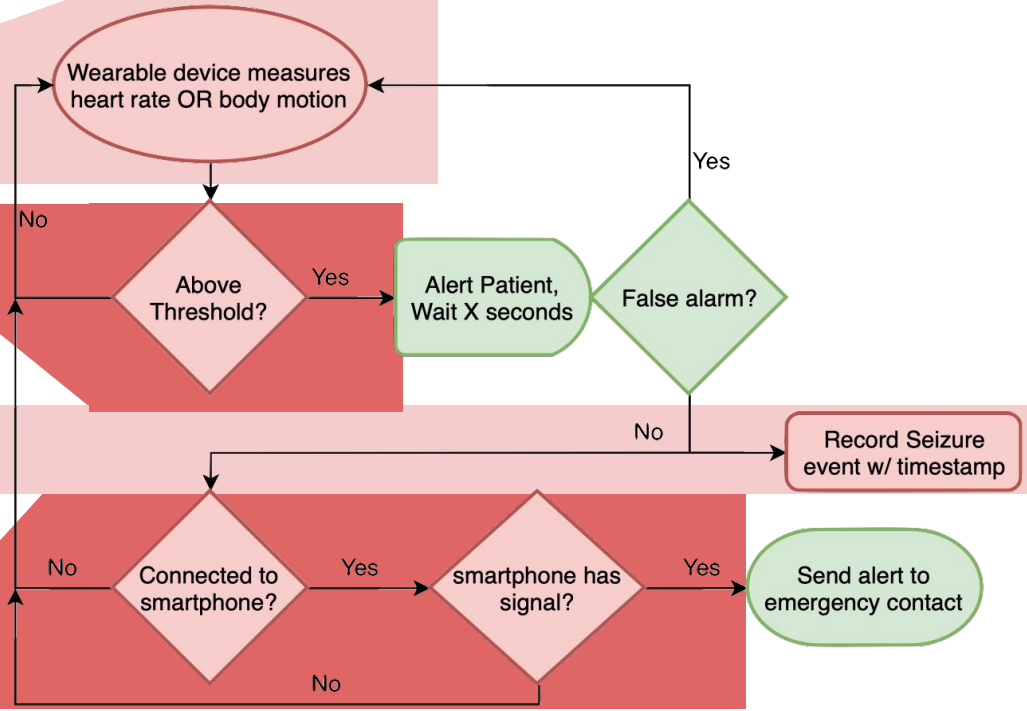
Current Process Flow

Wearables may access more data than HR/Motion.

Not all patients respond to seizures in the same way.

Current processes only begins recording seizure data after detection time.

Simpler notification capability is needed.



Solution Statement

Our proposed solution, SeizSmart, implements an advanced, wearable seizure detection capability using off-the-shelf smartwatch technology that is able to:

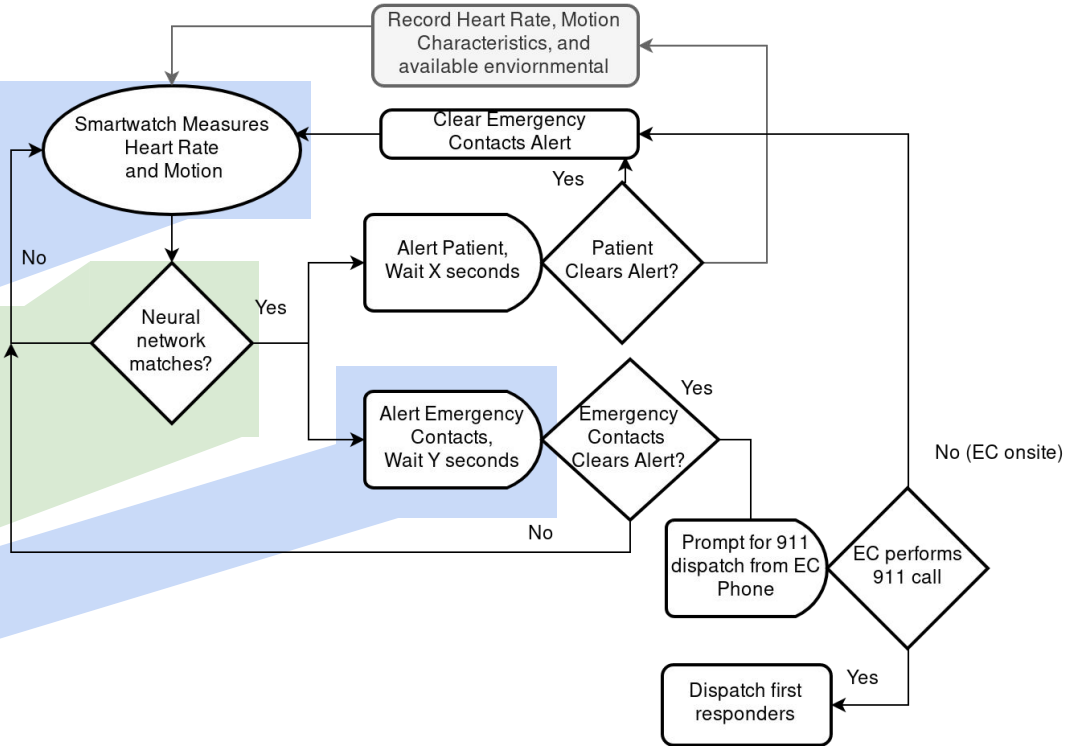
- automatically detect epileptic seizures from combined heart rate **and** motion metrics,
- detect seizures using an algorithm which matches individual patient seizure characteristics,
- track and record all information surrounding seizure events,
- and provide automatic notification to emergency contacts without requiring a relay.

Solution Process Flow

Detection is based on a combination of heart rate and body motion metrics.

Detection performance is enhanced using a patient-unique machine learning approach.

Emergency notification is issued directly from the user's smartwatch.



Target Consumers and End Users

Customers

- Medical providers
- Concerned party of individual with generalized seizures

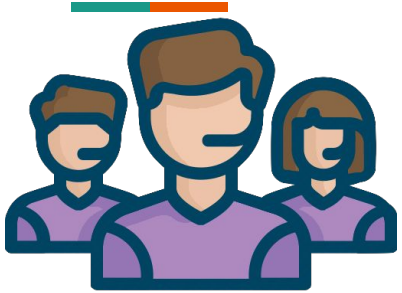
End-Users

- Individuals who have the most common types of generalized seizures:
  1. Clonic
  2. Tonic
  3. Tonic-Clonic
  4. Atonic
  5. Myoclonic

Benefits to Customer/User-base

- Detection Performance and Hardware Flexibility
  - Each user's individual seizure profile provides more accurate and customized seizure detection.
  - The user may configure emergency response notifications as desired.
  - SeizSmart is compatible with both Android and iOS smartwatch technology without the need for specialized hardware.
  - SeizSmart will be available without a subscription and a prescription will not be required.
- Peace of Mind
  - A smartphone does not need to be in close proximity to the smartwatch for detection and notification of emergency contacts.
  - SeizSmart is capable of notifying emergency personnel in extreme situations.

Prototype User Roles



Emergency Contact

- Concerned party
- Friend/Family of Patient

Patient

- Individual with generalized seizures

Tester

- The individual responsible for simulating a seizure testing the functionality and usability of the prototype

Competition Matrix

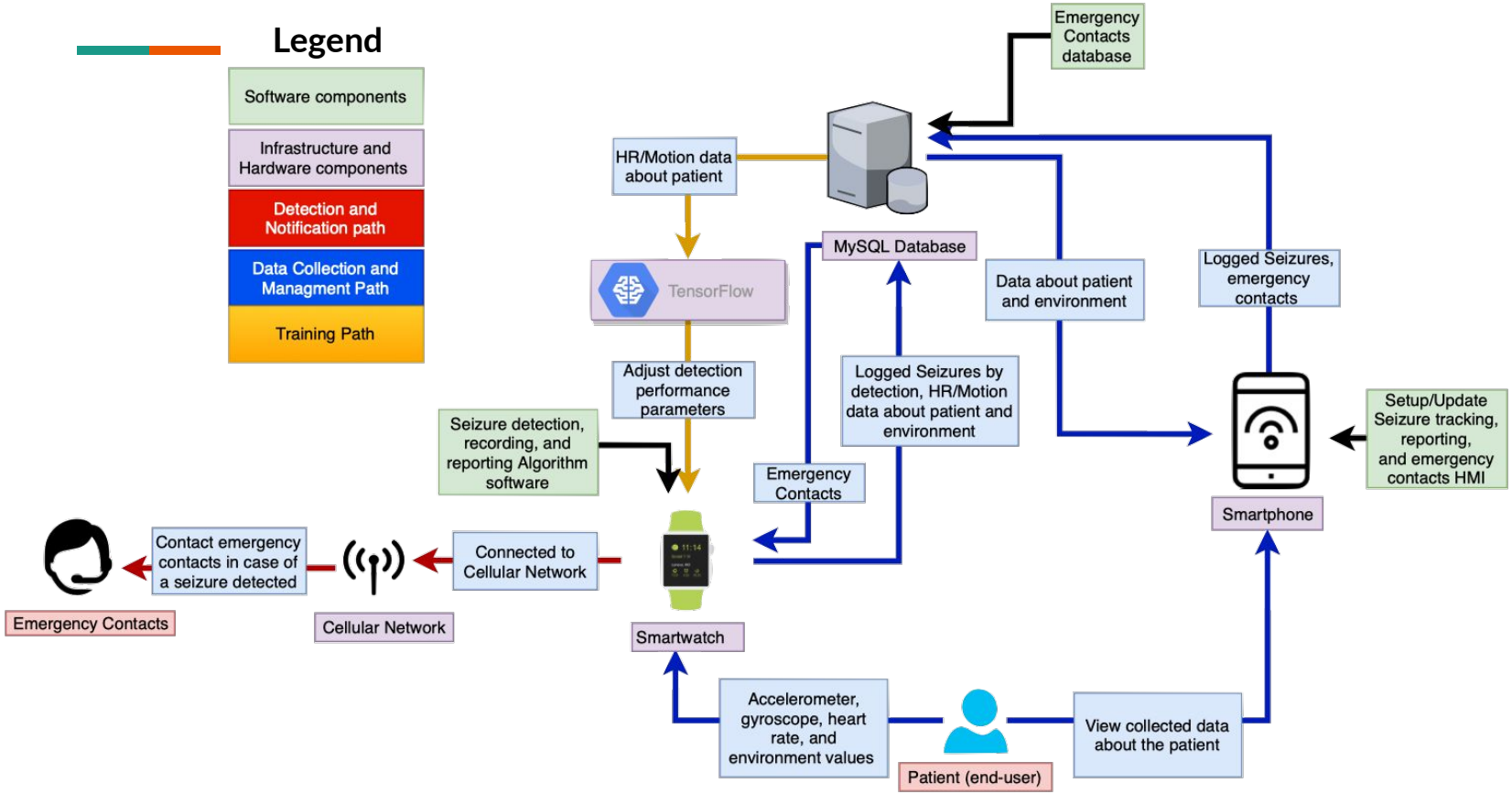
	SeizSmart	Direct			Indirect	
		SmartMonitor	empatica embrace 2	SeizAlarm	Epilepsy Journal	Epilepsy Health Storylines
Detect, record and track generalized seizures in real time	✓	✓	✓	✗	✗	✗
Monitor repetitive shaking motion	✓	✓	✓	✓	✗	✗
Continuously monitor the user's heart rate	✓	✗	✗	Only checks for elevated heart rate	✗	✗
Alert emergency contact when the user does not respond	✓	✓	✓	✓	✗	✗
Report data about the environment at the onset of a seizure being detected	✓	✗	✗	✗	✗	✗
Function fully without dependence on a smartphone or external device	✓	✗	✗	✗	✗	✗
Use machine learning to detect generalized seizures	✓	✗	✓*	✗	✗	✗
Require a subscription or prescription	✗	✓	✓	✗	✗	✗

Solution Deliverables

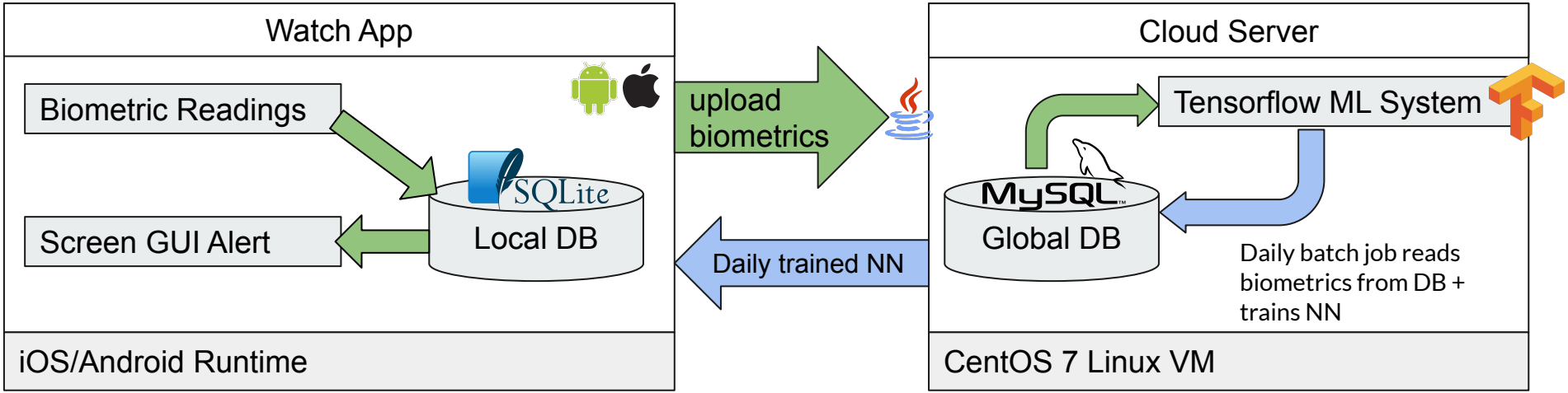
Android

- **Deliverables**:
  - Android watch app for detecting, Android smartphone app for reporting, recording, and adjusting detection threshold values
- **Server:**
  - HTTP REST API
- **Distribution**:
  - Google Play App Store

Prototype Major Functional Component Diagram



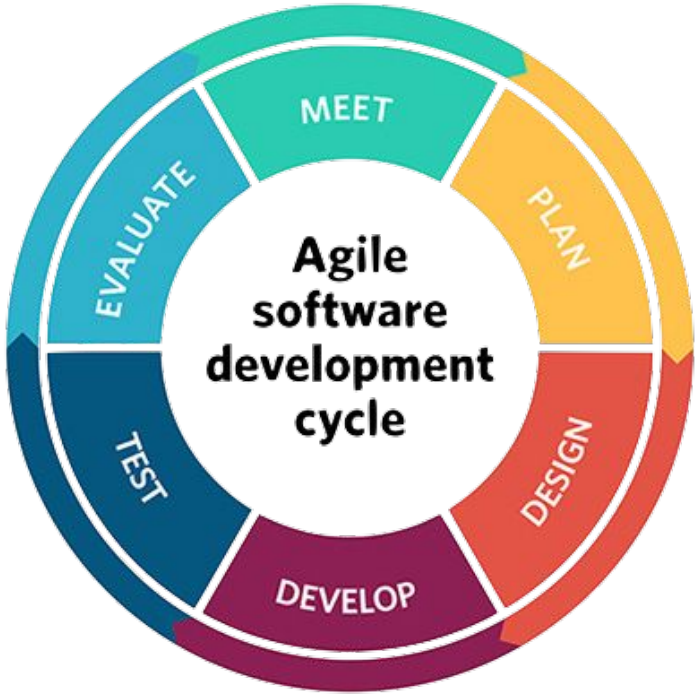
Hardware and Software Components



	Android Smartwatch	**Android Phone**
Min Version	Wear OS 2.6	Android 4.3
Hardware Requirements	Wifi, Cellular, Accelerometer, Gyroscope, optical heart-rate sensor	Wifi, Cellular

Agile Development Model

- Small, diverse team
- Goal is moving target
- Correctness is critical
- Time is limited



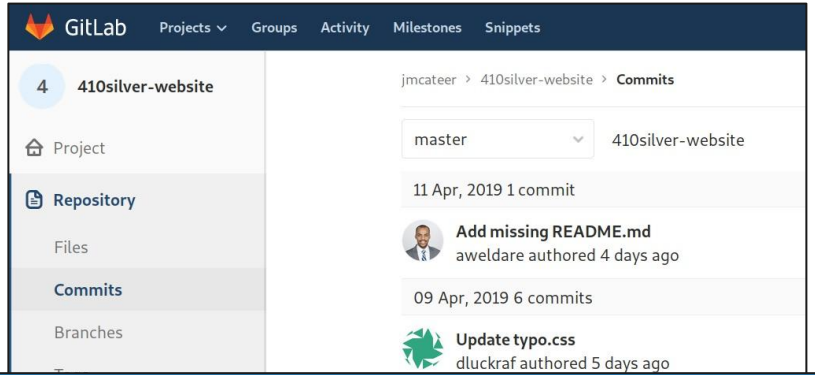
Agile plays to our team's strengths and gives the project a high probability of success

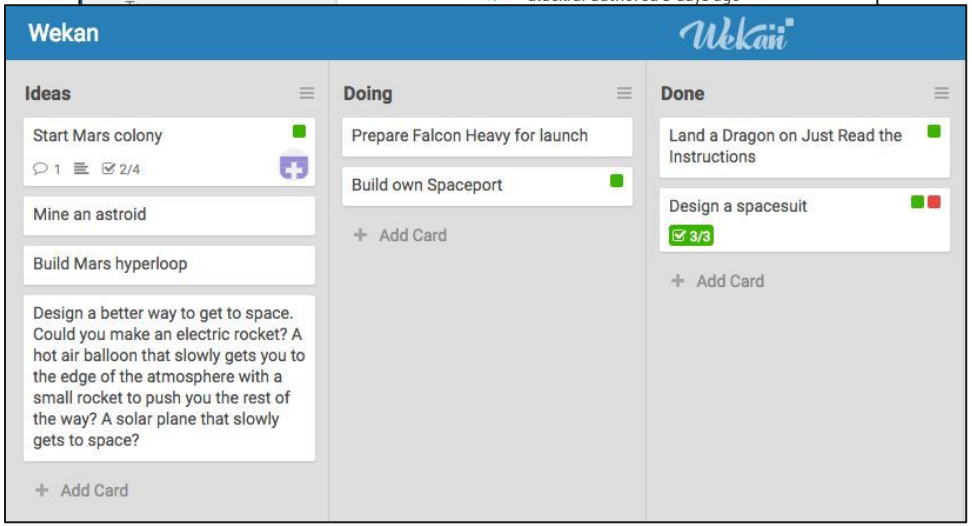
Coordination Tools

- CS gitlab
  - Shared codebase
  - **Issue tracking**
  - Already in use!

- Wekan kanban instance
  - Run off 411 VM
  - Use cards to **track work in parallel**

- Weekly Sprint Meetings
  - Google Hangouts

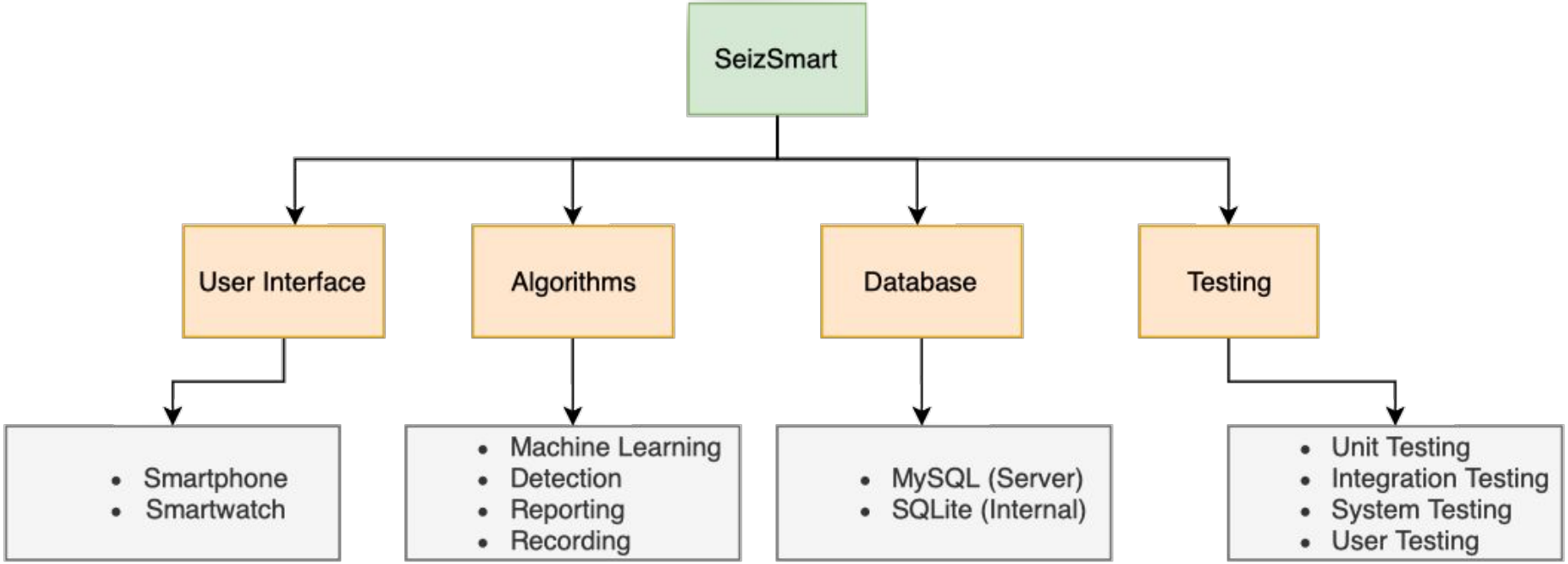




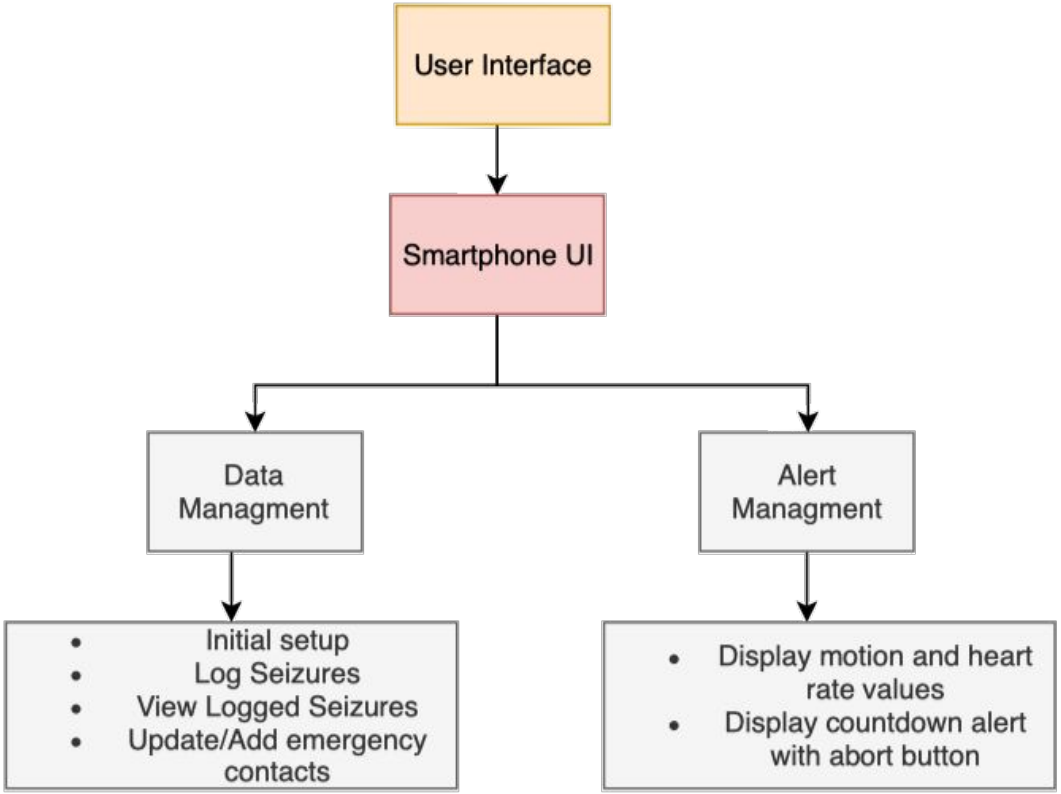
Development Tools

	Android	Server
Language	Java	Java
IDE	Android Studios	Vim
UI/UX	Android Studios	HTML5/CSS/JS
Database	SQLite	MySQL
Build Manager	Gradle	Gradle
Version Control	Git	Git
Issue Tracker	Gitlab	Gitlab
Testing Framework	JUnit	JUnit

Work Breakdown Structure (WBS) Overview

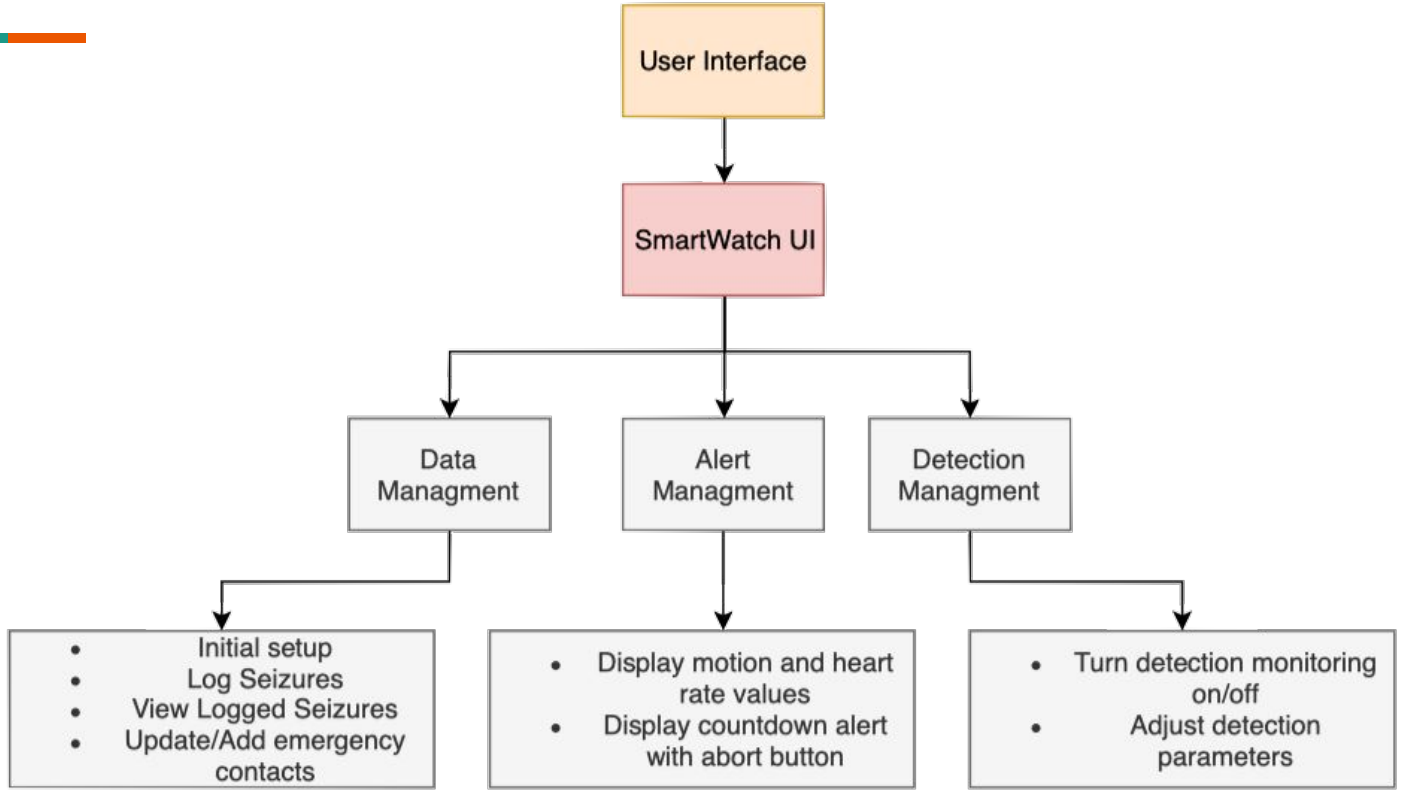


WBS - User Interface Smartphone



SmartPhone GUI Mockup - Patient/Emergency Contact

WBS - User Interface Smartwatch

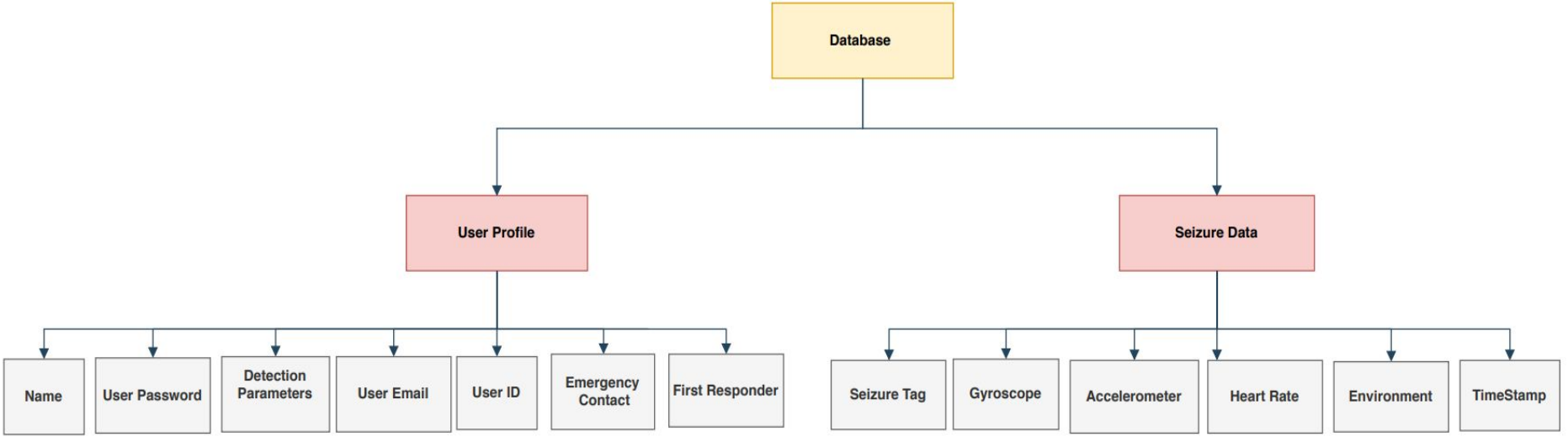


Smartwatch gui mockup

Database: External Storage MySQL

- MySQL is an open-source relational database management system.
- Stores all data from the watch to be used by machine learning algorithm.
- Data is easily exportable to csv or other formats for research teams.

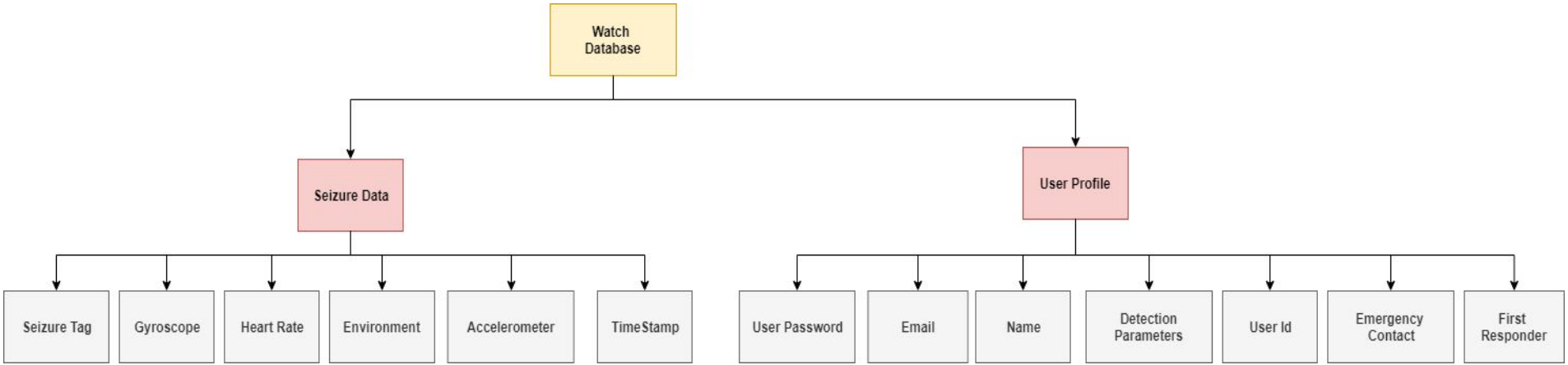
WBS - Server Database (External Storage)



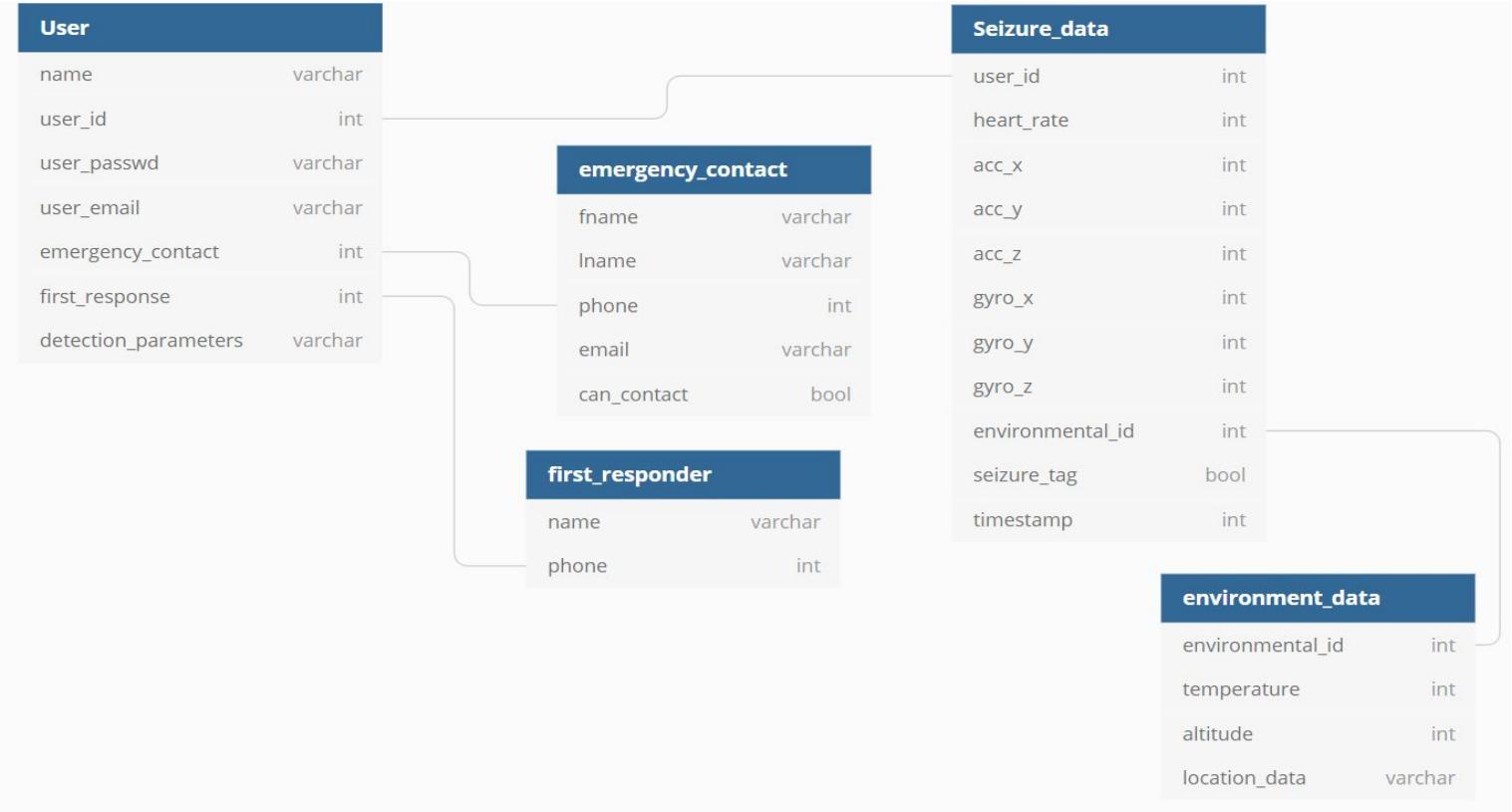
Database: Local Storage SQLite (Smart Watch)

- Used for local storage on the smartwatch.
- Will hold data before being sent to the main database on the server

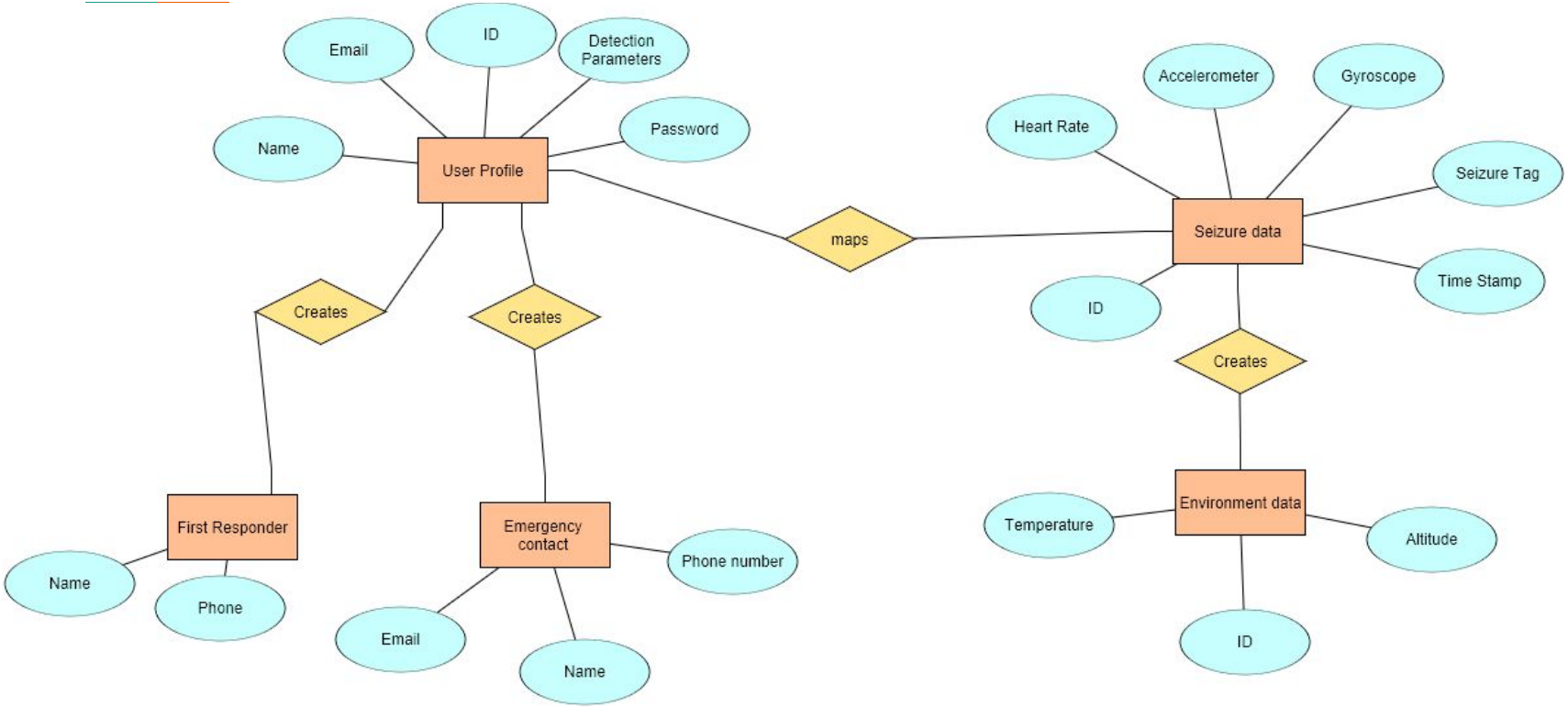
WBS - Smartwatch Database



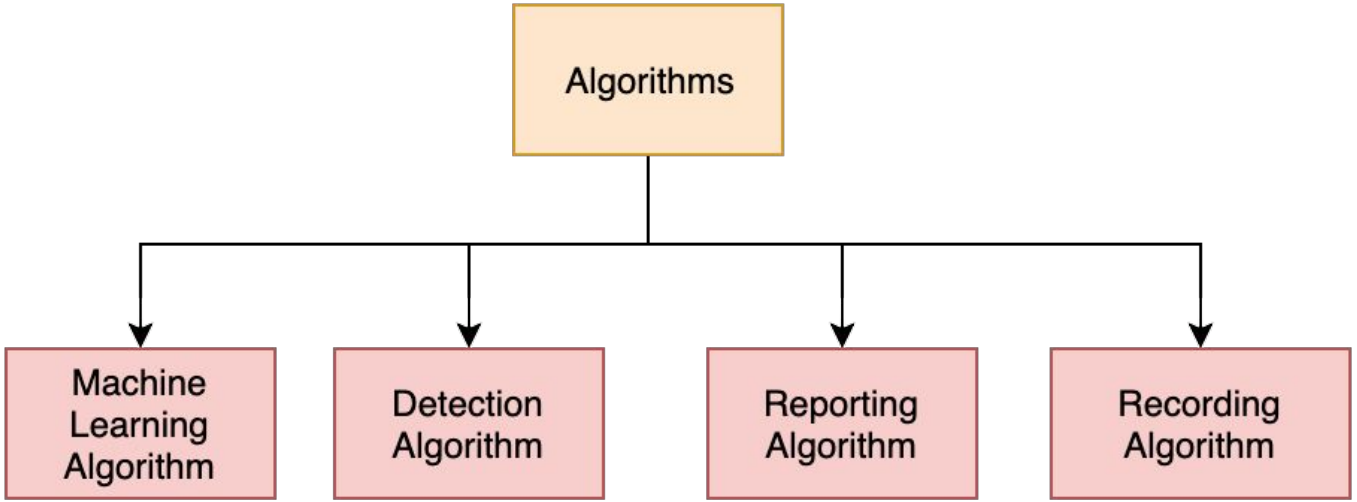
Database Schema



Entity Relationship Diagram (ERD)



WBS - Algorithms

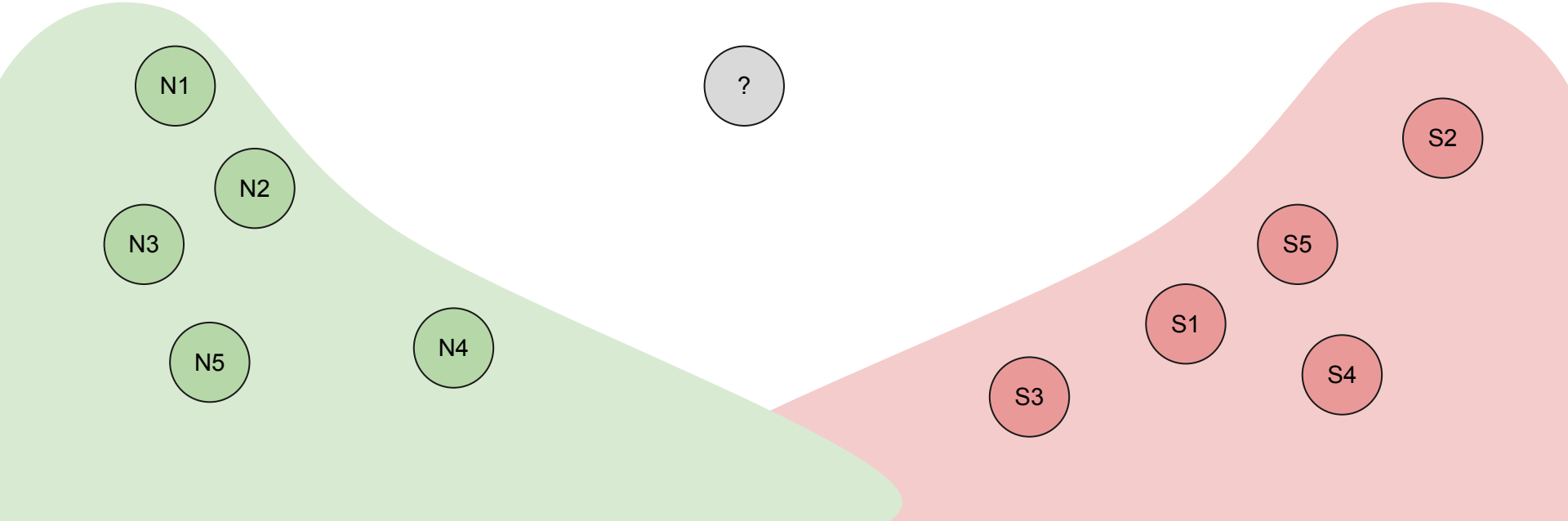


Machine Learning Algorithm

- **Purpose**
  - Build a unique seizure profile for each individual patient
- **Tools**
  - TensorFlow
- **Parameters**
  - Motion data collected about patient
    - Accelerometer values
    - Gyroscope values
  - Patient's heart rate
  - Seizure tag

Machine Learning Algorithm: Objective

Answers the question: given two sets containing N-dimensional element and a new N-dimensional element, which set does the new element belong to?



Machine Learning Algorithm: Preprocessing

Each training session will use:

Min, Average, and Max X,Y,Z acceleration over last 5 mins, 1 min, and 10 sec

- Must remove gravity; sdk has helper functions
- Then clamp value in m/s^2 between -1 and 1, add 1 and divide by 2 to get value between 0 and 1

Min, Average, and Max X,Y,Z gyroscope rotations over last 5 mins, 1 min, and 10 sec

- Add 360 to given degrees then divide by 720 to get value between 0 and 1

Min, Average, and Max 10-second heart rate measured over last 5 mins, 1 min, and 10 sec

- Clamp between 30 and 250 beats per minute; subtract 30 and divide by 220 to get value between 0 and 1

Total of 3*(3*3*3) + 3*(3*3*3) + 3 = 165 input nodes

Single output node is 0 if no seizure during time period, 1 if seizure during time period.

Machine Learning Algorithm: Training

Small portion of total network: x-axis rotation data & it's small role in detecting a seizure.
Training is computationally intensive, occurs on the server, and uses the Gradient Descent training algorithm

5m min = +0° = 0.5

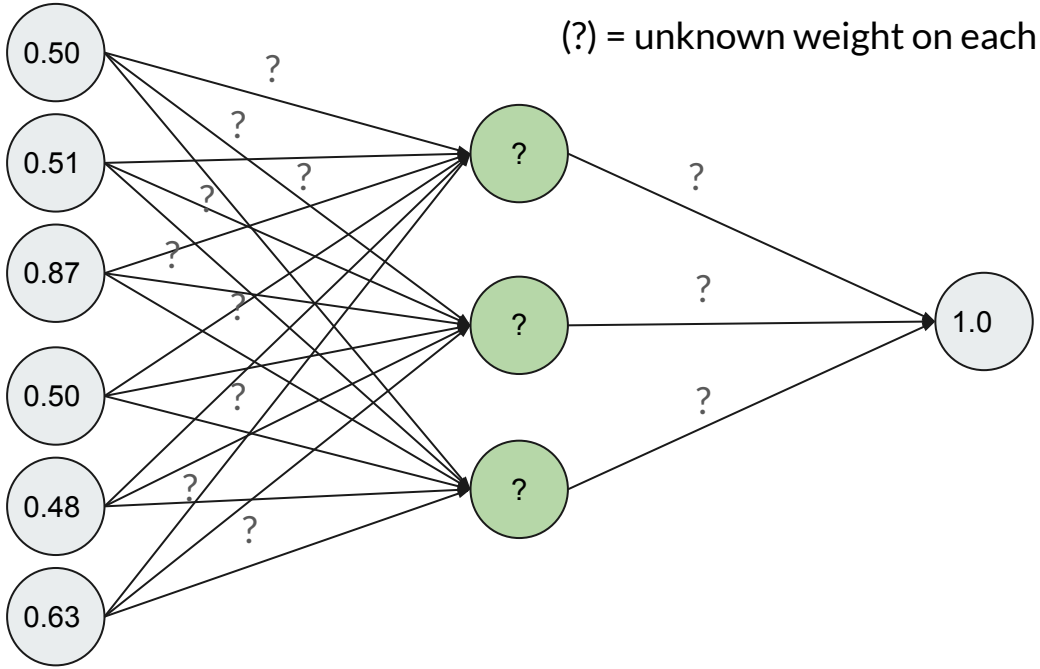
5m avg = +5° = 0.50694

5m max = +270° = 0.875

1m min = +0° = 0.5

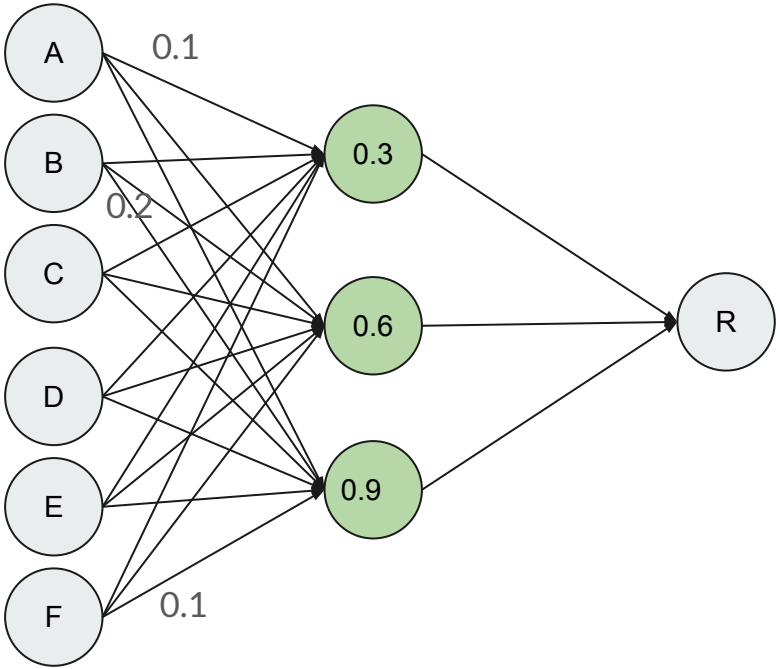
1m avg = -10° = 0.48611

1m max = +90° = 0.625



Machine Learning Algorithm: Evaluation

Evaluation is computationally trivial (adding/multiplying ~200 numbers) and occurs on watch in real-time as 10-second batches of data are read from sensors



To compute R using trained weight values:

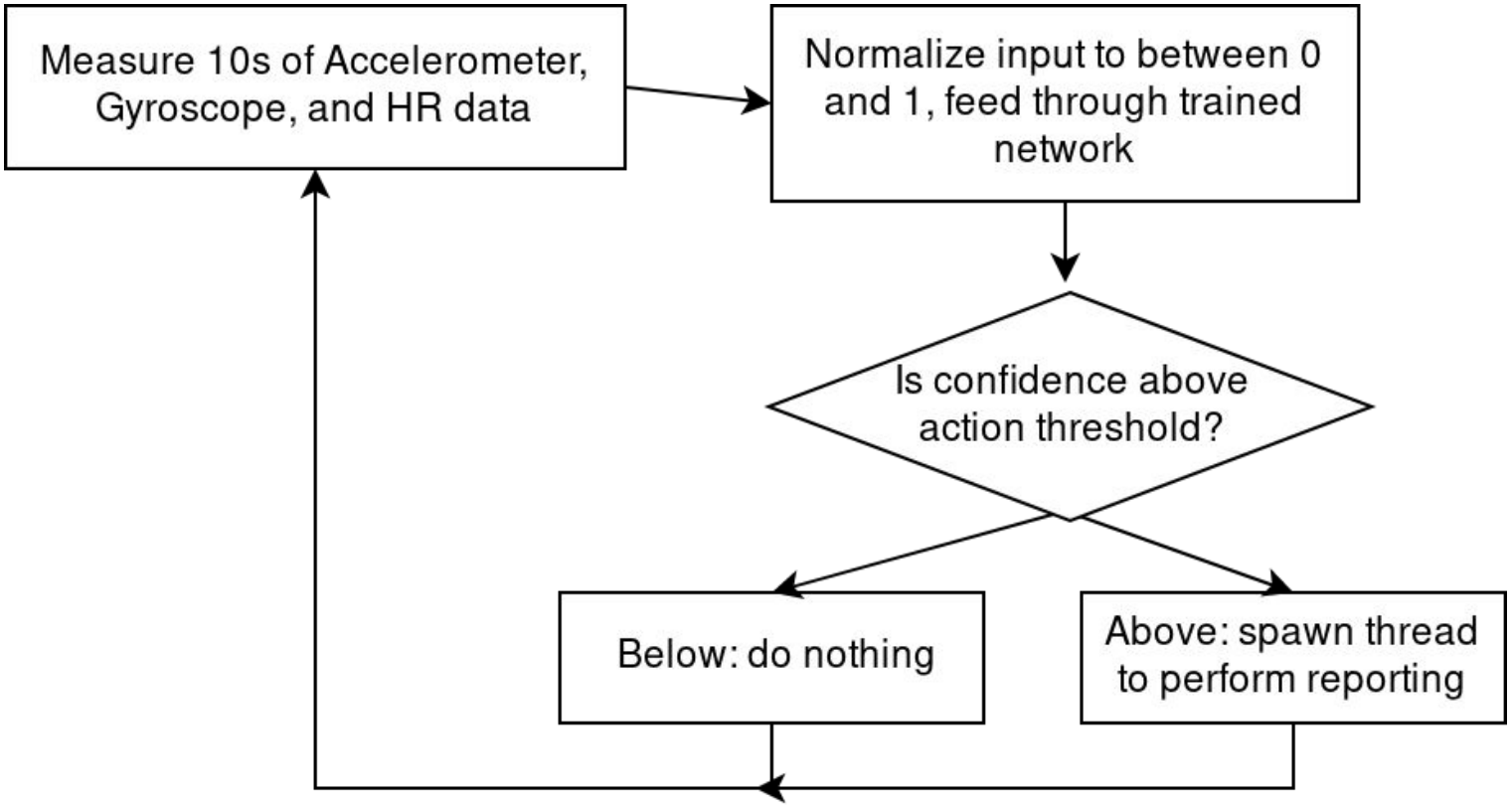
$$R = \sum(A*0.1 + B*0.2 \ldots F*0.1) * 0.3 + \sum(A*0.1 + B*0.2 \ldots F*0.1) * 0.6 + \sum(A*0.1 + B*0.2 \ldots F*0.1) * 0.9$$

Finally compare R against the user's preferred sensitivity coefficient. If set to 0.5, this means when R > 0.5 we act on a seizure event

Detection Algorithm

- **Purpose**
  - Determine if a patient is having a generalized seizure in real time
- **Tools**
  - Smartwatch sensors
  - Trained Neural Network
- **Parameters**
  - Acceleration 5m, 1m, 10s / avg, min, max / x, y, z
  - Gyroscope rotation values 5m, 1m, 10s / avg, min, max / x, y, z
  - Heart rate 5m, 1m, 10s / avg, min, max

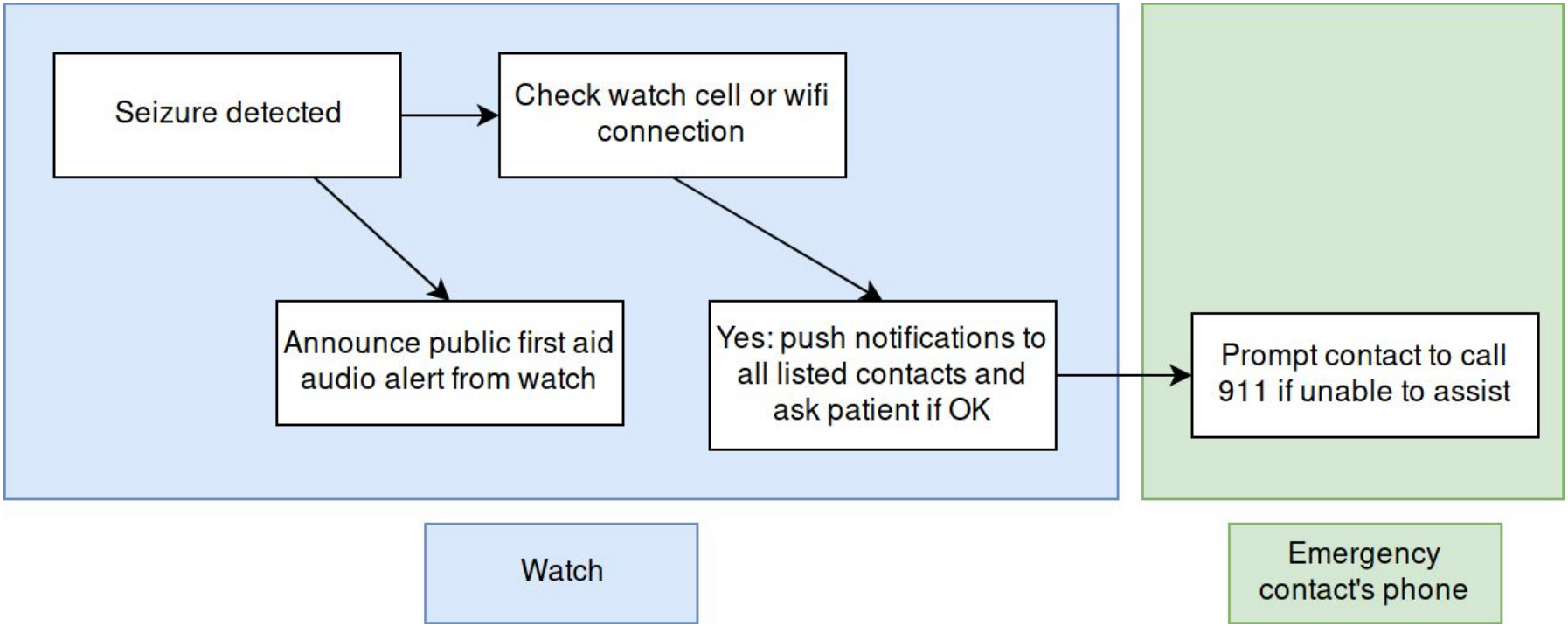
Detection Algorithm Logic Flow



Reporting Algorithm

- **Purpose**
  - To notify the patient's emergency contact and in some cases the patient's last resort emergency contact
- **Tools**
  - Smartwatch with cellular or wifi network
- **Parameters**
  - Data about the patient
    - Patient's emergency contacts list
    - Patient's last resort emergency contact
    - Patient's location coordinates
    - Patient's heart rate and body motion data

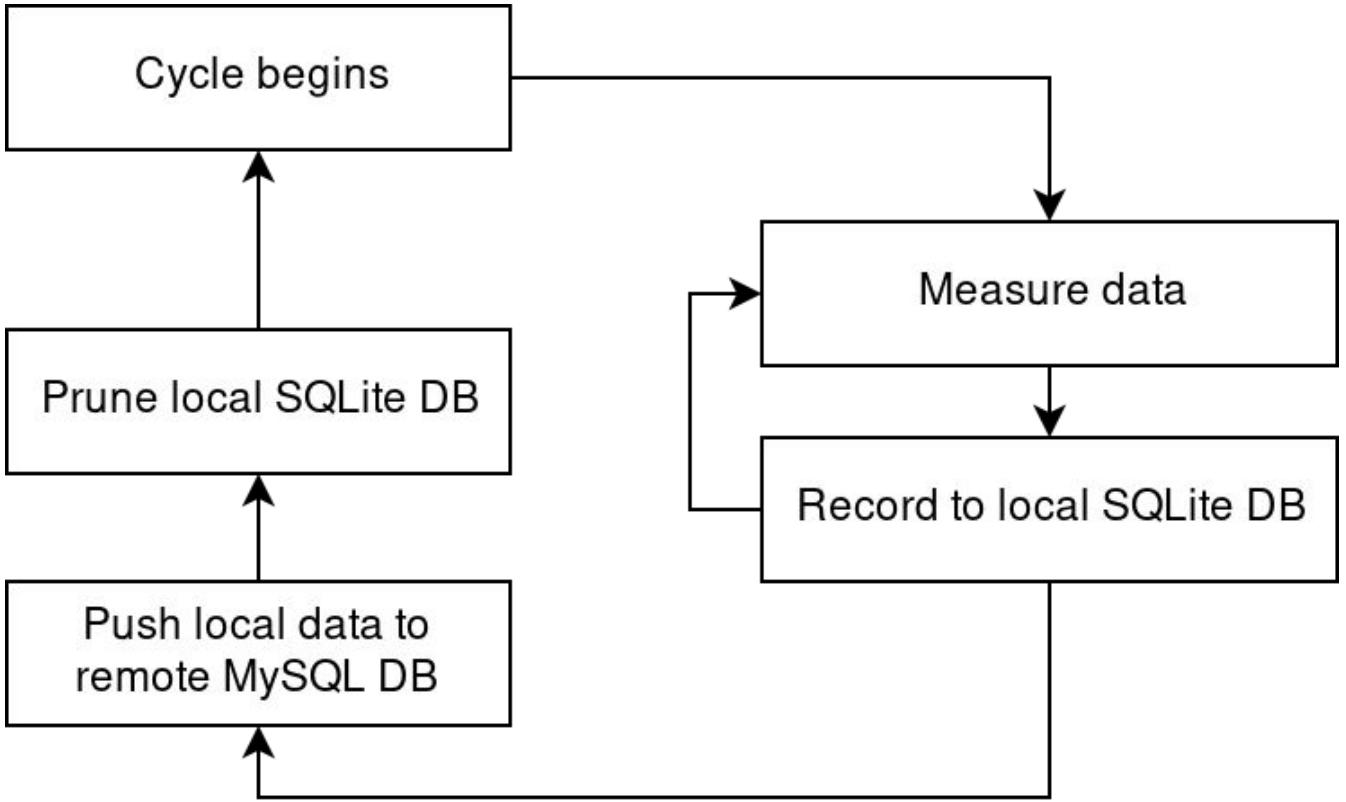
Reporting Algorithm Logic Flow



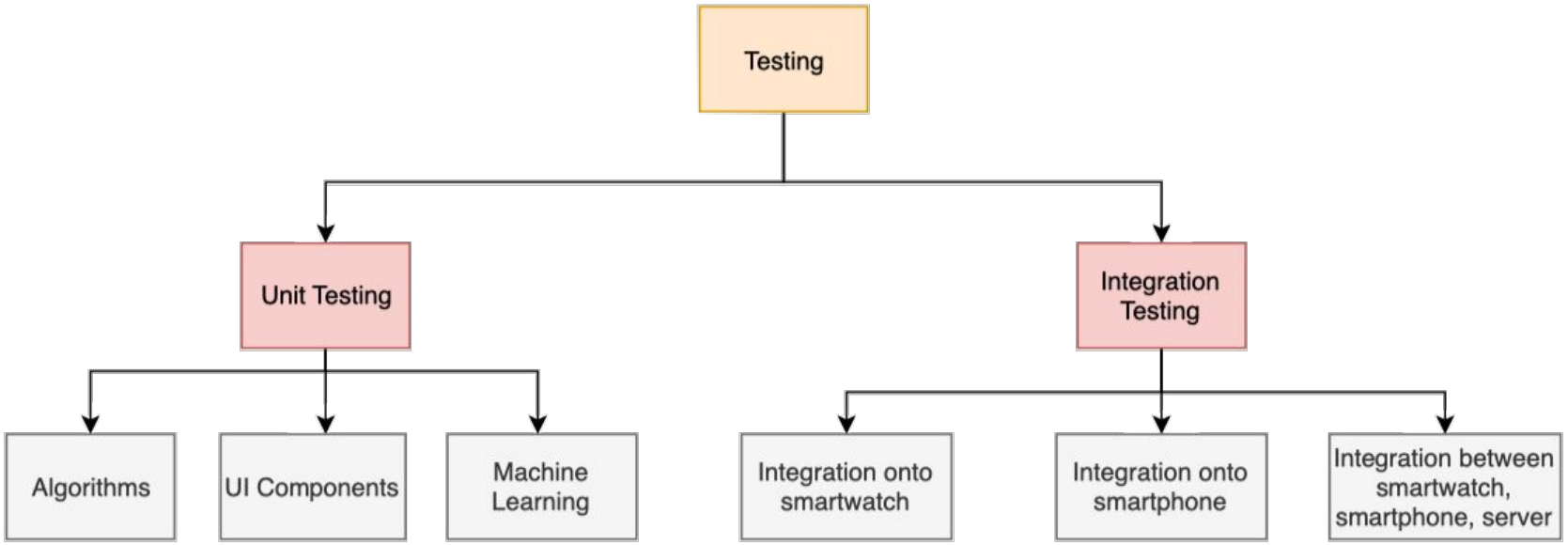
Recording Algorithm

- **Purpose**
  - Record seizure-related data used in training.
- **Tools**
  - SQLite
  - MySQL
- **Parameters**
  - Heart rate
  - Accelerometer readings
  - Gyroscope readings
  - Seizure tag

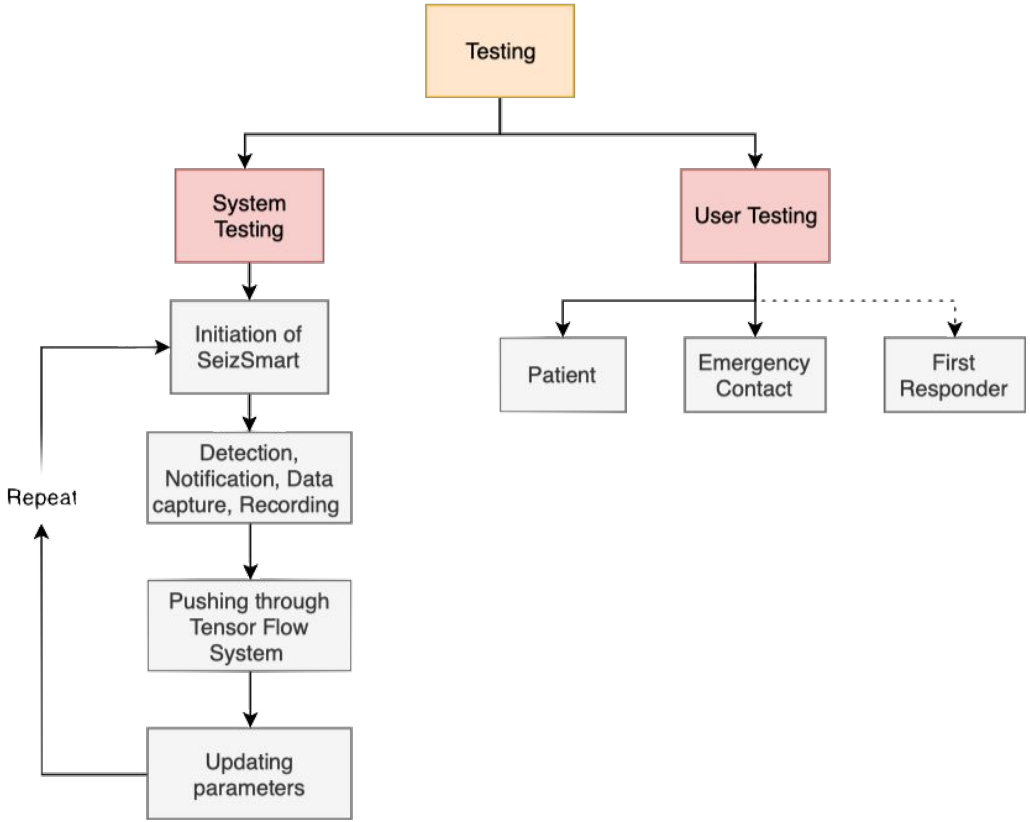
Recording Algorithm Logic Flow



WBS - Testing


Testing
Unit Testing
Integration Testing
Algorithms
UI Components
Machine Learning
Integration onto smartwatch
Integration onto smartphone
Integration between smartwatch, smartphone, server

WBS - Testing Continued

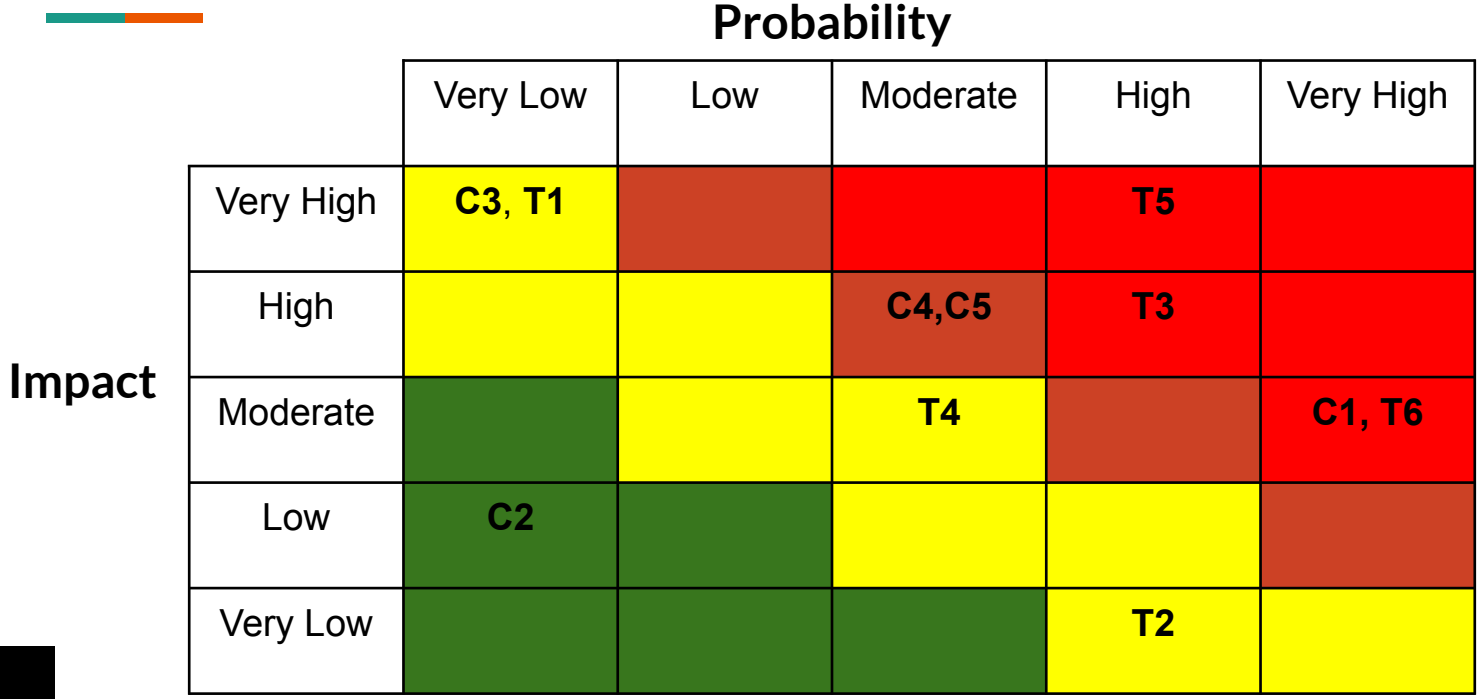


RWP vs Prototype

Functional elements	Real World Product	Prototype
Detect generalized seizures in real time	Fully Functional	Implemented through simulation
Record generalized seizures in real time	Fully Functional	Implemented through simulation
Track generalized seizures in real time	Fully Functional	Implemented through simulation
Monitor repetitive shaking motion	Fully Functional	Fully Functional
Continuously monitor the user's heart rate	Fully Functional	Fully Functional
Alert emergency contact when the user does not respond	Fully Functional	Fully Functional
Collect data about the environment at the onset of a seizure being detected	Fully Functional	Fully Functional
Use machine learning to detect generalized seizures	Fully Functional	Implemented through simulation
Fully functional without dependence on a smartphone or external device	Fully Functional	Fully Completed

Agile Sprints

Risk Matrix


Probability
Very Low
Low
Moderate
High
Very High
Impact
Very High
High
Moderate
Low
Very Low
C3, T1
T5
C4,C5
T3
T4
C1, T6
C2
T2

Customer Risks-C1

- The detection process will go through a “learning” phase which may cause the user to not trust the application due to an increase in false results

Mitigation

- Let the patient know ahead of time that there will be a learning phase for the application, give a basic explanation to reassure the user regarding why it is necessary

Probability

Impact

	Very Low	Low	Moderate	High	Very High
Very High	C3, T1			T5	
High			C4,C5	T3	
Moderate			T4		C1, T6
Low	C2				
Very Low				T2	

Customer Risks-C2

- May require a certain level of end user technical competency and commitment/dedication

Mitigation

- Provide detailed instructions of how to properly use the application

Probability

Impact

	Very Low	Low	Moderate	High	Very High
Very High	C3, T1			T5	
High			C4,C5	T3	
Moderate			T4		C1, T6
Low	C2				
Very Low				T2	

Customer Risks-C3

- Patient data could be leaked in the event of a potential data breach

Mitigation

- Encrypt all collected data about the patient

Probability

Impact

	Very Low	Low	Moderate	High	Very High
Very High	C3, T1			T5	
High			C4,C5	T3	
Moderate			T4		C1, T6
Low	C2				
Very Low				T2	

Customer Risks-C4

- If no network is available, important data can be lost

Mitigation

- We will preserve the most important data, which is seizure data, in the Smartwatch itself.

Probability

Impact

	Very Low	Low	Moderate	High	Very High
Very High	C3, T1			T5	
High			C4,[illegible]5	T3	
Moderate			T4		C1, T6
Low	C2				
Very Low				T2	

Customer Risks-C5

- If no network is available, emergency contacts can not be notified.

Mitigation

- An audio alert will sound and instructions will display on watch so anyone nearby can aid effectively.

Probability

Impact

	Very Low	Low	Moderate	High	Very High
Very High	C3, T1			T5	
High			C4 C5	T3	
Moderate			T4		C1, T6
Low	C2				
Very Low				T2	

Technical Risks-T1

- Security breach

Mitigation

- Encrypt all data in transit and at rest

Probability

Impact

	Very Low	Low	Moderate	High	Very High
Very High	C , T1			T5	
High			C4,C5	T3	
Moderate			T4		C1, T6
Low	C2				
Very Low				T2	

Technical Risks-T2

- Battery drainage due to the high use of sensors in smartwatch

Mitigation

- Only activate sensors that will be used and turn off all sensor listeners when not being used

Probability

Impact

	Very Low	Low	Moderate	High	Very High
Very High	C3, T1			T5	
High			C4,C5	T3	
Moderate			T4		C1, T6
Low	C2				
Very Low				T2	

Technical Risks-T3

- Ability to determine an appropriate amount of data needed to validate our initial model, and to then capture enough example data to effectively train the personalized algorithm

Mitigation

- Speak with experienced neurologists who may be able to suggest or guide us to the frequency of certain paths of the AI decision tree. Initialize trained network using public research data biometric readings

Probability

Impact

	Very Low	Low	Moderate	High	Very High
Very High	C3, T1			T5	
High			C4,C5	T3	
Moderate			T4		C1, T6
Low	C2				
Very Low				T2	

Technical Risks-T4

- Correlating data between sensors to detect a seizure

Mitigation

- Set the same sampling rate of all sensor updates

Probability

Impact

	Very Low	Low	Moderate	High	Very High
Very High	C3, T1			T5	
High			C4,C5	T3	
Moderate			T4		C1, T6
Low	C2				
Very Low				T2	

Technical Risks-T5

- Machine learning might degrade performance

Mitigation

- There will be an option to revert threshold values back in time, or completely reset threshold values back to initial values

Probability

Impact

	Very Low	Low	Moderate	High	Very High
Very High	C3, T1			T5	
High			C4,C5	T3	
Moderate			T4		C1, T6
Low	C2				
Very Low				T2	

Technical Risks-T6

- The detection process will go through a “learning” phase which may increase the number of false positives

Mitigation

- Let the patient know ahead of time that there will be a learning phase for the application. Starting out, we will apply typical biometrics of a user experiencing a seizure until the application “learns” the individual

Probability

Impact

	Very Low	Low	Moderate	High	Very High
Very High	C3, T1			T5	
High			C4,C5	T3	
Moderate			T4		C[illegible], T6
Low	C2				
Very Low				T2	

What SeizSmart Will Not Do

- It will not predict seizures in advance of known symptoms
- It detects all types of generalized seizures except for absence seizures
- It is not a medical application and is not intended to be used in the diagnosis, monitoring, prevention, or treatment of epileptic seizures.

Key Points Summary

- SeizSmart is a mobile application based on smartwatch technology that is designed to improve the detection, tracking, and reporting of generalized seizures.
- The Problem
  - Current applications only check for an increase in heart rate or rapid body movements.
  - Current applications require a prescription or subscription plan in order to detect and track seizures.
  - Current applications require the smartwatch to be in close proximity to the relay device to transmit alerts and notifications.
- The Solution
  - Continuously monitor the end-user's heart rate and body movements.
  - Apply machine learning to the collected data about the end-user's seizures to build a unique, personalized, more accurate seizure profile.
  - Execute within the smartwatch itself to enable independent operation without requiring proximity to a relay device.

Interactive Prototypes

- App:
  - https://xd.adobe.com/view/17e93316-724a-4f5a-6827-3e06b38ce038-61d8/
- Alert:
  - https://xd.adobe.com/view/1c7d93db-b2ca-40c6-71e2-d50d1892ada8-6a4c/
- Phone:
  - https://www.figma.com/proto/NXfp6jJo21H7FiibaDyuyVVS/SeizSmart-Phone-UI-Test?node-id=0%3A1&scaling=scale-down


Q&A

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References - Indirect Competitors

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Appendix A1 - User Stories (Patient)

a. As a patient, I need to receive an alert when a seizure has been detected
b. As a patient, I need to be given x amount of seconds to respond to the given alert before my emergency contact is notified
c. As a patient, I need to be able to cancel an alert
d. As a patient, I need to have the ability to turn detection mode on and off
e. As a patient, I would like to log seizures
f. As a patient, I would like to view all my recorded seizures
g. As a patient, I would like to pick which emergency contact receives a notification during the onset of a seizure.
h. As a patient, I need to add emergency contacts who will receive a notification during the onset of a seizure. (Need)
i. As a patient, I need to be able to switch on emergency notifications (Need)
j. As a patient, I need to be able to store and change emergency contacts as required (Need)
k. As a patient I would like to be able to tweak detection parameters as needed.
l. As a patient I would like the smartwatch to vibrate or emit an audio alarm when a seizure is detected.
m. As a patient, when I don't respond to my initial alert, I would like the smartwatch to emit an alarm or verbal notification to alert bystanders what is happening

Appendix A1 - User Stories (Patient) Continued

a. As a patient, when I don't respond to my initial alert, I would like the smartwatch to emit verbal instructions telling bystanders how to help me
b. As a patient, if I fall, I would like the watch to include that in the notification to my emergency contact/first responders

Appendix A2 - User Stories (Emergency Contact)

a. As an emergency contact, I need to receive an alert when a patient is having a seizure. (Need)
b. As an emergency contact, I need to have the ability to cancel an alert from being sent to first responders if I am available to assist the patient. (Need)
c. As an emergency, I need to know patient location and patient phone number during a seizure.
d. As an emergency contact, I need to know patient heart rate in the alert to confirm if this is an actual seizure or just a false positive.

Meta

Slide Color Key

New Slide

Old Slide

Discussion of presentation design?

Rubric