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Lab 1: Seizsmart Product Description

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Section 1: Introduction

A seizure is defined as an unanticipatedly abrupt surge of electrical activity in the brain. The way that an individual acts or appeared can be affected for a brief period of time during a seizure, for example with involuntary movements. Some commonly seen indicators that an individual is having a seizure involve the individual shaking or falling. Another indication that an individual is experiencing a seizure would be seeming oblivious to their surroundings. The nerve cells in the brain go through complex chemical changes which cause the abrupt surge of electrical activity. During a seizure, a disturbed brain cell can negatively affect the other brain cells' cognitive motor functions by either suppressing them and stopping them from sending messages to other brain cells or by exciting them and speeding them up. Figure 1 shows some statistics of Epilepsy and some problems that patients face regarding epilepsy.

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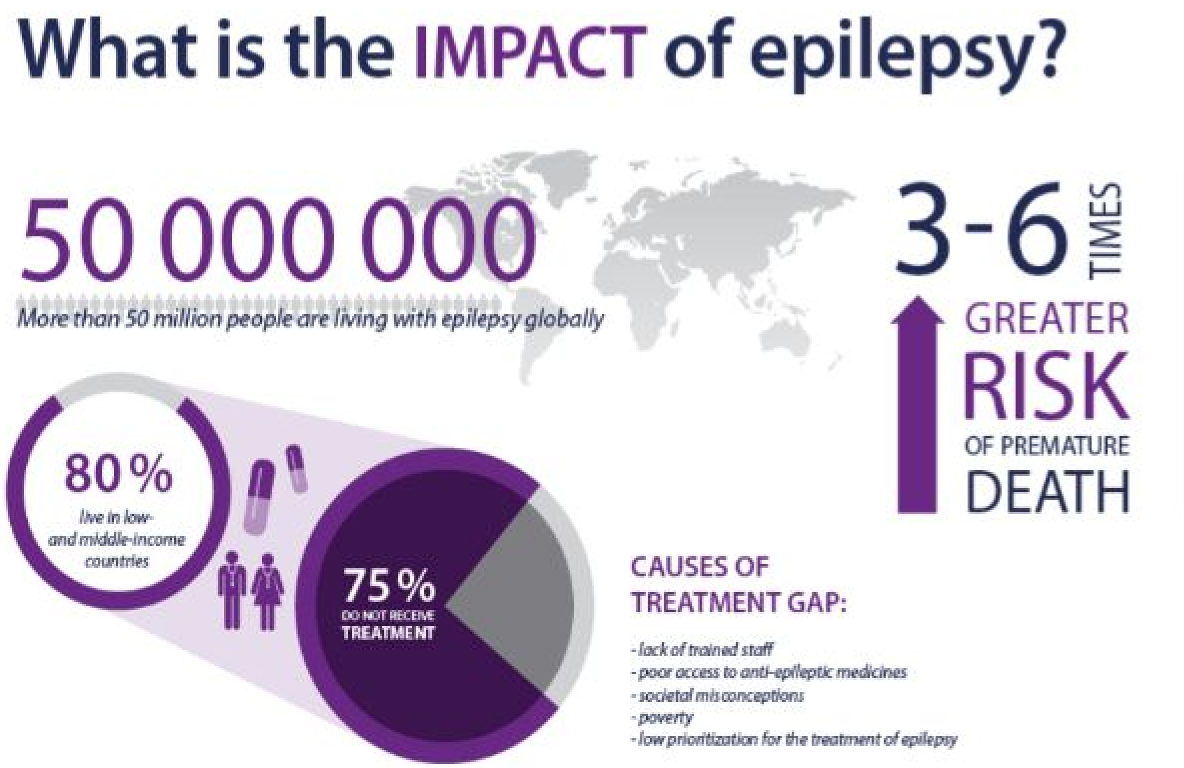

Figure 1: Background of epilepsy

Epilepsy is a disorder that is comprised of a group of different types of seizures. Diagnosis of epilepsy is determined when an individual has had two or more seizures. The groups of people affected by epilepsy span all ages. In addition to being diagnosed with epilepsy, approximately 25% of the individuals in that diagnosis group also have characteristics of generalized tonic-clonic seizures[4]. Individuals who are autistic, have suffered from a head infection or head trauma, and have suffered from a stroke are more likely to be affected by epilepsy. By 2020, cases of epilepsy are expected to increase further[10]. From 2014-2019, cases of epilepsy have increased[10]. Epilepsy is labeled the fourth most common neurological disease in the world[5]. Seizures are classified under one of two groups: generalized seizures and focal seizures.

Generalized seizures cause both sides of an individual's brain to be disrupted. Six common types of Generalized seizures are Absence, Tonic, Clonic, Tonic-clonic, Atonic, and Myoclonic seizures. Their attributes will be described: Absence seizures, which are also called Petit Mal seizures, are characterized by the individual staring into space or blinking rapidly, also an individual can become detached from their surroundings and sometimes becomes unresponsive to the people around them, they commonly last for a few seconds, and an individual may not remember experiencing one; tonic seizures are occurring when an individual experiences muscle tension in the arms and legs for 20 seconds; Clonic seizures are present when an individual experiences spasms of the muscles often causing the arm, face, and neck muscles to rhythmically jerk; Tonic-Clonic seizures are a combination of Tonic and Clonic seizures and are also called Grand Mal seizures; the common symptoms of Tonic-Clonic seizures include: an individual having spasms or muscle jerks, an individual losing consciousness, an individual falling to the ground, an individual crying out, and an individual feeling drowsy or tired; Tonic-Clonic seizures last from 1- 3 minutes and can also cause an individual to lose bladder or bowel control; Atonic seizures are characterized by the limping of an individual's muscles causing them to drop what they are holding or causing them to fall; An individual's head may also lean forward during Atonic seizures and they usually last for 15 seconds but happen multiple times in succession; Myoclonic seizure symptoms are mainly described as an individual's muscles abruptly jerking as if they have been shocked . These are the six common types of Generalized seizures.

Focal seizures are also called Partial seizures and as the name implies, they only occur in one part of the brain. There are 3 main types of Focal seizures: Simple focal, Complex focal, and Secondary generalized. Simple Focal seizures cause a disruption or an interference that alters how an individual's senses read everything around them. An individual usually notices a strange taste in smell or taste and can sometimes become dizzy and see light flashes. Complex Focal seizures are characterized by an individual crying, gagging, smacking their lips, laughing, or losing consciousness while looking awake. Complex Focal seizures could take several minutes before they end. Secondary generalized seizures are characterized by an individual usually having a Focal seizure followed by a Generalized seizure. Symptoms of a Secondary generalized seizure mimic the symptoms of Generalized seizures such as muscle slackness or convulsions.

The technology to be developed is called Seizsmart. Seizsmart will address the following 5 points: detecting Epileptic seizures timely and accurately is an obstacle and if seizures are left undetected then they can cause serious injury or death, the ability to automatically detect the onset of a seizure based on a combination of heart rate behavior and repetitive body movements is a capability that currently available devices do not provide; detecting seizures and notifying emergency contacts is a capability that is needed in order for a device to function efficiently and in order for current technological devices to accomplish this, the devices must be in the proximity of the smartphone which is used as a relay device; current technology is hard to aquire due to cost restraints or specialized hardware requirements, and current technology does not create a specific seizure profile that is unique to the body movements of the individual user. In total, Seizsmart will be designed to address the problems of affordably detecting unique, profile based seizures during their onset using a combination of heart rate and body movements and tracking the seizures in a timely manner while sending notifications to emergency contacts. Figure 2 depicts the current process flow.

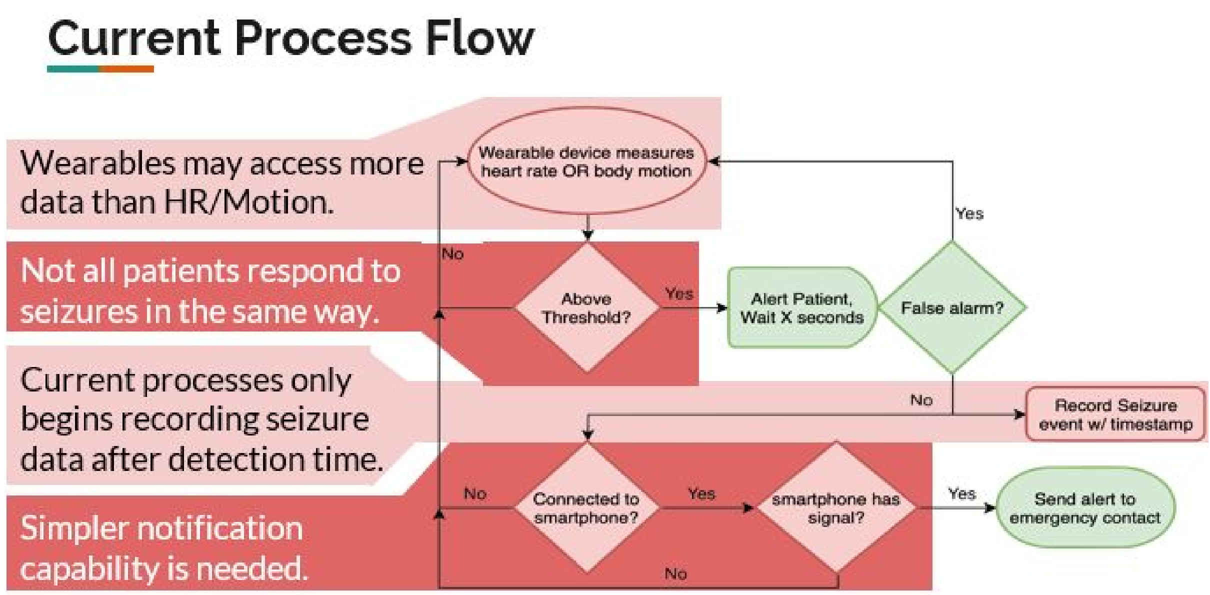

Figure 2: Current Process Flow

Seizsmart will be designed to implement an improved, wearable seizure detection tool that will only need to employ off-the-shelf smartwatch technology. The software tool will be designed to record and track all information encompassing a seizure event. Seizsmart will deliver automatic notification of seizure events to emergency contacts without the requirement and dependency of a relay device. An algorithm that uniquely matches an individual's patient seizure characteristics will be developed to aid Seizsmart in its seizure detection. Seizsmart will be developed analyse motion metrics and heart rates combined to automatically detect epileptic seizures. Figure 3 depicts the Solution Process Flow.

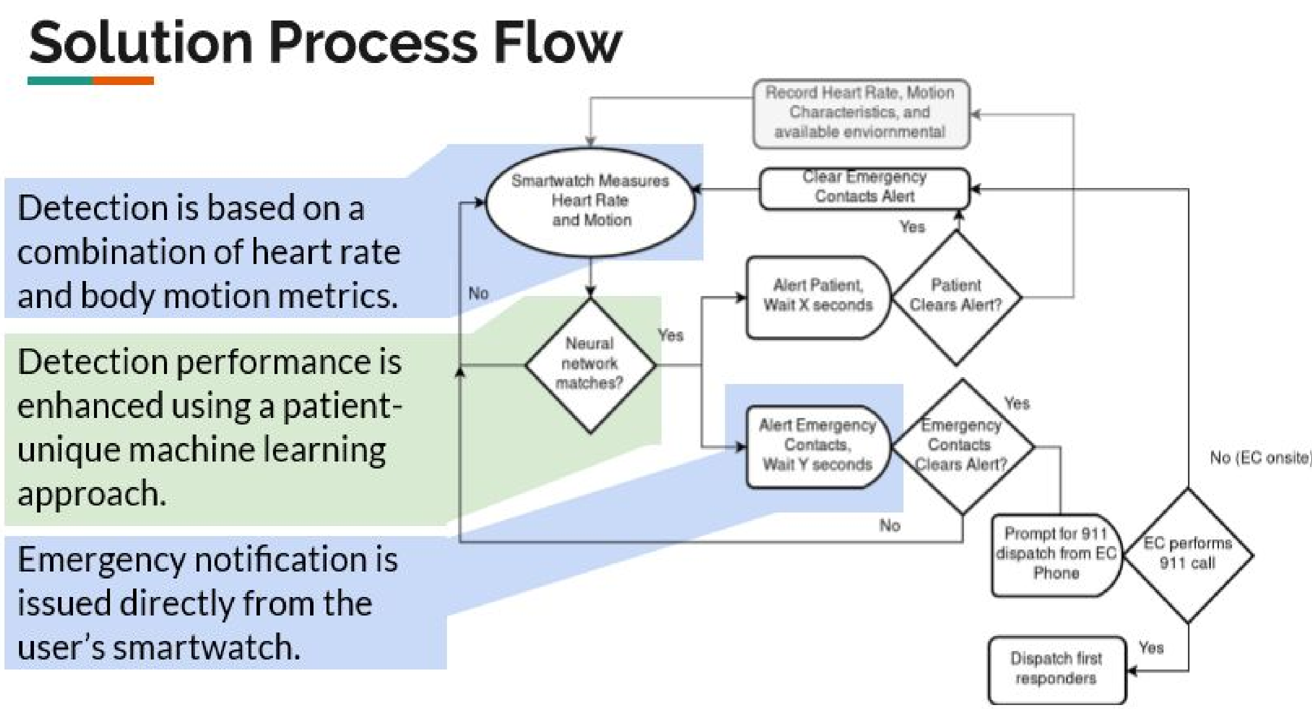

Figure 3: Solution Process Flow

Section 2: SeizSmart Product Description

The processing and data collection goals of the technology to be developed will be detailed. For optimal seizure detection, there will be 4 pieces of data that will be used as inputs: heart rate, motion, gyroscope, and accelerometer values. Once a seizure is detected, notifications to alert the emergency contacts are pushed from the smartwatch automatically. There will be a countdown alert with an abort button if an individual wishes to cancel the alert. The role of the smartwatch application is to receive false positive feedback, collect data, and perform direct notification over cellular comms. The role of the smartphone application will be to allow users to view data collected from the smartwatch and to allow users to configure the account by allowing them to make emergency contact edits.

In general, the goal of the technology to be developed is to record, track, and detect generalized seizures. Body motion and heart rate characteristics will be evaluated using machine learning technology in order to establish a seizure profile for each patient. Seizmart's technology is intended to be able to monitor body motion and heart rate performance continuously. The combination of body movements and heart rate will be used for detection indication. During the onset of a seizure, any available data about the environment will be collected. There will be an available option for first responders and emergency contacts to be notified automatically when it is appropriate. The smartwatch will send notifications directly to emergency contacts so it will not have to rely on a relay device to send notifications to emergency contacts. In order to make the detection process unique for each end-user, a trained neural network will be utilized.

Section 2.1: Key Product Features and Capabilities

Seizsmart will be developed to provide cost effective seizure detection services. The main reason is that standard smartphones and smartwatches can be used. There is no need for specialized hardware. Seizsmart will be designed to be an all in one seizure detection device that will be designed to use a combination of body movements and heart rate readings to aid in detection. A relay device will not be required while using the Seizsmart device, as Seizsmart will be designed to function without that dependency. Seizsmart will be designed to improve detection, tracking, and reporting of generalized seizures. The problem with current applications that they only check for rapid body movements or increased heart rates, they require subscription or prescription plans in order to detect seizures, and to transmit alerts and notifications, they require the smartwatch to be in close proximity to the relay device. Seizsmart will be developed to continuously monitor the end-user's body movements and heart rate, collect data about the end-user's seizures to build a unique, personalized, more accurate seizure profile by applying machine learning, and enable independent operation without requiring a relay device by executing the alert function from within the smartwatch

Seizsmart will not detect or attempt to make predictions of seizures in advance of known symptoms. Seizsmart is not intended for use as a prevention, monitoring, diagnosis or treatment device for epileptic seizures and is not a medical device. Seizsmart will not be able to detect absence seizures. Table 1 depicts the competition matrix.

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Competition Matrix		Direct			Indirect	
	SeizSmart	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	✗	✓	✓	✗	✗	✗

Table 1: Competition Matrix

Section 2.2: Major Components

The hardware requirements will be an accelerometer, a gyroscope, wifi, and an optical heart-rate sensor.

The development tools for the Android application will be Java for the programming language, Android studios for the ide and UI/UX, SQLite for the database, Gradle for the build manager, Git for version control, Gitlab for issue tracking, and JUnit for the testing framework.

The software tools needed to run the server are: Java for the programming language , Vim for the IDE, HTML5/CSS/JS for the UI/UX, MySQL for the database, Gradle for the build manager, Git for version control, Gitlab for issue tracking, and JUnit for the testing framework.

Determining if the patient is having a generalized seizure in real time is the purpose of the detection algorithm. The tools that are going to be utilized for this algorithm are smartwatch sensors and a Trained Neural Network. There will be 3 main parameters for this algorithm. The algorithm will include gyroscope rotational and accelerometer values on the x, y, and z plane as well as time intervals of 5 and 1 minutes, 10 seconds, and the minimum, maximum, and average on these time intervals. The algorithm will include acceleration values on the x, y, and z plane and time intervals of 5 and 1 minutes, 10 seconds, and the average, minimum, and maximum on these time intervals. Lastly, the algorithm will include heart rate values of 5 and 1 minutes, 10 seconds, and the minimum, maximum, and average on these time intervals. Figure 4 depicts the detection algorithm flow.

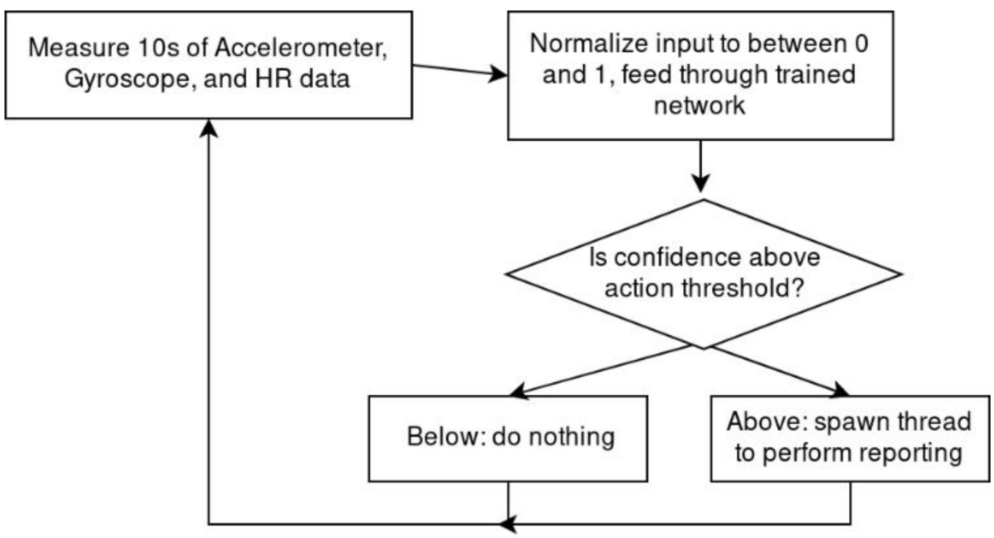

Figure 4: Detection algorithm flow

The purpose of the recording algorithm is to record data related to seizures used in training. The tools that will be used for this algorithm will be SQLite and MySQL. The parameters that will be used for this algorithm are a seizure tag, gyroscope readings, accelerometer readings, and heart rate readings. Figure 5 depicts the recording algorithm flow.

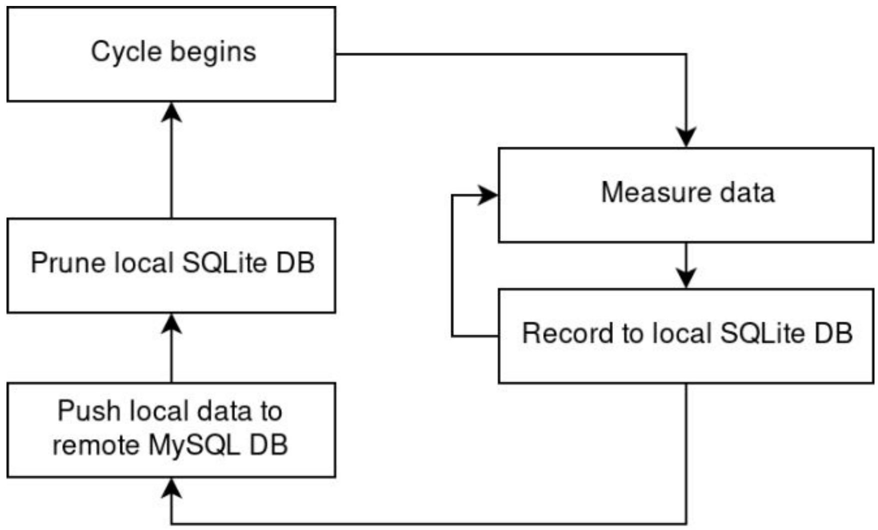

Figure 5: Recording algorithm flow

The purpose of the reporting algorithm is to make sure that the emergency contact of the patient is notified and depending on the circumstances, the last resort emergency contact. The core tool that will be needed for the algorithm is a smartwatch with a wifi or cellular network. The parameters for this algorithm are the data about the patient: The patient's heart rate and body motion data, the patient's location coordinates, the patient's emergency contact list, and the patient's last resort emergency contact. Figure 6 depicts the reporting algorithm.

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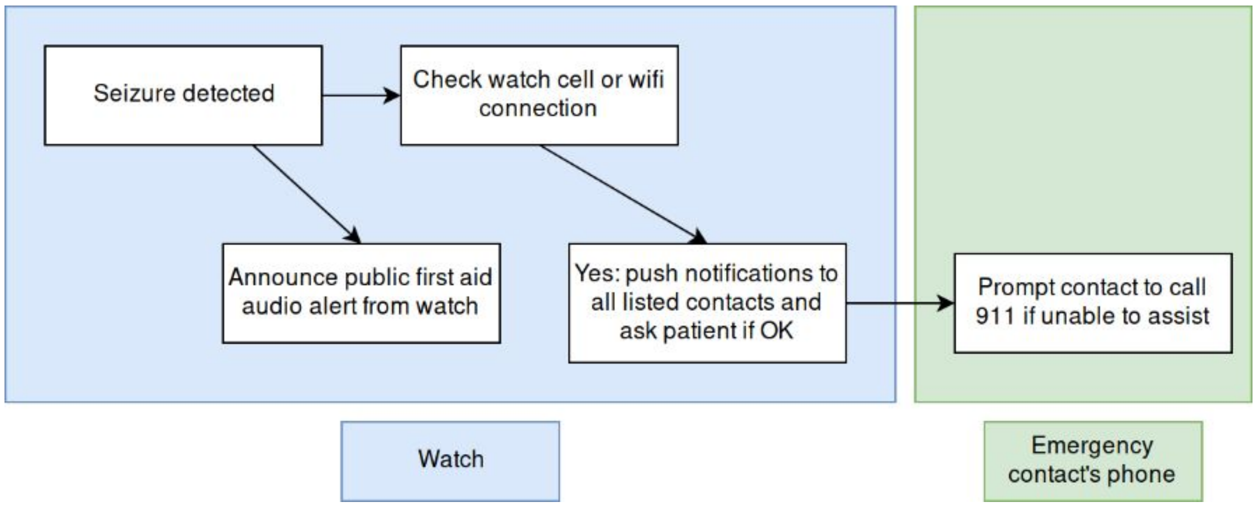

Figure 6: Reporting algorithm flow

Section 3: Identification of Case Study

This product is generally being developed for individuals who experience seizures. The target customers will be medical providers and anyone who is concerned about the individual with generalized seizures. The target end users are the individuals who experience seizures.

Optimized hardware flexibility and detection performance is one benefit that an end user would reap from using this technology. The end user's individual seizure profile will provide more accurate and customized seizure detection information. Emergency response notifications will be editable according to the user's preferences. Seizsmart will be compatible with IOS and Android smartwatch technology without the need for specialized hardware. The technology will be available without the requirement of prescription or subscription services. Seizsmart will be able to function without the requirement of a relay device and notification of emergency contacts will be available when they are needed the most.

Section 4: SeizSmart Product Prototype Description

A top level description of the prototype as it relates to the goals that were set for the end product will be detailed. The capabilities of the prototype will be reduced. Real world data will be simulated. Potential seizures will be detected based on a threshold. Table 2 depicts the Prototype vs. Real World Product Matrix.

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

Table 2: Prototype v. Real World Product Matrix

Section 4.1: Prototype Architecture (Hardware/Software)

The structure of the prototype and how it will demonstrate key features of the product will be documented. Two user interfaces , two databases, 4 core algorithms, and 4 unit tests are what comprise this piece of technology.

The smartphone user interface will have a data management section and an alert management section as the core sections.The data management section which will consist of an initial setup, a section which will allow the user to log seizures, a section which will allow a user to view logged seizures, and a section for the user to update or add emergency contacts. The alert management section will be comprised of a display that shows the heart rate and motion values and a display countdown alert with an abort button. The smartwatch user interface will be comprised of 3 sections: data management, alert management, and detection management. The data management section consists of an initial setup screen, a screen for logging seizures, a screen for viewing logged seizures, and an update/add emergency contacts screen. The alert management section consists of a display for motion and heart rate values and a display countdown alert with an abort button. The detection management section will have an option to turn detection monitoring on or off and adjust detection parameters.

Continuing from the brief description in section 2.2, MySQL will be used for external storage and SQLite will be used for internal smartwatch storage . The user profile database for MySQL will be split into a user profile section and a seizure data section. The user profile database will consist of a name, a user password, detection parameters, a user email, a user id, an emergency contact, and a first responder. The seizure section of the database will be comprised of a seizure tag, gyroscope data, accelerometer data, heart rate data, data on the environment, and a timestamp. The user profile and seizure data sections for the two databases to be developed are the same.

The 4 core algorithms that will form the foundation of the application are: machine learning, detection, reporting, and recording.

Testing forms that last core piece in making this prototype. There will be 4 types of testing: unit, integration, system, and user. Unit testing will be comprised of algorithm, UI component, and machine learning testing. Integration testing will be comprised of integration onto the smartwatch testing, integration onto the smartphone testing and integration between the smartwatch smartphone and server testing. System testing will involve testing the initiation of seizsmart, testing detection, testing notification, testing data capture, and testing recording. System testing will also include testing pushes through the tensor flow system and testing the update of parameters. User testing will involve patient, emergency, and first responder testing. Figure 7 depicts the MFCD.

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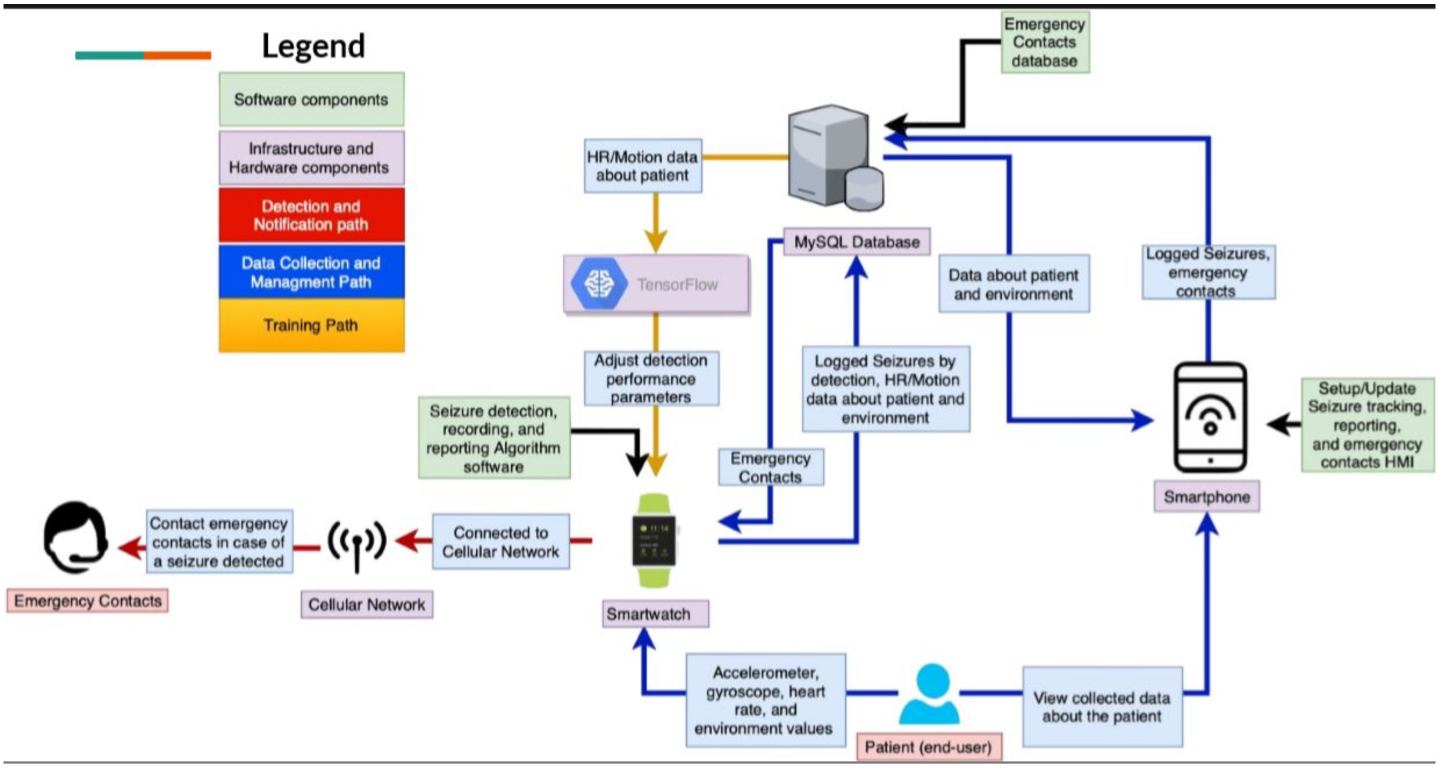

Figure 7: MFCD

Section 4.2: Prototype Features and Capabilities

The prototype will demonstrate its functionality in alerting emergency contacts when the end user is non responsive, analyzing and collecting data on the environment during the onset of a seizure, using a combination of continuous body movement and heart rate monitoring to detect seizures, having full functionality without the need of a relay device, and providing a reliable and economical means to detect seizures via a mobile device. Demonstrating the aforementioned features and capabilities is significant in showing how the problem will be handled because these functionalities will be designed to be in the prototype. The research and proposals prove to be a successful solution to the problem the risk mitigation is depicted in Figure 8.

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:

- The detection process will go through a "learning" phase which may increase the number of false positives
- May require a certain level of end user technical competency and commitment/dedication
- Patient data could be leaked in the event of a potential data breach
- If no network is available, important data can be lost
- If no network is available, emergency contacts cannot be notified.

Technical risks:

- Security breach
- Battery drainage due to the high use of sensors in smartwatch
- 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
- Correlating data between sensors to detect a seizure
- Machine learning might degrade performance

Figure 8: Risk Matrix

Section 4.3: Prototype Development Challenges

There are a number of expected challenges to be encountered while completing the prototype. The time that it will take to learn how to incorporate the Tensorflow, phone, and watch APIs is not known and can take longer depending on the individual. An unknown issue with the smartwatch hardware is the precision and sensitivity of the accelerometer and rotation. This could form an impediment for detection of slight tremors such as shivering. Lastly , the VM is behind a firewall so we would need to connect to the cs vpn to use it or we would need to use ssh tunnel.

In general, the challenges that are to be expected while the developers work to create the prototype include lack of knowledge, inability to adapt to a programming language and potentially trouble with abstract thinking. Some software tools may not run well on different machines. The developers are assumed to have various machine types that will be used individually while developing this prototype such as windows and mac.

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Section 5: Glossary

1. Absence(Petit Mal) seizure: This type of seizure has symptoms of rapid blinking or staring into space.
2. Artificial Intelligence(A.I.): Artificial intelligence is the application of rapid data processing,machine learning ,predictive analysis, and automation to simulate intelligent behavior and problem solving capabilities with machines and software.
3. Atonic seizure: This type of seizure causes an individual's muscles to go limp.
4. Clonic seizure: This type of seizure causes the muscles to spasm and jerk rhythmically
5. Complex focal seizure: This type of seizure can make a person confused or dazed. Individuals are also unresponsive for a few minutes.
6. Deep Learning: Deep learning is part of a broad family of methods used for machine learning that are based on learning representations of data. Deep learning is a specific approach used for building and training neural networks.
7. Emergency Contact: Anyone who cares for a patient; Usually family members.
8. Epilepsy: This is a disorder of the brain and usually is characterized as a group of seizures.
9. Focal(Partial) Seizure: Generally located in one area of the brain.
10. Generalized Seizure: Generalized seizures are seizures that affect both sides of the brain.
11. Machine Learning: Machine learning involves the construction of algorithms that adapt their models to improve their ability to make predictions. Computers learn and act without being explicitly programmed to do so.

12. Myoclonic seizure: This type of seizure causes an individual's muscles to jerk as if they had been shocked.
13. Patient: An individual who experiences generalized seizures. May also be referred to as the end user.
14. Secondary generalized seizure: This is usually characterized as a focal seizure followed by a generalized seizure.
15. Seizure: A seizure is a sudden surge of electrical activity in the brain that causes disruption and involuntary movements.
16. 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. Technically; a matrix of weights computed from training data used to classify new inputs as seizure or non-seizure related.
17. Simple focal seizure: These seizures generally cause a strange sense of taste or smell.
18. Smartphone: A smartphone is a cell phone that includes additional software functions, for example, an email and an internet browser Smartwatch: A smartwatch is similar to a smartphone and is a wearable computing device which allows text message viewing as a feature.
19. Tonic-clonic(Grand Mal) seizure: Makes a person cry out, lose consciousness, fall to the ground, or muscle jerks or spasms.
20. Tonic seizure: This type of seizure causes an individual's muscles to tense up.

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