## Abstract

Epilepsy is a brain disorder that causes recurring seizures, due to abnormal and uncontrolled electrical signals to the brain, caused by damaged brain cells. It affects anyone of any age or race, and can be developed later on in life as well. Around the world, 65 million people are affected by epilepsy. Living with epilepsy is not easy, as they face health complications and social consequences as an effect of it. It's treated by a variety of methods, but knowing when a seizure occurs is a difficult task.  Current technology only detects seizures after they have occured but Seizor will detect seizures before they occur and provide immediate help, through the use of electrical stimulation, bringing a new way of detecting seizures for those with epilepsy and not able to control them with other forms of treatment.

# Seizor

## Present Technology

Epilepsy is the result of neurons firing abnormally, sending wrong signals, and causing a seizure to occur. The occurrence of a seizure is indicated by involuntary movements, sensations, and loss of awareness. Much of the epilepsy prevention technology culminates around detecting and notifying caregivers to administer aid to individuals suffering from a seizure, which can be done through two main types of sensors: photoplethysmography and electromyography.

Photoplethysmography is an optical technique used to detect volumetric changes in peripheral blood circulation. This is typically conducted in the form of a device attached to parts of the body with a strong arterial supply or thin skin. The automatic nervous system, which regulates involuntary functions such as blood pressure or heart rate serves as an indication of a tonal seizure through a spike in heart rate. However, this technique isn't without flaws, as the sensors are prone to false positives, arising from an increase in blood pressure, caused by stress, movement, and exercise. The validity of alerts can be questioned, leading to a delay in response in the case of an actual epilepsy attack. Moreover, PPG may struggle with the detection of focal seizures (intense neural activity in one specific part of the brain), as it depends on automatic responses in the nervous system.

Electromyography (EMG) measures muscle stimulation/electrical activity in response to stimulation of nerves throughout the body. Electrodes, either placed on a surface or piercing the dermal layer, are placed on specific muscles such as the frontalis, trapezius, or biceps brachii. Electrical activity from muscle contractions is recorded, with seizures leading to a sudden increase due to involuntary movement. In tonic seizures, these discrepancies are noted by long, high-amplitude bursts of signal while clonic seizures appear as repeated and rhythmic spikes. However, the technique is not ideal for long-term/everyday use. Surface electrodes may shift or fall off while sleeping or performing tasks involving movement. Needle electrodes, which can enter individual motor units quicker and provide more accurate action potentials, cause pain and discomfort for patients. The procedure also requires the needle to break through the skin barrier, exposing the patient to the risk of infection through an unclean needle. These techniques are not suited for use in daily life, and can only monitor for seizures in certain periods: when they are attached to the muscle. It is uncomfortable and impacts their daily life.

An emerging technology used for the detection of epilepsy attacks is Embrace2, a wrist watch that detects possible convulsive seizures and alerts caregivers through EDA (electrodermal activity) known as skin conductance, skin surface temperature via a Peripheral Temperature Sensor, and motion (3-axis accelerometer) to measure changes in a person's sympathetic nervous system. As the world's first FDA-cleared wrist-worn wearable, the device safely transmits information using AI to process raw data through a seizure detection algorithm. The AI specifically looks for patterns in the data which may correspond to tonic-clonic seizures. Abnormal and rapid movements from the accelerometer, coupled with skin temperature or increased sweating from the strain and exertion on muscles is registered and sent to a caregivers smartphone or another connected device through Bluetooth, SMS messages, and other wireless connections. Post-seizure, the device keeps track of the duration and intensity, allowing for the adjustment of plans used to counteract these sudden spasms.

The main issue with the current technology is that it does not allow for the forecasting of seizures. It detects seizures after they have occurred and lack predictive features, which can aid patients and doctors when identifying future episodes of epilepsy. Moreover, they are not able to offset seizures at the moment of occurrence. Our technology aims to predict oncoming seizures and offset them at the same time. This treatment is meant to be used when other treatments have failed, but can be used in tandem with other treatments.

## History

Seizures were first noted way back in Mesopotamia, to a 4000-year-old Akkadian tablet, noting a person having a seizure and its following symptoms, of a loss of awareness and consciousness and uncontrolled muscle movements. Late Baboylanians were later able to identify different types of seizures and their different outcomes. However, seizures have had a long history of being caused by evil or malevolent spirits, and thus treatment involves spiritual and religious cures.

Hippocrates in the 5th century dared to make a connection with epilepsy to the brain. It was popularized in the 17th century, and many more medical professionals came to research epilepsy and the need for hospitalization for those with epilepsy. In 1989, Dr. Robert Bentley Todd brought about the idea that electrical discharges may be the cause of seizures and later, when Hans Berger invented the EEG (human electroencephalogram) in 1924, it allowed them to confirm that seizures were a cause of abnormal discharge of neurons in the brain.

Treatment for epilepsy ranges from ketogenic diets, to AED (antiepileptic drugs) to surgery. Acupuncture has been used in China to help reduce epileptic effects, but its efficacy is still doubted and not very commonly used. Surgery for epilepsy was first performed in the 19th century and developed through the years. Different types of surgery exist for different types of epilepsy and each have their benefits and disadvantages. Focal resection is the most common type of surgery performed, where it aims to remove the area of the brain where the neurons fire off uncontrollably (seizure focus), and is only done when the area is not in a critical region of the brain. Anti-epileptic drugs came around the 19th century, specifically phenobarbital which has an anti-epileptic or anticonvulsant property to it. Along with phenobarbital, other types of AEDs are used, depending on the type of seizure and its symptoms. AEDs are often the first form of treatment for epileptic patients and are then followed by other treatments.

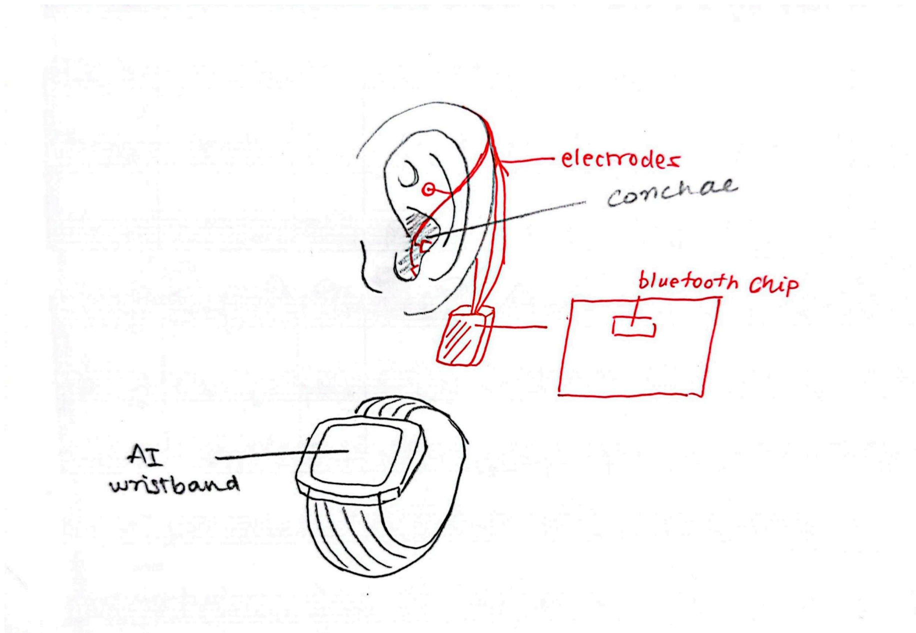
One final and common form of treatment is minimally invasive treatments such as neurostimulation devices, like vagus nerve stimulation (VNS) and deep brain stimulation (DBS), both of which use electrodes to trigger the signals that cause a seizure and cause them to stop the seizure. VNS utilizes the discharge of electric pulses from a device to stimulate the vagus nerve through the spinal cord- to help regulate abnormal neural activity by balancing excitatory and inhibitory signals. The vagus nerve is a set of nerves that run from the brainstorm to the intestines. Studies report improved seizure control with an increased duration of use of VNS, noting a mean decrease in seizure frequency of ~76.3% after a 10.4-year usage (Elliott, 2010). As a treatment for patients with drug-resistant epilepsy, chronic, intermittent electrostimulation modifies the brain by increasing the level of neurotransmitters (norepinephrine and serotonin) in the brain, leading to more control over seizures.

## Future Technology

Each method of preventing epilepsy has its benefits and disadvantages. To combat this, our technology Seizor, will incorporate multiple types of treatments to provide the most accurate and efficient treatment possible. We acknowledge that for those with seizures, gaining opportunities is difficult due to the nature of the disorder and impacts their daily life, from their education to jobs. Seizor is dedicated to providing a device that detects seizures and allows patients to operate more independently throughout their daily life. The Seizure device consists of two parts, an earpiece and a wristband.

The earpiece is a more advanced and newer version of VNS, called tVNS- transcutaneous vagus nerve stimulation. Similar to VNS, where it uses discharge of electric pulses through the vagus nerve to stimulate the focal area in the brain, where the uncontrolled discharge occurs. By being placed on the outer ear, or on the concha, it sends discharges to the auricular branch of the vagus nerve.

The wristband on the other hand is a detecting device. It forecasts seizures before they arise, and uses a multitude of detection techniques, EDA, temperature, accelerometer, heart rate, and previous EEG data from previous doctor visits, which will provide a variety of information for the AI in this wristband to detect patterns. It will use a machine learning model called LTSM deep learning (long-term short memory). The benefits of such a model are that it can decide which information must be discarded and how much of it through its front gate, and retain important information. Thus as the user uses the wristband throughout their daily life, the AI will continue to update its database and provide better forecasted results of when a seizure may occur. This kind of modal function and adaptive ability can also allow for the AI to reduce false positives, by having more information to rely on, rather than simply deducing occurrences through sweat and heart rate.




Once a seizure is forecasted, the wristband will then send a signal to the earpiece, both of which are connected through Bluetooth. Going through a channel, the chip in the tVNS will pick up the signal and emit mild electrical pulses through the electrodes, allowing the vagus nerve to be stimulated and modulate brain activity, reducing excessive electrical activity. The electrical pulses can be monitored and adjusted by the wristband's Bluetooth feature, based on past data and trials, to combat the fluctuation of inhibitory or exhibitory synapses.

## Breakthroughs

For this to work, many breakthroughs are required. To begin with, tVNS, while known, has not been FDA-approved to be used for epilepsy and still requires far more testing and clinical testing. Research has been ongoing and successful, for example MayoClinic has stated that "around two-thirds of people's seizures have been forecasted successfully", using the same machine learning type and similar data. However, this requires a dedicated clinical trial and requires far more accuracy in differentiating different kinds of seizures.

Currently, seizure detectors only detect tonic-clonic seizures, characterized by the jerking of the limbs. However, other types of seizures can be accurately identified given proper clinical trials, and proper data for the AI model, through the usage of EEG sensors.

Moreover, there is the issue of the Bluetooth device. To ensure the effectiveness of Seizor, there must be a stable detection and transmission of wireless signals from the earpiece to the wristband. Without this, there could be a delay in triggering the earpiece, and miss the optimal time to produce intense or mild electric signals, depending on how strong the seizure is forecasted to be. Bluetooth is already commonly used in wearable EEG devices, due to low energy consumption and its ability to connect with devices in a small range. There is a risk that these signals can be interfered with by other electronics, like Wi-Fi routers, and thus reduce its efficiency. Environmental obstructions can also affect Bluetooth signal quality, as rain and water can limit its range and performance. The AI model must have an effective and fast algorithm that can tailor to the needs of the user and adjust the voltage required. It is also imperative that the pulse is carefully regulated and therefore, more control is required from the AI, and there cannot be much room for error.

Finally, a long battery life is required. Currently, scientists are researching solid-state batteries, electrical batteries that utilize a solid electrolyte to conduct ions between the electrodes, instead of liquid or gel polymers found in lithium-polymer or other lithium-ion batteries. Although more energy-dense, these batteries are often expensive, as in most cases, cathodes are composed of Lithium Cobalt Oxide, Lithium Iron Phosphate, Lithium Nickel Cobalt Oxide, and other Lithium alloys. Experts predict that prices may vary from USD 80-90/ kWh, making them too expensive for mass production. More research can be done to power batteries using less costly materials to become more feasible for commercial distribution. Seizures do not stop during the night, so having the wristband and earpiece on at night allows the user and their family to feel at ease knowing that if a seizure occurs, it can be detected late at night. The battery should be able to sustain the user for a week, before needing to be charged, and perhaps, sensors that require less power to work during downtime, or during times when seizures do not commonly occur for that patient.

## Design Process

At the start of this project, we were focused on only forecasting seizures before they would occur. We rejected many ideas and features which would make our device operation extremely different from our current model. Coupled with changing the aim of our product, we changed components such as the simulator, structural framework, and method of prevention.

Originally, we planned for the device to employ VNS or Vagus Nerve Stimulation. Although both operate by releasing electrical impulses throughout the brain, the VNS is surgically implanted near the collarbone and connects to a wire leading to the vagus nerve. This increases the transmissibility of consistent impulses which is less susceptible to disruption. However, although not as accurate, the tVNS was favored over this model as it provides a less intrusive functionality, with an external application rather than the addition of external elements into the body. The stimulator may pose various health and safety risks, as the presence of batteries located near inside the device may be dangerous and can rupture if damaged. Thus, we decided to use the tVNS model instead, which operates externally through an earpiece with the same functionality as the VNS.

Another consideration we held throughout our brainstorming process is the use of a smart headband rather than a watch to act as an EEG sensor. We believed that the headband would offer more accurate results, with receptors being located close to the brain, rather than near the wrist. This allows for better readings of signals, which can generate more accurate data and improved predictions from our AI model. However, the headband poses some practicality issues, as wearing a headband in a public setting could lead to some stigma by others unaware of the condition. Thus, we decided to opt for using a wristwatch, which is a more covert method of monitoring health while balancing day-to-day tasks.

Finally, we experimented with the aim of our devices and had originally planned to create a model that can provide real-time feedback for the wearer using the AI model. Instead of actively preventing the seizure using tVNS, our device would aim to advise the wearer on methods to reduce the risk of seizure such as exercises like walking, running, cycling, etc using an AI model that monitors past epilepsy history. Although the idea was more feasible, it lacked the necessity for any technological advances to be made to combat the seizures. Instead, we decided to implement a more ambitious goal, which may only be achieved when medical and technological advancements are made. Our current model aims to prevent seizures from occurring, and is prospective rather than the retrospective model given before.

## Consequences

If this passes all the required testing, Seizor would have a large impact on epileptic individuals. By allowing them to have their seizures forecasted before they occur, this allows them to receive intervention immediately, which has the potential to reduce seizures, and improve their control and or the severity of them. This provides a non-invasive method of keeping track of seizures and allows both doctor and patient to be updated on the it's news and pursue other avenues of treatment.

It also allows for greater independence for patients. Oftentimes, those with seizures are barred from opportunities, jobs, and education, due to seizures impacting their daily life. If their job is dependent on them driving back and forth to work, it becomes much harder for them to find jobs. Those with seizures also may feel it affects their family life and relationships. Through Seizor, seizures can be monitored and combatted immediately. This helps those who lose awareness during seizures due to its automatic function and allows for increased autonomy.

As AI develops in the future, more personalized treatment can be offered to patients, as well as improved identification of specific types of seizures, not just tonic-clonic seizures or focal seizures. This helps not just those with seizures, but an increase in research in the neurology field helps for many other disorders that patients may face, that can use VNS technology, such as those suffering from anxiety and chronic pain.

With all these benefits, there are many risks to this technology. False positives still have the possibility of arising, no matter how good the AI is. Seizures can be missed, and misinterpreted, which can be a problem, especially because the electric discharge is automatic. Moreover, if the administration of the electrical currents is more than needed or calculated wrongly by the AI, then this could become potentially dangerous. It could risk their health, and the effects of tVNS are still relatively unknown, due to it being new in the industry. Prolonged stimulation of the brain could have negative impacts that we are unaware of. Moreover, because the earpiece does not impact only a specific part of the brain where the seizure is mainly occurring, this could be harmful to the user if used for a long time. Over time, it is possible that sensors will improve and the electric signals can impact only specific parts of the brain, but this is still a concern that should be recognized.

Finally, it can simply be uncomfortable to wear for long periods. It could cause skin irritation and headaches if worn too frequently, and there is the problem of overheating caused by the battery that could also harm the user.

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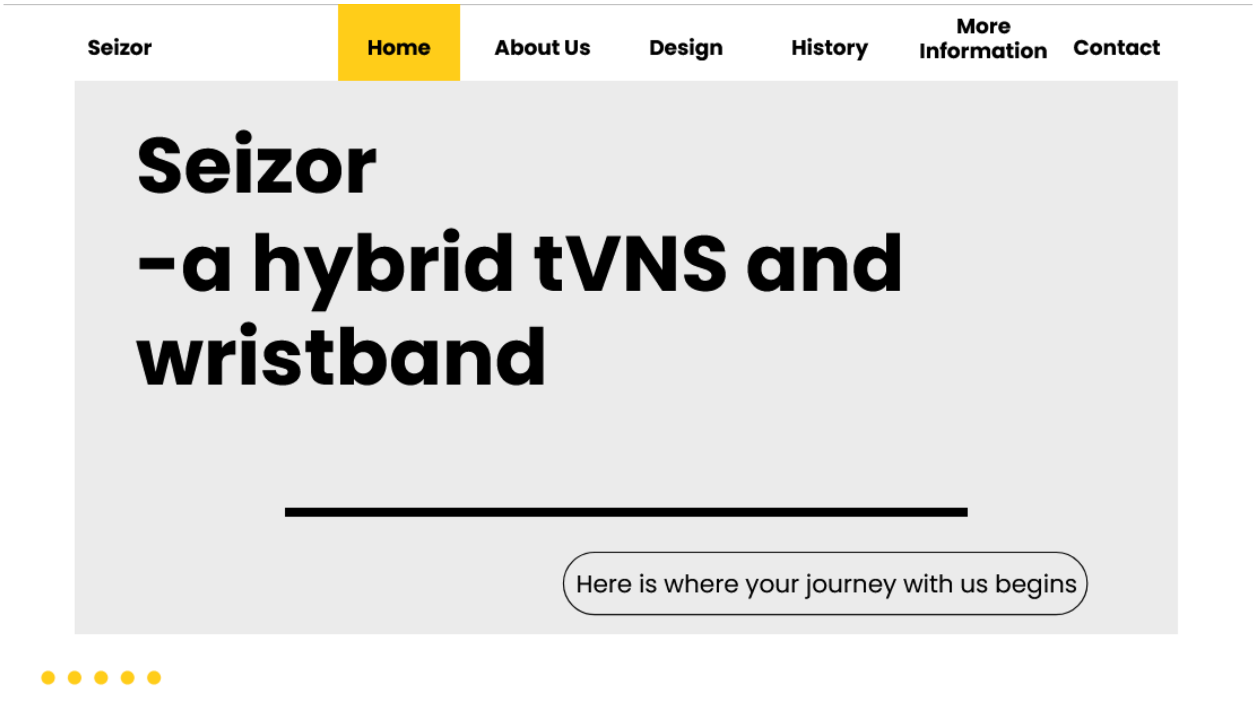


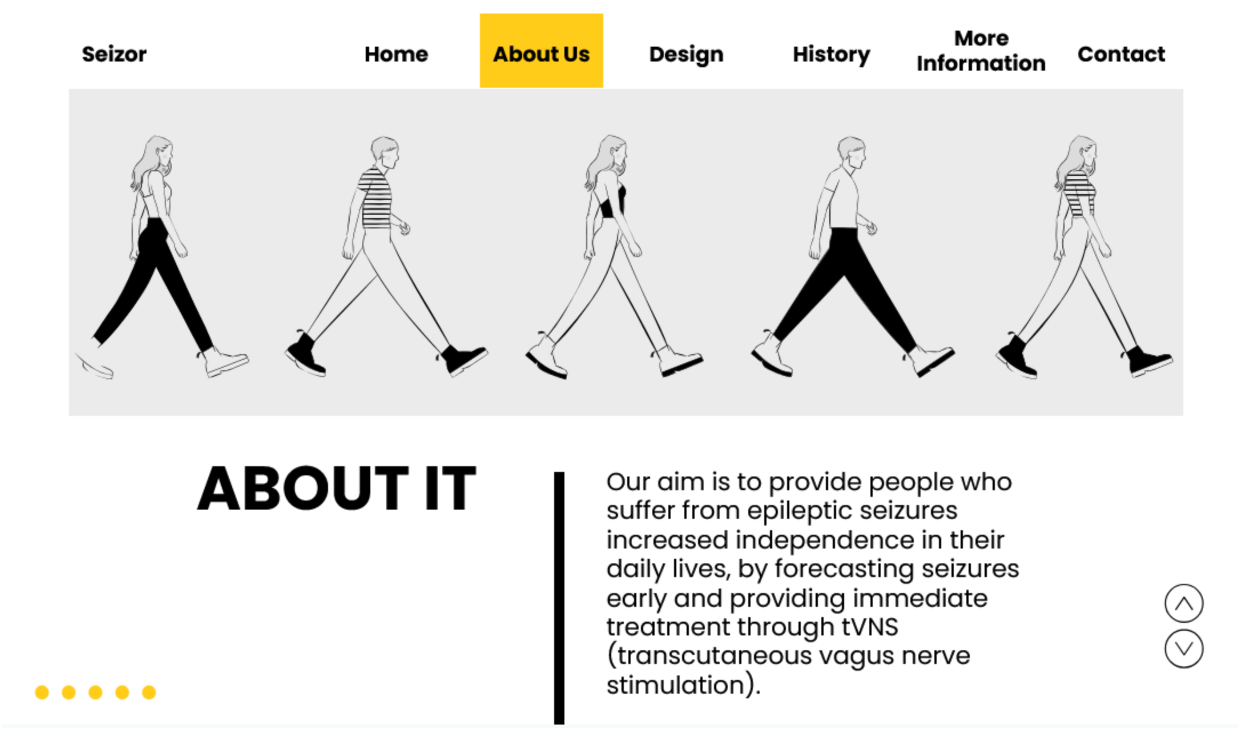

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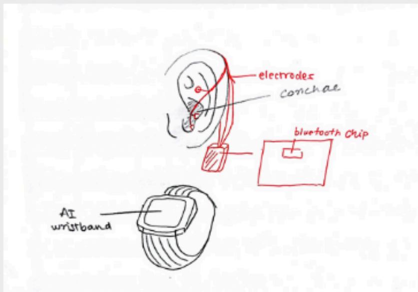


Seizor is made up of two pieces, the earpiece and the wristband. The wristband acts as a detector, forecasting seizures before they occur, with top-notch AI features, dedicated to tailor it's database to your experiences and data.

The earpiece is connected to the outer part of the ear, specifically on the concha. It receives transmissions from the wristband via bluetooth and acts as a preventative measure, by emitting electrical signals to the brain, allowing it to reduce the intensity of a seizure.

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# Seizor

Technology has always been evolving to help those with seizures from all walks of life. Previous treatment has been regulated to surgery, AED's (antiepileptic drugs), Electromyography (EEG's) and other forms, like ketogenic diets. Recent technology has slowly evolved to give rise to VNS (Vagus Nerve Stimulation) and tVNS, which is a main component of Seizor and how it works. By passing electrical pulses through the vagus nerve, it is an effort to reduce the overactivity in certain parts of the brain, where the seizure is occuring.

The wristband in Seizor is equipped with a variety of sensors aimed to detect seizures accurately and efficiently. It uses EDA, accelerometers, temperature and sweat, as well as previous iEEG records from hospital visits, all aimed to produce the most accurate prediction and forecast when the seizure occurs.

Our AI uses Long-term short memory learning models, which are well equipped for holding large sets of data and important data that can be brought back to check on a patient's history.

Please contact us if you have more questions on how the AI works.