ENGINEERING WORLD HEALTH 2021
DESIGN COMPETITION

LOW-COST, EEG BASED WEARABLE SEIZURE PREDICTION ALARM

TEXAS ENGINEERING WORLD HEALTH

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I. Problem Definition

Epilepsy is a chronic and severe neurological disease that affects 65 million people worldwide [1]. Although idiopathic in many cases, epileptic seizures may be caused by previous trauma to the brain such as hypoxia during labor, head injury, and/or bacterial meningitis [2]. Beyond physiological symptoms caused by excessive neuronal activity in the brain, epilepsy is frequently the subject of social stigma, with patients often suffering from discrimination, misunderstanding, and ostracization from wider society due to the loss of self-reliance and autonomy [1]. Although many cases can successfully be treated, treatment is often too inaccessible or expensive for patients, preventing them from treating the disease as well as mitigating its symptoms [1]. This is especially clear in low and middle-income countries where vast treatment gaps already exist across the board for many diseases, with the global median epilepsy treatment gap for active epilepsy ranging from 25% to 100% in 2012 [2]. One of the most dangerous and consequences of epilepsy is the possibility of sudden unexpected death in epilepsy (SUDEP) [3]. Considering that patients were found to be prone and pulseless just 15 minutes after the beginning of a SUDEP-inducing seizure, it is believed that devices and methodologies allowing for quick or premature intervention before each seizure is necessary for epilepsy patients to avoid potential SUDEP or general bodily injury [3].

To address the treatment gap for epileptic seizures in developing low and middle-income nations, we propose a simple and efficient seizure prediction system consisting of a neural network and an associated low-cost wearable alarm system. The integral comfort and safety features associated with this system would greatly reduce the mortality rate from SUDEP and general injury. By working towards this goal, we intend to allow patients to not only receive any possible urgent biomedical treatment in advance of the seizure, but also mitigate any potential injury from a sudden fall by simply laying prone. This is achieved through training a machine learning model to classify between preictal (before an ictal or seizure event) and interictal EEG data segments [4]. This model is then paired with a novel 16 channel 10-20 system EEG head cap that alerts the user and their family of an onset of a seizure. The electrode system is connected to a Open BCI Cyton-board with a Daisy attachment that filters the raw EEG signals. These signals are sent, via bluetooth, to a Raspberry Pi, which stores the machine learning algorithm. If the model detects the presence of preictal waveforms in sensor data, which indicates the onset of a seizure, then the Pi will output an alarm system providing the user and surrounding pedestrians both visual and auditory feedback. Built to be low-cost and with minimal complexity, this system is lightweight and simple enough for widespread use by epilepsy patients with lack of treatment options throughout the developing world.

II. Statement of Impact in Developing World

Current approaches to seizure treatment around the world focus on treatment with anti-epileptic drugs (AEDs) after an initial diagnosis based on symptoms presented [5]. AED administration in developing countries can cause severe side effects from anemia to hepatitis, and with malabsorption and malnutrition syndromes (factors which can interfere with AED efficacy) being common facts of life across poorer countries, epilepsy can be controlled -- with around 70% of patients in the developing world eventually entering long-term remission -- but only with extreme difficulty through the pharmaceutical-driven methods applied throughout the developed world [5]. Therefore, it becomes necessary to explore whether technology can play a role in alleviating difficulty in treating epilepsy. Recent steps forward in treating epilepsy in developed countries have begun to explore advances in machine learning and artificial intelligence as tools for detecting the presence of a seizure [6]. These prior methods have focused on comparing nonlinearity between epileptic ictal EEG samples with normal samples to potentially immediately inform a patient and their surroundings after ictal onset [6].

However, since patients can be found without a pulse within just 15 minutes of ictal onset during a SUDEP event and can easily fall from a standing position and cause self-injury almost immediately, our solution instead surpasses detection to focus on short-term prediction [3]. This allows patients and their families to monitor their own status without needing permanent access to a nurse or doctor, especially in the developing world where healthcare worker shortages are prevalent. By giving the patient a few minutes of leeway between detection of preictal waveforms and the ictal phase itself, our solution allows patients to move themselves to a safe place and a safe prone position to minimize any injuries and receive monitoring from their families. Considering that reducing the frequency and impact of convulsive seizures can reduce a critical risk factor for SUDEP, allowing family members time to reach the patient and provide that necessary supervision or medication before ictal onset through the signal given by our brain-computer interfacing EEG headset may lower SUDEP and general injury incidence through prediction and prevention [7]. For this reason, we consider this treatment modality far more effective to compensate for the poor current state of healthcare and support systems for epilepsy found in the developing world, as compared to current responsive systems used in the developed world that medical professionals have tried to simply apply to a radically different situation. Our solution empowers patients and their families to take a larger role in their own health through the use of novel technologies that help to further streamline and increase efficacy of epilepsy treatment in the developing world.