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# Poster: RADAR-base: Epilepsy Case Study

**Zulqarnain Rashid**

Institute of Psychiatry,  
Psychology & Neuroscience  
King's College London  
London, SE5 8AF, UK  
zulqarnain.rashid@kcl.ac.uk

**Callum L Stewart**

Institute of Psychiatry,  
Psychology & Neuroscience  
King's College London  
London, SE5 8AF, UK  
callum.stewart@kcl.ac.uk

**Sebastian Böttcher**

Epilepsy Center, Medical Center  
- University of Freiburg  
79106 Freiburg, Germany  
sebastian.boettcher@uniklinik-  
freiburg.de

**Yatharth Ranjan**

Institute of Psychiatry,  
Psychology & Neuroscience  
King's College London  
London, SE5 8AF, UK  
yatharth.ranjan@kcl.ac.uk

**Richard JB Dobson**

Institute of Psychiatry,  
Psychology & Neuroscience  
King's College London  
London, SE5 8AF, UK  
richard.j.dobson@kcl.ac.uk

**Amos A Folarin**

Institute of Psychiatry,  
Psychology & Neuroscience  
King's College London  
London, SE5 8AF, UK  
amos.folarin@kcl.ac.uk

**Abstract**

The traditional hospital set-up is not appropriate for long-term epilepsy seizure detection in naturalistic ambulatory settings. To explore the feasibility of seizure detection in such a setting, an in-hospital study was conducted to evaluate three wearable devices and a data collection platform for ambulatory seizure detection. The platform collects and processes data for study administrators, clinicians and data scientists, who use it to create models to detect seizures. For that purpose, all data collected from the wearable devices is additionally synchronized with the hospital EEG and video, with gold-standard seizure labels provided by trained clinicians. Data collected by wearable devices shows potential for seizure detection in out-of-hospital based and ambulatory settings.

**Author Keywords**

mHealth; mobile app; seizures; epilepsy; brain disorders

**ACM Classification Keywords**

H.5.m [Human-centered computing (HCC)]: Ubiquitous and mobile computing.

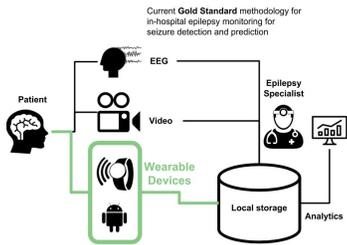
**Introduction**

The 22m Euro Remote Assessment of Disease and Relapse - Central Nervous System (RADAR-CNS) Innovative Medicines Initiative (IMI2) is a research programme aimed

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**Figure 1:** Data flow for the epilepsy study, enabling A) investigation of data quality from the wearable devices and B) comparison of clinical information from new data streams to gold standard methods (EEG and video).

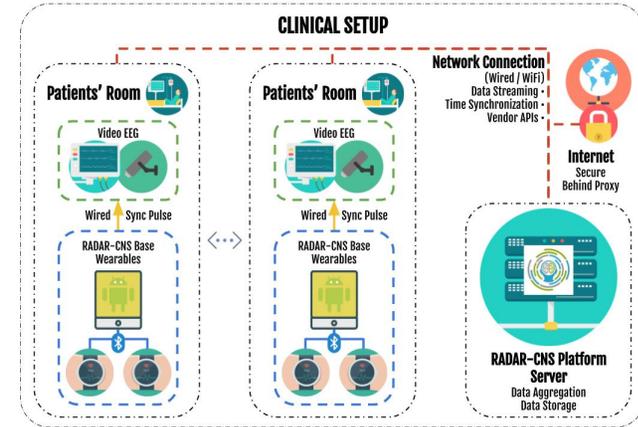
at developing novel methods and infrastructure for measuring major depressive disorder, epilepsy, and multiple sclerosis [1]. The goals of RADAR-CNS are achieved through the RADAR-base platform [2]. RADAR-base aims to provide a highly extensible platform that enables remote streaming data collection, secure data transmission and scalable solutions for data storage, management and access. This paper focuses on the Epilepsy which uses in-hospital deployments of the platform to evaluate the capability of unobtrusive wearable devices for seizure detection.

Epilepsy is a common serious neurological condition, affecting around 6 million people in Europe. A person may experience a seizure at any place in any situation (both night and day). Wearable devices have the potential to detect seizures in daily living conditions allowing the study of factors and precursors influencing seizure onset. The downstream opportunity of real-time streaming capabilities of the RADAR-base platform is especially advantageous in epilepsy, as it may form the basis of a system to prevent e.g. sudden unexpected death in epilepsy (SUDEP).

The first application of RADAR-base is currently ongoing in a trial of approximately 200 patients across two sites. Patients are recruited prior to undergoing routine inpatient video-EEG monitoring as part of their conventional care. Patients are typically recorded for 5-7 days. During this period, additional devices are worn by the patient including the Empatica E4, Biovotion Everion, and Faros 180. The concurrently recorded video-EEG provides a gold standard against which the capability of these devices to detect generalized tonic-clonic and focal seizures can be evaluated.

### Related Work

Many studies measuring non-EEG sensor seizure detection performance have been conducted [4]. The major-



**Figure 2:** System Overview: Wearable devices are streaming data to RADAR-base platform in parallel to video-EEG.

ity of work has used accelerometers, however increasing availability of different sensors has led to a greater focus on multimodal seizure detection [4]. Most studies so far have been conducted in clinical environments or confined to a single room and data often manually transferred [3]. However, Vandecasteele et. al. [5] used a commercially available cloud-based platform to store privacy-sensitive data. Similarly, Velez et. al. [6] transferred data over Bluetooth to a paired tablet device, which then uploaded to a database over WiFi. However, only potential seizure events detected by the wearable device were transferred. By contrast, the RADAR-base platform, provides a step change in the capability for continuous high-frequency recordings from commonly worn devices to be uploaded and processed in real-time, while guaranteeing full control over the data and platform architecture.



**Figure 3:** In-hospital epilepsy patient wearing devices (green), connected to a tablet (red).

## Methods and Procedures

The RADAR-CNS epilepsy case study involves collecting data to a locally deployed server hosting the RADAR-base platform, which synchronously collects data in parallel to the video-EEG set-up. The requirements fulfilled by the data collection apparatus are: (i) integration of several different wearable device types for separate collateral data collection; (ii) capability to stream the device data in real-time, with little or no patient interaction; (iii) easy management of the involved devices for patients and study staff; (iv) synchronisation of the wearable sensor data with the video-EEG to an accuracy of 1/10s.

The wearable devices will route their data through an Android device, one per patient. From there it is sent to the platform server, for processing and availability to study staff. In turn, the Android devices and video-EEG machines regularly synchronise with a common time-server. A detailed clinical set-up is shown in Figures 1 and 2. Figure 3 shows a patient in a hospital ward wearing several devices, and the tablet streaming the sensor data to the platform.

The sensor set was established based on the need for several parameters of interest such as heart rate variability (via PPG, EKG), acceleration and electrodermal activity. Devices capable of streaming some or all of these included the Empatica E4 (wrist), Biovotion Everion (upper arm), and Faros 180 (chest). An additional factor in the choice of devices was the sensor placement, which can affect the quality of the data produced. For example, there is greater moment of inertia at the wrist as compared to the upper arm or chest, so movements generated by spasm during seizures produce a stronger signal. Conversely, photoplethysmography is sensitive to light and motion artefacts, resulting in significant noise in recordings at the wrist, especially during motor seizures.

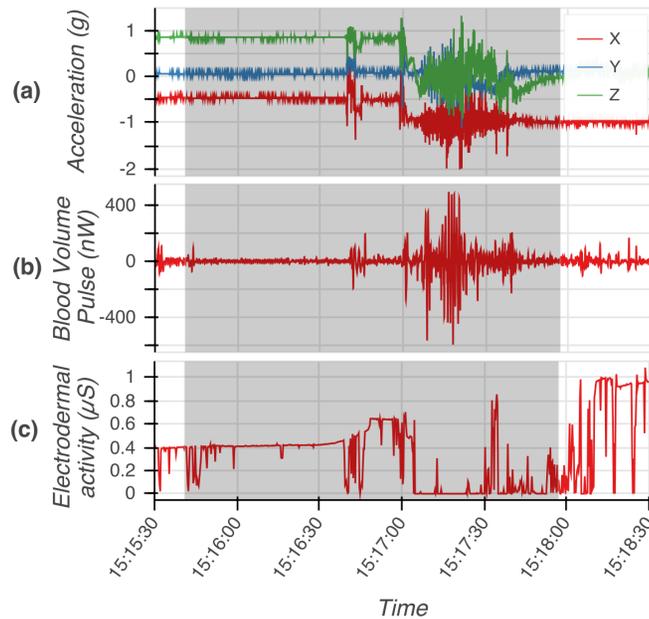
In addition, the selected devices are all capable of connecting to an Android device and streaming the collected raw data in real-time via a bluetooth connection. Removing the need for future ambulatory patients to manage data downloads in their home and provides clinicians with a real-time overview of the patient's condition and research study management.

The Platform provides structured raw data that can easily be processed, e.g. to analyse the utility and effectiveness of the devices in epilepsy studies. Furthermore, raw data can be used offline to train new seizure detection models, which can be incorporated into the platform's real-time data processing infrastructure to test them on new data as it is being collected. Thus the platform also provides the possibility for real-time seizure detection and alerting.

## Results

The presented set-up has been successfully tested in an ongoing clinical trial at the video-EEG monitoring units of both the Clinical Neurophysiology Department at King's College Hospital London and the Epilepsy Center at the University Hospital of Freiburg. As of June 2018, 125 patients have been enrolled at both of the sites.

Where possible, participants have concurrently worn all three devices, the Empatica, Biovotion and Faros. Figure 4 shows a three-minute segment of acceleration, blood volume pulse and electrodermal activity during a focal seizure event. The motor component can clearly be seen in the accelerometry, as well as the significant impact of the patients movements on the blood volume pulse signal, which is generated by the photoplethysmography sensor of the Empatica E4. Characteristic changes in all signals have been observed during seizure events of several different types (generalized tonic-clonic and focal seizures).



**Figure 4:** Empatica E4 sensor data. The shaded area indicates a focal seizure with a motor component. (a) Accelerometer. (b) Photoplethysmogram. (c) Electrodermal activity.

### Conclusion and Future Work

We are investigating the potential of wearable devices as clinically valuable alternatives to complement hospital-based technologies, and as a prerequisite to future ambulatory passive remote monitoring of patients in their home environment. The capabilities of the RADAR-base platform are sufficient for an in-hospital study of patients with epileptic seizures, and a further out-of-hospital ambulatory is under planning.

### Acknowledgements

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