2nd INTERNATIONAL CONGRESS ON MOBILE DEVICES AND SEIZURE DETECTION IN EPILEPSY

Lausanne, Switzerland

September, 6-7, 2019

Co-Chairs : Philippe Ryvlin & Sándor Beniczky

CHUV

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About Eisai

Our motivation is the potential for more people living with epilepsy to be seizure free. It is what drives us as individuals working within Eisai and is supported throughout the company by our guiding philosophy of *human health care*.

This means giving first thought to patients and their families and to increasing the benefits health care provides.

Using our scientific knowledge and understanding of the real, everyday challenges faced by patients around the world, Eisai strives to improve the life chances of people living with epilepsy, through thinking beyond the seizure and focussing on what matters most to patients and those who care for them.

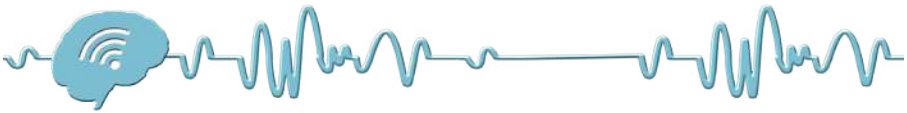
For more information about Eisai, please visit **www.eisai.co.uk**

Epilepsy is **challenging** but don't let it *define* you as a person. It is only one part of who you are. *Live* life and always have **gratitude**.

Nicola, Ollie's mum
(Ollie was diagnosed with epilepsy at 2 months old)

EMEA-EPI-19-00015
Date of preparation: June 2019

SUMMARY



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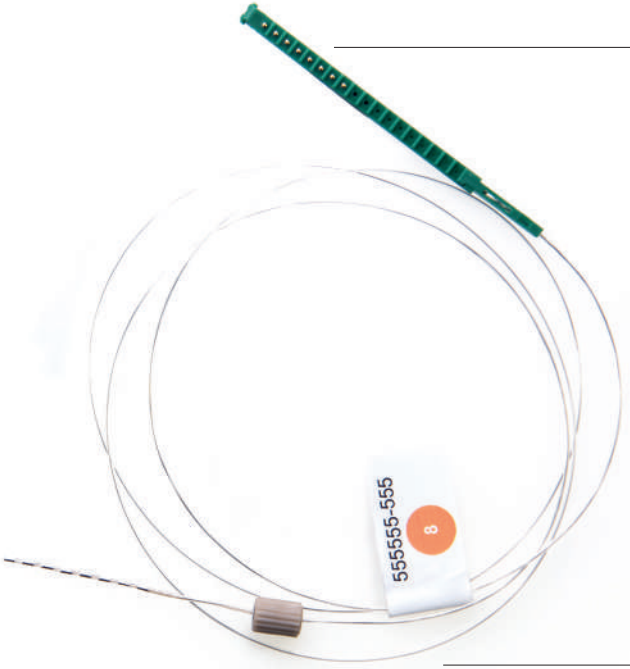

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COMMITTEE

Co-chairs:
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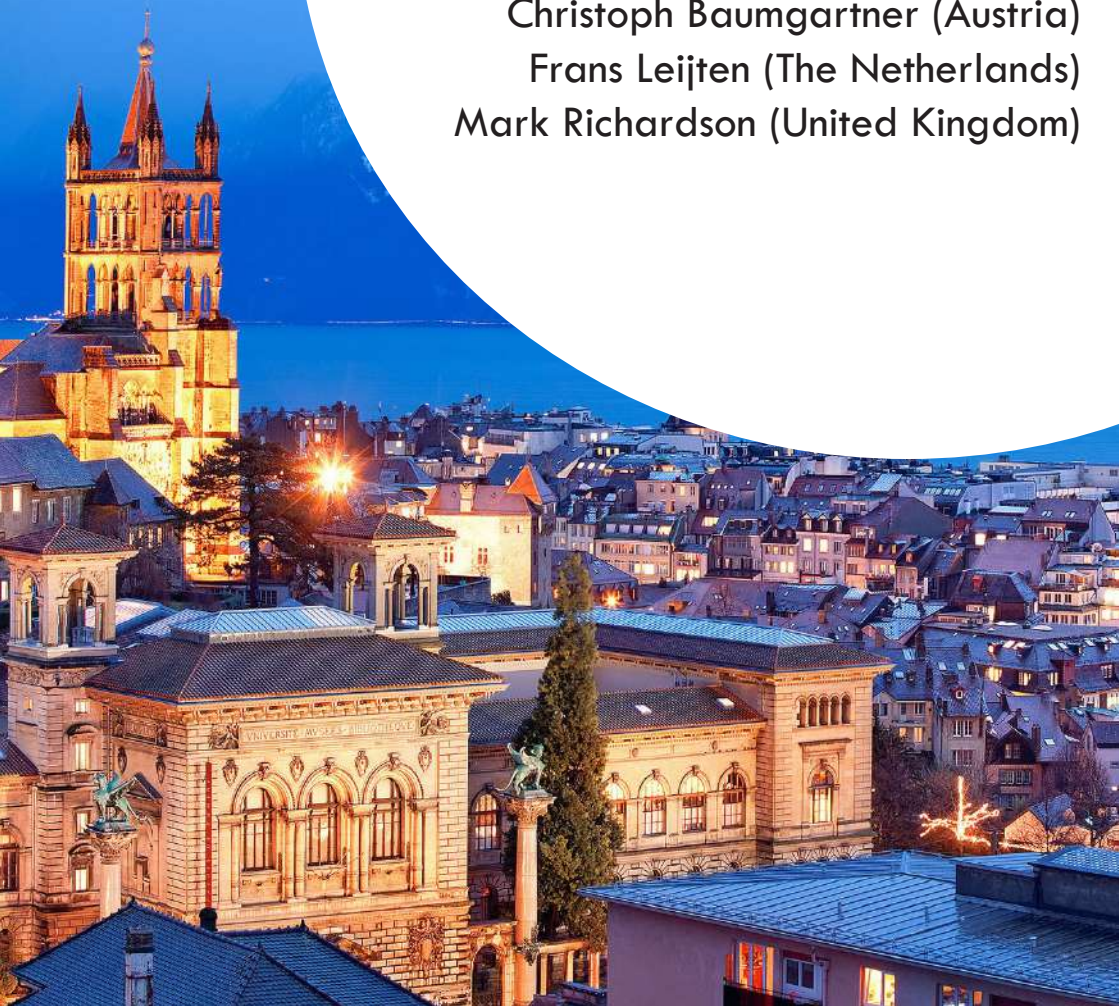
Sándor Beniczky (Denmark)

Members:
Christoph Baumgartner (Austria)
Frans Leijten (The Netherlands)
Mark Richardson (United Kingdom)



EDITORIAL

We are honored to welcome you to the Second International Congress on Mobile Health Devices and Seizure Detection in Epilepsy to be held in Lausanne September 6-7 2019.

The first edition held in Copenhagen in 2017 was very successful in gathering 150 stakeholders active in the field.

The main topics of this second edition:

- State-of-the-art and Innovative technologies for EEG and non-EEG based seizure detection
- Clinical needs for seizure detection
- Reimbursement issues for mHealth solutions in epilepsy

According to the rapid developments observed in the field, we are very confident that this second edition will be even more successful, taking advantage of the unique NeuroTechnology environment of the Lemanic region.

Best regards,

Sándor Beniczky,
Aarhus & Dianalund

Philippe Ryvlin,
Lausanne

PROGRAM AT A GLANCE

MASTERCLASS - Thursday, September 5

Reserved to registered participants only (not included in the «student» or «congress» fee)

Salle BU21 Séminaire 15

03:00 – 04:30 pm	**Welcome**
	Current Best practice of Home-Video Telemetry - Presentations and discussion
05:00 – 06:00 pm	**Future Development - Presentations and discussion**
06:00 – 06:50 pm	**Workshop with Panel discussion / practical demonstrations**
06:50 – 07:00 pm	**Feedback and close**

CONGRESS - Friday, September 6

Auditoire César Roux

08:15 – 08:30 am	**Welcome message**
08:30 – 10:00 am	**Session 1: Why do we need seizure detection at home**
10:30 – 11:30 am	Sponsored lecture: EISAI
11:30 – 01:00 pm	**Session 2: State-of-the-art non-EEG-based seizure detection**
01:00 – 02:15 pm	**Lunch break and Poster discussion**
02:15 – 03:00 pm	Sponsored lecture: NEURO EVENT LABS
03:00 – 04:15 pm	Platform session 1: Mobiles devices
04:45 – 06:00 pm	Platform session 2: Seizure detection (1)
06:30 – 08:00pm	**Visit and welcome aperitif at the Olympic Museum & Congress dinner**

CONGRESS - Saturday, September 7

Auditoire César Roux

08:15 – 09:45 am	**Session 3: State-of-art EEG-based seizure detection/prediction**
10:15 – 10:35 am	Sponsored lecture: MICROMED
10:35 – 10:55 am	Sponsored lecture: EPIHUNTER
10:55 – 12:25 pm	**Session 4: Reimbursement of seizure detection devices/services**
12:25 – 01:45 pm	**Lunch break and Poster discussion**
01:45 – 03:00 pm	Platform session 3: Seizure detection (2)
03:00 – 03:30pm	Keynote lecture
04:00 – 05:15 pm	Platform session 4: Seizure prediction
05:15 – 05:30 pm	**Concluding remarks**

PROGRAM

MASTERCLASS - Thursday, September 5

Salle BU21
Séminaire 15

Reserved to registered participants only (not included in the «student» or «congress» fee

03:00 – 04:30 pm	**Welcome** **Current Best practice of Home-Video Telemetry - Presentations and discussion** *Chairs: Mark Richardson & Sushma Goyal* - Impact and development of HVT *Franz Brunnhuber* - Logistics and challenges of a nationwide reader panel *Jeremy Slater* - Types of HVT integration *Zaloa Agirre* - Rules and Regulations of Cloud computing in the NHS *Damian Lewsley*
04:30 – 05:00 pm	**Break**
05:00 – 06:00 pm	**Future Development - Presentations and discussion** *Chairs: Zaloa Agirre & Stephan Walters* - EEG and Cloud Computing *Gardar Thorvardsson* - King's Cloud Experience *Franz Brunnhuber & Devi Amin* - Artificial intelligence and seizure classification *Andrew Knight*
06:00 – 06:50 pm	**Workshop with Panel discussion / practical demonstrations** - Non-collodion application and bandaging *Sushma Goyal & Matthew Sparkes* - HVT case studies *Zaloa Agirre* - How to set up HVT *Franz Brunnhuber & Devi Amin*
06:50 – 07:00 pm	**Feedback and close**

PROGRAM

CONGRESS - Friday, September 6

Auditoire César Roux

08:15 – 08:30 am	**Welcome message**
08:30 – 10:00 am	**Session 1: Why do we need seizure detection at home** *Chairs: Andrea Rossetti, Switzerland & Michael Sperling, USA* - The physician's view *Mark Richardson, United Kingdom* - The caregiver's view *Francesca Sofia, Italy* - The view of people with epilepsy *Rebecca McGhee, Scotland, UK*
10:00 – 10:30 am	**Coffee break**
10:30 – 11:30 am	Sponsored lecture: EISAI **Does mobile technology have the power to change how we manage epilepsy?**
10:30am	- Welcome and introduction *Co-Chairs: Sándor Beniczky, Department of Clinical Medicine, Aarhus University, Denmark & Philippe Ryvlin, Department of Clinical Neuroscience, University Hospital of Lausanne, Switzerland*
10:40am	- Mobile technology and holistic management of people with epilepsy *Daniel Friedman, NYU Langone School of Medicine, New York, NY, USA*
11:00am	- Lessons from psychiatry *Nikolaos Koutsouleris, Department of Psychiatry and Psychotherapy, University of Munich, Germany*
11:20am	- Panel discussion and Q&A *All faculty*

PROGRAM

11:30 – 01:00 pm

Session 2: State-of-the-art non-EEG-based seizure detection

Chairs: Mark Richardson, UK & Jan Novy, Switzerland

- Quantifying severity of GTCS
Sandor Beniczky, Denmark

- Detecting focal seizures
Philippe Ryvlin, Switzerland

- Novel technologies for multi-parametric seizure detection in smart wearable devices
David Atienza, Switzerland

01:00 – 02:15 pm

Lunch break and Poster discussion

02:15 – 03:00 pm

Sponsored lecture: NEURO EVENT LABS

neuroeventlabs

Chair: Philippe Ryvlin, Switzerland

- This is Neuro Event Labs
CEO NEL Kaapo Annala

- Algorithmic modelling of epileptic episodes
CTO NEL Andrew Knight

- Clinical use of Nelli to help patients, case studies
CMO NEL & Prof. Jukka Peltola

- Validation of Nelli in homelike EMU setting
Dr. Sándor Beniczky

Usage of Nelli in research, new biomarkers for SUDEP
Prof. Philip Ryvlin

- What's next
CEO NEL Kaapo Annala

03:00 – 04:15 pm

Platform session 1: Mobiles devices

Chairs: David Atienza, Switzerland & Simone Benatti, Italy

03:00pm

OC01 - Circadian and Multiday Rhythms, and Seizure Clusters in Naturally Occurring Canine Epilepsy

Nicholas GREGG (1), Ned PATTERSON (2), Beverly STURGES (3), Benjamin BRINKMANN (1), Gregory WORRELL (1) - (1) Mayo Clinic, United States, (2) University of Minnesota, United States, (3) University of California at Davis, United States

03:15pm

OC02 - A home based trial on multimodal nocturnal seizure detection in children: interim results of the PROMISE study

Anouk VAN WESTRHENEN (1, 2), Frans LEIJTEN (3), Richard LAZERON (4, 5), Roland THIJS (1, 2) - (1) Stichting Epilepsie Instelling Nederland (SEIN), The Netherlands, (2) Leiden University Medical Center, department of neurology, The Netherlands, (3) University Medical Center Utrecht, department of neurology, The Netherlands, (4) Academic Center of Epileptology Kempenhaeghe, The Netherlands, (5) Faculty of Electrical Engineering, Technical University Eindhoven, The Netherlands

03:30pm

OC03 - In-field validation of epihunter for the detection of absence seizures using wearable EEG

Dirk LOECKX, Tim BUCKINX - epihunter NV, Belgium

03:45pm

OC04 - e-Glass: A Wearable System for Real-Time Epilepsy Monitoring

Renato ZANETTI, Dionisije SOPIC, Amir AMINIFAR, David ATIENZA - Embedded Systems Laboratory (ESL), Swiss Federal Institute of Technology Lausanne (EPFL), Switzerland

04:00pm

OC05 - Heart rate variability parameters as surrogate markers of seizure severity

Anca Adriana ARBUNE (1, 2), Jesper JEPPESEN (3, 4), Philippe RYVLIN (5), Sandor BENICZKY (1, 4, 3) - (1) Department of Clinical Neurophysiology, Danish Epilepsy Centre, Denmark, (2) Department of Clinical Neurosciences, "Carol Davila" University of Medicine and Pharmacy, Romania, (3) Department of Clinical Neurophysiology, Aarhus University Hospital, Denmark, (4) Department of Clinical Medicine, Aarhus University, Denmark, (5) Department of Clinical Neurosciences, CHUV, Switzerland

04:15 – 04:45 pm **Coffee break**

04:45 – 06:00 pm **Platform session 2: Seizure detection (1)**

Chairs: Christoph Baumgartner, Austria & Sándor Beniczky, Denmark

04:45pm

OC06 - Automated seizure detection based on heart rate variability using a wearable ECG device

Jesper JEPPESEN (1), Anders FUGLSANG-FREDERIKSEN (1), Peter JOHANSEN (2), Jakob CHRISTENSEN (3), Beniczky SÁNDOR (1) - (1) Department of Neurophysiology, Aarhus University Hospital, Denmark, (2) Department of Engineering, Aarhus University, Denmark, (3) Department of Neurology, Aarhus University Hospital, Denmark

PROGRAM

05:00pm

OC07 - Detection of Epileptic Seizures using Hybrid Artificial Intelligence Techniques based Wavelet Transforms and Information Criteria

Ozan KOCADAGLI (1), Candan GURSES (2) - (1) Department of Statistics,Faculty of Science and Letters, Mimar Sinan University, Turkey, (2) Department of Neurology, School of Medicine, Koc University, Turkey

05:15pm

OC08 - Computer-assisted diagnostic review for epilepsy

Ewan NURSE (1), Shannon CLARKE (1), Philippa KAROLY (2), Udaya SENEVIRATNE (3), Dean FREESTONE (1) - (1) Seer Medical, Australia, (2) University of Melbourne, Australia, (3) Medicine Monash Health, Australia

05:30pm

OC09 - Personalized multimodal detection of focal impaired awareness seizures using behind-the-ear EEG and heart rate

Thomas DE COOMAN (1), Kaat VANDECASTEELE (1), Evy CLEEREN (2), Wim VAN PAESSCHEN (2), Sabine VAN HUFFEL (1) - (1) Department of Electrical Engineering - KU Leuven, Belgium, (2) Department of Neurology, UZ Leuven, KU Leuven, Belgium

05:45pm

OC10 - Technical Validation of Sensor Dot: a Multimodal Wearable for Ambulatory Monitoring of Epileptic Seizures

Benjamin VANDENDRIESSCHE (1), Dorien WECKHUYSEN (2), Jonathan DAN (3), Evy CLEEREN (2), Wim VAN PAESSCHEN (2) - (1) Case Western Reserve University, United States, (2) University Hospital Leuven, Belgium, (3) KU Leuven, Belgium

06:30 – 08:00pm

Visit at the Olympic Museum & Welcome aperitif for all the participants

Followed by the congress dinner (only upon reservation)

LE MUSÉE OLYMPIQUE

CONGRESS - Saturday, September 7

Auditoire César Roux

08:15 – 09:45 am	**Session 3: State-of-art EEG-based seizure detection/ prediction** *Chairs: Frans Leijten, The Netherlands & Franz Brunnhuber, UK* - Detecting/prediciting seizures with intracerebral EEG *Mark Cook, Australia* - Seizure monitoring in coma and ICUs *Christoph Baumgartner, Austria* - Novel technologies for chronic EEG recordings *Simone Benatti, Italy*
09:45 – 10:15 am	**Coffee break**
10:15 – 10:35 am	Sponsored lecture: MICROMED **Home LTM for Paediatric presurgical assessment: is the technology ready yet? Audit of a 4 years' experience** *Caroline Scott, UK*
10:35 – 10:55 am	Sponsored lecture: EPIHUNTER **Living with absence epilepsy - a parent's view** *Chairs: Dirk Loeckx, CSO Epihunter NV, Hasselt, Belgium & Sándor Beniczky, Department of Clinical Medicine, Aarhus University, Denmark* *Tim Buckinx, CEO Epihunter NV, Hasselt, Belgium*
10:55 – 12:25 pm	**Session 4: Reimbursement of seizure detection devices/ services** *Chairs: Caroline Scott, UK & Francesca Sofia, Italy* - The regulators point of view *Kim Rochat, Switzerland* - The companies' point of view *Matteo Lai, Italy* - The medical justification *Michael Sperling, USA*
12:25 – 01:45 pm	**Lunch break and Poster discussion**

PROGRAM

01:45 – 03:00 pm	**Platform session 3: Seizure detection (2)** *Chairs: Philippe Ryvlin, Switzerland & Michael Sperling, USA*
01:45 pm	**OC11** - Novel algorithm for seizure detection in wearable electroencephalography Jonathan DAN (1, 2), Benjamin VANDENDRIESSCHE (3), Wim VAN PAESSCHEN (1), Dorien WECKHUYSEN (1), Alexander BERTRAND (1) - (1) KU Leuven, Belgium, (2) Byteflies, Belgium, (3) Byteflies, United States
02:00 pm	**OC12** - Automated video-based detection of nocturnal motor seizures in children Anouk VAN WESTRHENEN (1, 2), George PETKOV (1), Stiliyan KALITZIN (1), Roland THIJS (1, 2), On behalf of the DUTCH TELEEPILEPSY CONSORTIUM (3) - (1) Stichting Epilepsie Instelling Nederland (SEIN), The Netherlands, (2) Leiden University Medical Center, department of neurology, The Netherlands, (3) TeleEpilepsy Consortium, The Netherlands
02:15 pm	**OC13** - Real-Time Epileptic Seizure Detection Based on Cardiorespiratory Response Farnaz FOROOGHIFAR (1), Amir AMINIFAR (1), Philippe RYVLIN (2), David ATIENZA (1) - (1) EPFL, Switzerland, (2) CHUV, Switzerland
02:30 pm	**OC14** - A multimodal garment with integrated sensors - the next step in the development Kristina MALMGREN (1), Dongni JOHANSSON BUVARP (1), Jan WIPENMYR (2) - (1) Institute of Neuroscience and Physiology, Sahlgrenska Academy at Gothenburg University, Sweden, (2) RISE Research Institutes of Sweden AB, Sweden
02:45 pm	**OC15** - Detection of nonconvulsive seizures using limited montage EEG Olga TARASCHENKO, Nicholas SWINGLE, Aditya VUPPALA, Proleta DATTA, Swetha PEDAVALLY - University of Nebraska Medical Center, United States
03:00 – 03:30 pm	**Keynote lecture** **Dilemma's in science-commerce collaboration: experiences from NightWatch®** *Frans Leijten, The Netherlands*
03:30 – 04:00 pm	**Coffee break**

04:00 – 05:15 pm **Platform session 4: Seizure prediction**

Chairs: Mark Cook, Australia & Franz Brunnhuber, UK

04:00 pm **OC16** - Epileptic Seizure Prediction Using EMU Data and Personalized Deep Learning

Mehrdad NOURANI (1), Jay HARVEY (2) - (1) University of Texas at Dallas, United States, (2) UT Southwestern Medical Center, United States

04:15 pm **OC17** - Nonlinear brain-heart interactions in children with focal epilepsy assessed by mutual information of EEG and heart rate variability

Anton POPOV (1, 2), Riccardo PERNICE (3), Ivan KOTIUCHYI (4, 2), Luca FAES (3), Alessandro BUSACCA (3), Volodymyr KHARYTONOV (5) - (1) Department of Electronic Engineering, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine, (2) Ciklum R&D Engineering, United Kingdom, (3) Department of Engineering, University of Palermo, Italy, (4) Department of Biomedical Engineering, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine, (5) TMO "Psychiatry", Ukraine

04:30 pm **OC18** - My Seizure Gauge: Seizure detection and prediction with noninvasive wearable devices

Benjamin BRINKMANN (1), Ewan NURSE (2), Mona NASSERI (1), Dean FREESTONE (2), Mark RICHARDSON (3) - (1) Mayo Foundation, United States, (2) Seer Medical, Australia, (3) King's College, United Kingdom

04:45 pm **OC19** - Non-invasive seizure forecasting

Philippa KAROLY (1), Matias MATURANA (1), Ewan NURSE (2), Dean FREESTONE (2), Mark COOK (1) - (1) The University of Melbourne, Australia, (2) Seer Medical, Australia

05:00 pm **OC20** - Predicting epileptic seizures using machine learning and a novel wearable device

Rajlakshmi BORTHAKUR (1), Sanjib SINHA (2) - (1) Terra Blue Exploration Technologies Private Limited, India, (2) NIMHANS, India

05:15 – 05:30 pm **Concluding remarks**

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GENERAL INFORMATION

RECEPTION DESK

Thursday, September 5	**02.00pm** (Salle BU21 - Sém. 15)
Friday, September 6	**07.30am** (Auditoire César Roux)
Saturday, September 7	**07.30am** (Auditoire César Roux)

Posters' setup

Friday, September 6 before 10.00am

Posters must be taken off on Saturday, September 7 after lunch. No poster will be kept after 04.00pm.

LUNCHES

Friday, September 6
01.00-02.15pm
Saturday, September 7
12.25-01.45pm

COFFEE BREAKS

Coffee breaks will be served on the exhibition space.

SOCIAL PROGRAM

Friday, September 6

Quai d'Ouchy 1, 1006 Lausanne, Switzerland

LE MUSÉE OLYMPIQUE

06.30-08.00pm
Visit at the Olympic Museum & welcome aperitif (for all congress' participants)

08.00pm
Followed by the congress dinner (only upon reservation)

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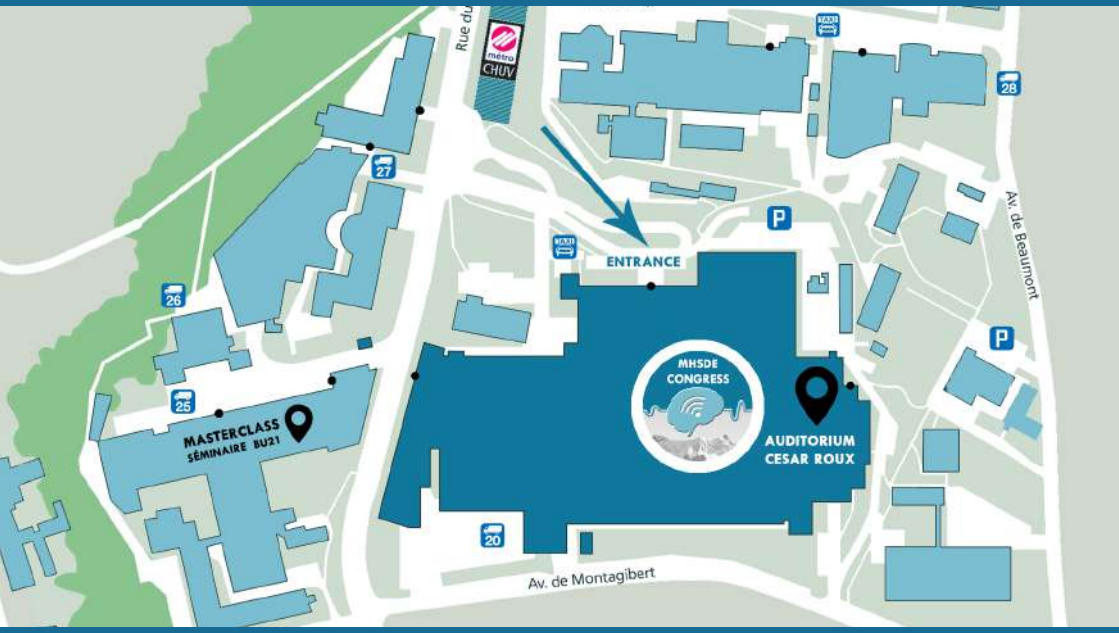
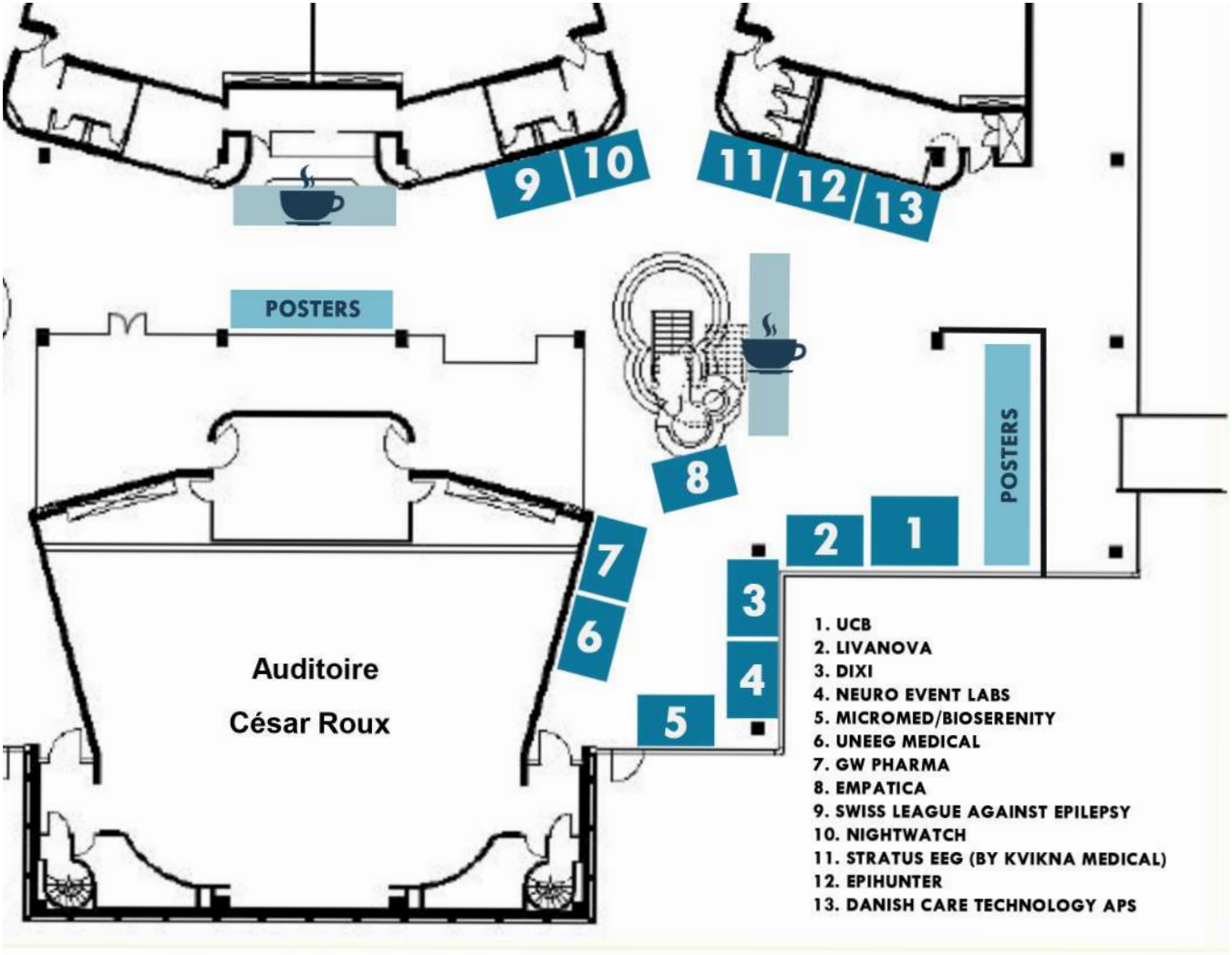


EXHIBITION MAP



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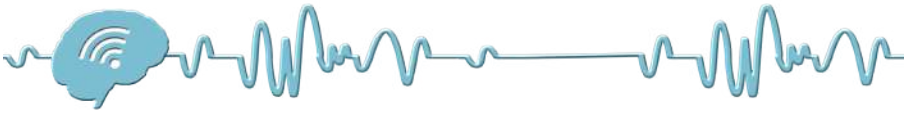
ABSTRACTS' SUMMARY



LECTURES ABSTRACTS

Session 2: State-of-the-art non-EEG-based seizure detection

Quantifying severity of Generalized Tonic-Clonic Seizures

Sandor Beniczky, Denmark

Our objective was to test the hypothesis that neurophysiological biomarkers of muscle activation during convulsive seizures reveal severity of the seizures, and to determine whether automatically computed surface electromyography (EMG) parameters during seizures can predict postictal generalized EEG suppression (PGES), indicating an increased risk for sudden unexpected death in epilepsy (PGES). Wearable EMG devices have been clinically validated for automated detection of generalized tonic-clonic seizures (GTCS). Our goal was to use automated EMG measurements for seizure-characterization and risk-assessment. Quantitative parameters were automatically computed from surface EMG signals, recorded during convulsive seizures, from deltoid and brachial biceps muscles, in patients admitted to long-term video-EEG monitoring. These parameters consisted in the durations of the seizure phases (tonic, clonic), durations of the clonic bursts and of the silent periods, as well as the dynamics of their evolution (slope). We compared them with the duration of the PGES.

We found significant correlations between the automatically computed EMG parameters and the duration of PGES ($p<0.001$). Stepwise multiple regression analysis identified as independent predictors, in deltoid muscle the duration of the clonic phase, and in biceps muscle the duration of the tonic-clonic phases, the average silent period and the slopes of the silent period and of the clonic bursts. An algorithm constructed from these parameters identified seizures at increased risk (PGES $\geq$20s) with an accuracy of 87%.

We concluded that automatically computed ictal EMG parameters correlate with PGES. This study provides evidence that quantitative ictal EMG parameters are biomarkers for high-risk convulsive seizures.

Session 2: State-of-the-art non-EEG-based seizure detection

Detecting focal seizures

Philippe Ryvlin, Switzerland

While a number of non-invasive biosignals and related sensors and algorithms have demonstrated their capacity to detect generalized tonic-clonic seizures (GTCS) with clinically-relevant sensitivity and specificity, this has not yet been achieved for focal seizures, the most frequent seizure-type in patients with drug-resistant epilepsy.

The main challenge to detect focal seizures is the great variety of such attacks across patients, in contrast with the high homogeneity of GTCS. When considering the currently available biosensors, i.e. EEG, EKG, photoplethysmography (for heart rate and SPO2), 3D-accelerometry and electro-dermal activity, it is clear that each of these biosensors will be sensitive to only some types of focal seizures. For instance, 3D-accelerometry will be able to detect stereotyped large and/or unusual movements, such as hypermotor seizures, as long as these movements involved the body part equiped with the sensor. In less kinetic seizures, changes in heart rate (in particular tachycardia), respiration and oxygen saturation or electrodermal activity might be more helpful (and more reliably monitored). However, experience with implanted EKG embedded in a vagus nerve stimulator has shown that increased heart rate > 50% was only observed in 16% of seizures. Moreover, using such a threshold, false detections occurred at an unacceptable rate of one per hour. While EEG remains the hallmark of epileptic seizures, we still lack non-invasive recording systems which patients could wear permanently without stigma, though a number of initiatives are working on such solutions. The latter will also have to deal with the challenging issues of artefacts and signal to noise ratio for some seizure types.

According to the above, one promising direction is the development of multimodal detection systems with embedded machine learning. Such systems would enable to adapt both the role of the different sensors (i.e. permanent monitoring versus on-demand activiation) and the detection algorithm to the individual patient and seizure type.

LECTURES ABSTRACTS

Session 2: State-of-the-art non-EEG-based seizure detection

Novel technologies for multi-parametric seizure detection in smart wearable devices

David Atienza, Switzerland

Smart wearable devices is poised as the next frontier of innovation to be able to provide personalized healthcare by interacting also with our everyday objects, which can be interconnected in ways that improve our lives and transform the medical industry. This new family of smart wearable devices provide a great opportunity for the next-generation of artificial intelligence (AI) based epilepsy-monitoring devices. However, major key challenges remain in achieving this potential due to inherent resource-constrained nature of wearable systems, coupled with their (in principle) limited computing power and data gathering requirements for Big Data medical applications, which can result in degraded and unreliable behavior and short lifetime. In this talk, Prof. Atienza will first discuss the challenges of ultra-low power (ULP) design and communication in smart wearable devices for epilepsy monitoring in the context of Big Data medical analytics. Then, the opportunities for edge computing and edge AI in next-generation smart wearables will be highlighted as a scalable way to fully deliver the concept of personalized medicine for seizure detection. This new trend of smarter wearabler architectures will need to combine new ULP multi-core embedded systems with neural network accelerators, as well as including energy-scalable software layers to monitor seizures by event-driven monitoring. Overall, the next-generation of smart wearable devices will be able to gracefully adapt the energy consumption and precision of the seizure detection outputs according to the requirements of our surrounding world and available energy at each moment in time, as living organisms do to operate efficiently in the real world.

Session 3: State-of-art EEG-based seizure detection/prediction

Detecting/prediciting seizures with intracerebral EEG

Mark Cook, Australia

Remarkable insights into the patterns underlying seizure activity have been provided by data acquired in recent years from long-term intracranial monitoring devices. The NeuroVista study captured continuous intracranial recordings from subdural electrodes to predict seizures, demonstrating not only that this was possible but as well that striking patterns could be recognised that provided new approaches to the problem of seizure prediction. A large amount of data has also been obtained through the Neuropace system, which captures only small amounts of EEG activity, but which captures data relating to the timing of seizures, confirming these striking patterns. The short and long scales of seizure activity likely provide insights into the systems driving seizures, and potentially new perspectives on many problems that have defied explanation, such as drug-resistance. Similar patterns of activity have been confirmed in electrical recordings captured from deep brain stimulation and evoked potentials, examining features of critical slowing, providing yet another novel means of predicting seizure activity. We have confirmed these cycles are not simply features of drug-resistant epilepsies using two comprehensive databases of human seizures (SeizureTracker, and NeuroVista), demonstrating that multi-temporal cycles are significant, and highly prevalent. We found that the majority (80%) of patients showed circadian (24-hour) modulation of their seizure rates. More interestingly, many patients showed strong circaseptan (weekly) rhythms, with a clear 7-day period. Cycles longer than 3 weeks were equally prevalent in males and females, including monthly cycles. The causes of multi-scale variation in seizure rates are yet to be comprehensively explored but are likely to include a range of environmental and endogenous factors. Seizure cycles are robust, patient-specific, and more widespread than previously understood. Detecting multi-scale oscillations in seizure rate may provide new approaches to treatment decisions and the interpretation of drug trials. Knowledge of these cycles can be used to develop patient specific forecasting algorithms. The potential application of these finding to minimally invasive seizure detection systems currently being commercialised will be discussed.

LECTURES ABSTRACTS

Session 3: State-of-art EEG-based seizure detection/prediction

Seizure monitoring in coma and ICUs

Christoph Baumgartner, Austria

Nonconvulsive seizures (NCS) and nonconvulsive status epilepticus (NCSE) represent a major problem in neurological intensive care patients. Prolonged NCSE may contribute to secondary brain injury and is associated with worse neurological outcome and increased mortality. Therefore, rapid diagnosis and treatment of NCSE is of high clinical relevance. Indeed, NCSE is more frequently than previously anticipated occurring in 8-34% of neurological and non-neurological intensive care patients with the incidence varying according to the specific patient population studied. However, clinical signs indicating NCS and NCSE are usually subtle or completely invisible. Therefore, the clinical diagnosis of NCS and NCSE is usually impossible. On the other hand, short-term routine electroencephalography (EEG) frequently fails to detect subsequently developing NCSE. Thus, NCS could be seen only in 15% of patients at the start of EEG recording and only in 56% of patients within the first hour of EEG recording in whom subsequently NCSE was documented on critical care continuous EEG (CCEEG). Therefore, CCEEG represents the only reliable method for the detection of NCS and NCSE. CEEG also provides unique information on important interictal EEG abnormalities, including rhythmic and periodic EEG patterns of 'ictal-interictal uncertainty' (RPPIIIU), including periodic discharges (PD), rhythmic delta activity (RDA), and spike-and-wave complexes (defined according to the American Clinical Neurophysiology Society Standardized Critical Care EEG Terminology (ACNS SCCET)) the as well as on other non-specific abnormalities. CEEG is also useful to monitor sedation depth and to instantly assess subclinical changes of the patient's neurological status. However, CCEEG is associated with significant technical and personnel efforts especially regarding the immediate review and analysis of the ongoing EEG recordings. Therefore, the development of automatic computer-based algorithms for CCEEG analysis is of high clinical relevance. In the present talk we will review sensitivity and specificity of computer-based automatic EEG analysis techniques to detect NCS, NCSE, RPPIIIU and other non-specific abnormalities, to monitor sedation depth and to rapidly assess subclinical changes in the patient's neurological condition. We will discuss usefulness of these techniques in a 24/7 intensive care setting and their applicability by not extensively EEG trained intensive care personnel.

Session 3: State-of-art EEG-based seizure detection/prediction

Novel technologies for chronic EEG recordings

Simone Benatti, Italy

EEG is a well-established method for non-invasive analysis of brain signals. There are several commercial battery-powered systems, based on reliable commercial off-the-shelf components, which obtain a high-quality signal recording, comparable to conventional hardwired systems. Nevertheless, EEG processing requires data transfer to external gateways, visual inspection of neuroscientists or clinicians, and non-portable computational platforms for data processing.

Recent advances of machine learning and deep learning techniques hold promise for a valuable support to diagnostics and monitoring neural activity. Embedding these algorithms in minimally intrusive devices can lead to a paradigm shift in the treatment of major neurological disorders.

To tackle this challenge, where high computational workloads need to be performed in reduced form factors at extreme energy efficiency, it is paramount to develop low-power digital platforms which can be integrated into unobtrusive wearable devices, such as glasses or small adhesive patches, enabling long-term monitoring of the brain activity.

In this talk, I will give an overview of how to address this challenge using a Parallel Ultra-Low Power (PULP) heterogeneous computing approach.

LECTURES ABSTRACTS

Session 4: Reimbursement of seizure detection devices/services

The regulators point of view: Medical devices - Necessary clinical data for marlet access

Kim Rochat, Switzerland

The European Market is a fantastic opportunity for medical devices manufacturers as it is organized within a common legal framework for all participating countries including Switzerland. With the new European Regulation on medical devices that enter into application in May 2020, the industry is going through changes that impact dramatically medical devices manufacturers as the level of expectations and scrutiny have raised significantly. Among these expectations, clinical data is now in the center of the attention and becomes a crucial topic in order to get the "CE Mark", the authorization to place a medical device on the European Market. When this new regulation will enter into application all medical devices manufacturers will have to provide a clinical evaluation of their products in order to demonstrate positive risk / benefit for the patient.

The presentation will cover the medical device regulatory framework in Europe including the stakeholders and the key requirements to place a seizure detection device. The clinical evaluation process will also be discussed in order to identify what are the expectations of the regulatory bodies contributing to clear the access to market for such device. Within these requirements, the role of clinical data obtained through clinical investigation and post-market surveillance will be discussed. Further, since more and more medical devices are now software designed to work on mobile platforms such as smartphones, particular requirements for such device will also be highlighted. To close the presentation, the role of clinical data in the reimbursement process will also be presented thus linking the necessity to consider these aspects early in the development process to optimize the clinical effort toward a successful medical device.

Session 4: Reimbursement of seizure detection devices/services

The companies' point of view: The case of Embrace by Empatica in the US Market

Matteo Lai, Italy

Wearable seizure detection technologies have been in development for the past years, but they were only recently approved by the Food and Drug Administration in the US.

These products share some common goals: as an alerting tool, to provide a critical intervention for refractory patients, especially in outpatient settings and a as potential aid against SUDEP. As a diagnostic tool, to improve the current reliance on seizure diaries as a gold standard, delivering an objective endpoint for the initial diagnosis, treatment and management of epilepsy.

While there are currently two products approved for marketing in the US - Embrace by Empatica and SPEAC by Brain Sentinel - reimbursement efforts have not yet advanced to the wishes and expectations of the medical and the patient community.

This lecture presents the broader context around the efforts required to obtain reimbursement in the US market: the progress so far and what work still remains, providing examples of important milestones and challenges encountered. A special emphasis is placed on some underestimated challenges for successful reimbursement and broader adoption: the need for strong community collaboration (from medical professionals, patients, companies and regulators) and the limited awareness around new technologies in the field.

LECTURES ABSTRACTS

Session 4: Reimbursement of seizure detection devices/services

The medical justification

Michael Sperling, USA

Seizure detection devices have the potential to improve the treatment of people with epilepsy. Proper use can lead to improved seizure control, reduced injury rates, enhanced medical and psychological well-being, and improved outcomes in multiple domains. In doing so, they have the potential to reduce the cost of epilepsy, including medical and societal costs. As many people with epilepsy are unaware of some or all of their seizures, seizure detection devices provide an essential means of assessing therapeutic response and optimizing treatment. Detecting "hidden" seizures can lead to more effective pharmacotherapy, and when married to therapeutic devices, seizure detection can trigger prompt therapy that may abort or shorten seizures. For example, direct seizure detection triggers electrical stimulation in the responsive neurostimulation device. Indirect seizure detection via measuring increase in heart rate triggers electrical stimulation by the vagus nerve stimulator. Studies are underway for other stimulation and drug delivery methods that may reduce seizure burden.

Employing seizure detection in a variety of settings should reduce the need for emergency room visits, lower injury rates, and keep patients out of the hospital. More accurate detection of more severe seizure types (e.g., focal to bilateral tonic-clonic or generalized tonic-clonic seizures) can lead to alterations in therapy that have the potential to save lives, by reducing the occurrence of seizure with fatal consequences. Improved detection that leads to more effective treatment can help reduce the disability associated with seizures if better seizure control can be attained, leading to reduced need for disability pensions and personal care. The knowledge that someone might be watching to ensure safety can provide psychological relief and a heightened sense of security, leading to an improved quality of life and greater engagement in society.

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ORAL COMMUNICATIONS

OC01 Circadian and Multiday Rhythms, and Seizure Clusters in Naturally Occurring Canine Epilepsy

Nicholas GREGG (1), Ned PATTERSON (2), Beverly STURGES (3), Benjamin BRINKMANN (1), Gregory WORRELL (1) - (1)Mayo Clinic, United States, (2)University of Minnesota, United States, (3)University of California at Davis, United States

OC02 A home based trial on multimodal nocturnal seizure detection in children: interim results of the PROMISE study.

Anouk VAN WESTRHENEN (1,2), Frans LEIJTEN (3), Richard LAZERON (4), Roland THIJS (1,2) - (1) Stichting Epilepsie Instelling Nederland (SEIN), The Netherlands, (2) Leiden University Medical Center, department of neurology, The Netherlands, (3) University Medical Center Utrecht, department of neurology, The Netherlands, (4) Academic Center of Epileptology Kempenhaeghe, The Netherlands, (5) Faculty of Electrical Engineering, Technical University Eindhoven, The Netherlands

OC03 In-field validation of epihunter for the detection of absence seizures using wearable EEG

Dirk LOECKX, Tim BUCKINX - Epihunter NV, Belgium

OC04 e-Glass: A Wearable System for Real-Time Epilepsy Monitoring

Renato ZANETTI, Dionisije SOPIC, Amir AMINIFAR, David ATIENZA - Embedded Systems Laboratory (ESL), Swiss Federal Institute of Technology Lausanne (EPFL), Switzerland

OC05 Heart rate variability parameters as surrogate markers of seizure severity

Anca Adriana ARBUNE (1,2), Jesper JEPPESEN (3,4), Philippe RYVLIN (5), Sandor BENICZKY (1,4,3) - (1)Department of Clinical Neurophysiology, Danish Epilepsy Centre, Denmark, (2)2. Department of Clinical Neurosciences, "Carol Davila" University of Medicine and Pharmacy, Romania, (3)Department of Clinical Neurophysiology, Aarhus University Hospital, Denmark, (4)Department of Clinical Medicine, Aarhus University, Denmark, (5)Department of Clinical Neurosciences, CHUV, Switzerland

OC06 Automated seizure detection based on heart rate variability using a wearable ECG device

Jesper JEPPESEN (1), Anders FUGLSANG-FREDERIKSEN (1), Peter JOHANSEN (2), Jakob CHRISTENSEN (3), Beniczky SÁNDOR (1) - (1)Department of Neurophysiology, Aarhus University Hospital, Denmark, (2)Department of Engineering, Aarhus University, Denmark, (3)Department of Neurology, Aarhus University Hospital, Denmark

OC07 Detection of Epileptic Seizures using Hybrid Artificial Intelligence Techniques based Wavelet Transforms and Information Criteria

Ozan KOCADAGLI (1), Candan GURSES (2) - (1)Department of Statistics,Faculty of Science and Letters, Mimar Sinan University, Turkey, (2)Department of Neurology, School of Medicine, Koc University, Turkey

OC08 Computer-assisted diagnostic review for epilepsy

Ewan NURSE (1), Shannon CLARKE (1), Philippa KAROLY (2), Udaya SENEVIRATNE (3), Dean FREESTONE (1) - (1)Seer Medical, Australia, (2)University of Melbourne, Australia, (3)Medicine Monash Health, Australia

OC09 Personalized multimodal detection of focal impaired awareness seizures using behind-the-ear EEG and heart rate

Thomas DE COOMAN (1), Kaat VANDECASTEELE (1), Evy CLEEREN (2), Wim VAN PAESSCHEN (2), Sabine VAN HUFFEL (1) - (1)Department of Electrical Engineering - KU Leuven, Belgium, (2)Department of Neurology, UZ Leuven, KU Leuven, Belgium

OC10 Technical Validation of Sensor Dot: a Multimodal Wearable for Ambulatory Monitoring of Epileptic Seizures

Benjamin VANDENDRIESSCHE (1, 4), Dorien WECKHUYSEN (2), Jonathan DAN (3, 4), Evy CLEEREN (2), Wim VAN PAESSCHEN (2) - (1)Case Western Reserve University, United States, (2)University Hospital Leuven, Belgium, (3)KU Leuven, Belgium, (4) Byteflies, Belgium

OC11 Novel algorithm for seizure detection in wearable electroencephalography

Jonathan DAN (1,2), Benjamin VANDENDRIESSCHE (3), Wim VAN PAESSCHEN (1), Dorien WECKHUYSEN (1), Alexander BERTRAND (1) - (1)KU Leuven, Belgium, (2)Byteflies, Belgium, (3)Byteflies, United States

ORAL COMMUNICATIONS

OC12	Automated video-based detection of nocturnal motor seizures in children. *Anouk VAN WESTRHENEN (1,2), George PETKOV (1), Stiliyan KALITZIN (1), Roland THIJS (,21), Dutch BEHALF OF THE DUTCH TELEEPILEPSY CONSORTIUM (3) - (1)Stichting Epilepsie Instelling Nederland (SEIN), Netherlands, (2)Leiden University Medical Center, department of neurology, Netherlands, (3)TeleEpilepsy Consortium, Netherlands*
OC13	Real-Time Epileptic Seizure Detection Based on Cardiorespiratory Response *Farnaz FOROOGHIFAR (1), Amir AMINIFAR (1), Philippe RYVLIN (2), David ATIENZA (1) - (1)EPFL, Switzerland, (2)CHUV, Switzerland*
OC14	A multimodal garment with integrated sensors - the next step in the development *Kristina MALMGREN (1), Dongni JOHANSSON BUVARP (1), Jan WIPENMYR (2) - (1)Institute of Neuroscience and Physiology, Sahlgrenska Academy at Gothenburg University, Sweden, (2)RISE Research Institutes of Sweden AB, Sweden*
OC15	Detection of nonconvulsive seizures using limited montage EEG *Olga TARASCHENKO, Nicholas SWINGLE, Aditya VUPPALA, Proleta DATTA, Swetha PEDAVALLY - (1)University of Nebraska Medical Center, United States*
OC16	Epileptic Seizure Prediction Using EMU Data and Personalized Deep Learning *Mehrdad NOURANI (1), Jay HARVEY (2) - (1)University of Texas at Dallas, United States, (2)UT Southwestern Medical Center, United States*
OC17	Nonlinear brain-heart interactions in children with focal epilepsy assessed by mutual information of EEG and heart rate variability *Anton POPOV (1,2), Riccardo PERNICE (3), Ivan KOTIUCHYI (4,2), Luca FAES (3), Alessandro BUSACCA (3), Volodymyr KHARYTONOV (5) - (1)Department of Electronic Engineering, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine, (2)Ciklum R&D Engineering, United Kingdom, (3)Department of Engineering, University of Palermo, Italy, (4)Department of Biomedical Engineering, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine, (5)TMO "Psychiatry", Ukraine*
OC18	My Seizure Gauge: Seizure detection and prediction with noninvasive wearable devices *Benjamin BRINKMANN (1), Ewan NURSE (2), Mona NASSERI (1), Dean FREESTONE (2), Mark RICHARDSON (3) - (1)Mayo Foundation, United States, (2)Seer Medical, Australia, (3)King's College, United Kingdom*
OC19	Non-invasive seizure forecasting *Philippa KAROLY (1), Matias MATURANA (1), Ewan NURSE (2), Dean FREESTONE (2), Mark COOK (1) - (1)The University of Melbourne, Australia, (2)Seer Medical, Australia*
OC20	Predicting epileptic seizures using machine learning and a novel wearable device *Rajlakshmi BORTHAKUR (1), Sanjib SINHA (2) - (1)Terra Blue Exploration Technologies Private Limited, India, (2)NIMHANS, India*

OC01 Circadian and Multiday Rhythms, and Seizure Clusters in Naturally Occurring Canine Epilepsy

Nicholas GREGG (1), Ned PATTERSON (2), Beverly STURGES (3), Benjamin BRINKMANN (1), Gregory WORRELL (1)
(1) Mayo Clinic, United States, (2) University of Minnesota, United States, (3) University of California at Davis, United States

Long-term intracranial EEG demonstrates circadian and multiday modulation of seizure risk in humans. Seizure clusters are common and impact health and quality of life. Periodic patterns of seizure risk suggest chronotherapy, whereby electrical stimulation and medications are delivered based on seizure risk, may be useful. Dogs can accommodate devices designed for humans and may be a platform for chronotherapy development.

6 dogs with naturally occurring epilepsy were monitored with long-term intracranial EEG devices (NeuroVista or Medtronic Summit RC+S). Seizures were identified by a detection algorithm with epileptologist confirmation. MATLAB circular statistics toolbox was used to evaluate periodicity of seizures over multiple periods (1 day, 7 days, and median inter-seizure interval). Seizure timing data were visualized with angular histograms, and the resultant vector amplitude, R, assed non-uniformity. Statistical significance was determined by the Rayleigh test ($P<0.05$). Clustered seizures were defined as seizures occurring within 24 hours of a prior seizure. To remove bias from clusters, only lead seizures were analyzed for multiday periods. Periodicity within seizure clusters was evaluated using similar methods. Mayo Clinic, UC-Davis, and U. Minnesota IACUCs approved the study.

4 dogs had statistically significant periodicity of seizure timing – 3 dogs had circadian seizure rhythms, and one had a 7-day rhythm. 4 dogs had seizure clusters. 1 dog had significant periodicity of within cluster seizure timing. Circadian and multiday seizure cycles, and seizure clusters are common in dogs with naturally occurring epilepsy, as in humans. Periodic patterns of seizure risk may be useful to guide timing of medication and brain stimulation therapy. These findings suggest potential usefulness of dogs as a model for chronotherapy development for epilepsy.

NeuroVista Inc. and Medtronic Inc. supplied devices. Supported by NIH grants UH2 NS095495 and R01 NS092882.

OC02 A home based trial on multimodal nocturnal seizure detection in children: interim results of the PROMISE study.

Anouk VAN WESTRHENEN (1, 2), Frans LEIJTEN (3), Richard LAZERON (4), Roland THIJS (1,2)
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Home-based seizure detection device (SDD) studies addressing the implementability and the effects of SDDs on quality of life (QoL) are still lacking. The PROMISE study aims to address this knowledge gap. In a previous study we demonstrated good performance of the NightWatch, a wearable multimodal (heart rate & accelerometry) SDD, in adults in a residential care setting.1 We here present the interim results of the implementation of the Nightwatch in a family home setting.

This prospective multicenter intervention study included children aged 4-16 years with ≥1 major nocturnal motor seizure per week. A two-month period of nocturnal NightWatch implementation was compared to a preceding two-month baseline period using questionnaires on feasibility, caregiver's stress (Caregiver strain Indiax (CSI)), sleep (Pittsburgh Sleep Quality Indiax (PSCI)) and QoL (EQ-5D-5L). The performance of NightWatch was assessed by analyzing video tracings of all possible seizures (seizure diaries and NightWatch alarms) and 5% of all nights were screened to identify possible missed seizures. We classified tonic-clonic, generalized tonic >30 seconds, hyperkinetic and others, including clusters >30 minutes as 'major seizures'.

This interim analysis on ten children (median age 8 years, range 5-16) included 562 recorded nights and 272 major seizures (median number of seizures per participant: 1). NightWatch detected all major seizures (sensitivity 100%) with a median false alarm rate of 0.20 per participant per night (range 0.09-3.83). After implementation of NightWatch, the CSI indicated reduced stress levels in 67% of caregivers. Subjective health scores improved by 10% (EQ-5D-5L) while the PSQI showed no considerable changes. NightWatch scored high on implementability and was evaluated as an easy-to-use device.

1. Arends J et al. Multimodal nocturnal seizure detection in a residential care setting: A long-term prospective trial. Neurology. 2018;91(21):e2010-e2019.

OC03 In-field validation of epihunter for the detection of absence seizures using wearable EEG

Dirk LOECKX, Tim BUCKINX
Epihunter NV, Belgium

Self-reported absence seizure frequency is highly unreliable. A solution to better detect absence seizures may help improve the quality of life of people with epilepsy and their caregivers, and help neurologists and researchers to better assess therapy impact. E.g. making absence seizures visible for children in class could improve learning and social interaction. Epihunter has developed a wearable absence seizure tracker. It is based on a consumer EEG headset streaming data to a smartphone that runs a deep learning algorithm. Results of the algorithm on frontal single-lead EEG derived from clinical EEG were shown in [1]. This abstract describes initial results on in-field data.

Epihunter has collected in-field EEG data of 5 subjects with each >20h of EEG data and, on average, >1 seizure/h. The data is collected in an uncontrolled real-life situation, using Brainlink, a commercially available wearable EEG device by Macrotellect, and the epihunter app. For each subject, we manually annotated the absence seizures (defined as spike-trains lasting more than 3s) in the most recent 5-6h of data (26.5h, 137 seizures). We validated the results of the detection algorithm described in [1] with the manual annotations, calculating sensitivity (SEN), positive predictive value (PPV), and false alarm interval (FAI). These were respectively 99.6%, 90.3% and 4.7h in [1].

The in-field validation showed a SEN of 95.6% (40%-100%; 6 FN on 131 seizures), a PPV of 91.0% (50%-100%; 13 FP and 131 TP), and a FAI of 2.04h (0.46h-infinity). The FPs were concentrated in 2 subjects, who have mainly focal onset impaired awareness seizures. From the hindsight, most of them could have been classified as a seizure. We have shown that automatic absence seizure detection is possible on wearable single-lead EEG, using an algorithm developed from clinical EEG.

[1] Loeckx, D., Buckinx, T., & Lagae, L. (2019). Validation of automatic absence seizures detection in single-lead frontal EEG. IEC2019, accepted

OC04 e-Glass: A Wearable System for Real-Time Epilepsy Monitoring

Renato ZANETTI, Dionisije SOPIC, Amir AMINIFAR, David ATIENZA
Embedded Systems Laboratory (ESL), Swiss Federal Institute of Technology Lausanne (EPFL), Switzerland

Epilepsy is one of the major chronic diseases affecting millions of people worldwide. The used procedures for epilepsy monitoring involve EEG caps that are not accepted by patients for daily use, due to impact of social stigma. We propose e-Glass as solution, a wearable system for the real-time seizure detection and long-term patient monitoring, with electronics and electrodes embedded and hidden in the glasses.

e-Glass system consists of three blocks: 1) processing unit, 2) three EEG channels (dry electrodes) and a 3D accelerometer, 3) Bluetooth interface. We propose a seizure detection methodology based on machine learning, processing EEG signals on the device to optimize the use of resources and extend the battery lifetime. The methodology is evaluated using the Physionet.org CHB-MIT Scalp EEG database in the following two schemes: 1) using data from all 23 EEG channels and 2) data from only two channels (F7T3 and F8T4). As features, we use the total signal power along with relative bandpowers (delta, theta, alpha, and beta) for the detection based on a subject-dependent random forest. In addition, a BIOPAC EEG2 module is used as gold standard to assess e-Glass signal quality, placing both systems' electrodes side-to-side during spontaneous-EEG acquisition.

We reach a sensitivity and specificity, respectively, of: 1) 96.95% and 95,77%, all electrodes; 2) 93,69% and 92,71%, for only two channels . Our results demonstrate that the classification performance is marginally affected when using only two channels , in comparison with the case in which all electrodes are used. Moreover, considering that e-Glass spontaneous-EEG has only a 20% amplitude drop in relation to the BIOPAC module, our proposed system provides a high degree of wearability with no major performance loss. Furthermore, it allows for 24.11 hours of continuous monitoring, reducing the impact of social stigma due to its inconspicuous technology.

OC05 Heart rate variability parameters as surrogate markers of seizure severity

Anca Adriana ARBUNE (1, 2), Jesper JEPPESEN (3,4), Philippe RYVLIN (5), Sandor BENICZKY (1, 4, 3)
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There is need for automated detection and characterization of epileptic seizures, in terms of measuring their severity. Ictal autonomic changes are associated with seizures, and might play an essential role in the pathomechanism of sudden unexpected death in epilepsy patients (SUDEP). Previous studies showed promising results for automated seizure detection using ictal autonomic changes. In this study we aimed at defining objective parameters reflecting seizure severity, that could be implemented into wearable devices.

We explored the peri-ictal (preictal and postictal) changes in heart rate variability (HRV), normalized to their interictal values. We calculated parameters reflecting the activity of the parasympathetic nervous system: high-frequency power (HF) and root mean square of successive RR intervals that differ by more than 50 ms (RMSSD). For measuring changes in the sympathetic nervous system we used cardiac sympathetic Indiax (CSI) and the ratio of LF-to-HF power (LF/HF). In addition, we determined the mean heart rate value (HR-mean) that reflects both an increase in sympathetic and decrease in parasympathetic activity. For seizure severity we measured the duration of the postictal generalized EEG suppression (PGES), seizure duration and the intensity of ictal muscle activity, expressed as the duration of tonic bursts with frequent exceeding the detection threshold for zero-crossings (ZC-above). We included 40 patients who had 77 motor seizures recorded in the epilepsy monitoring unit: 61 generalized tonic seizures (GTCS) and 16 other major motor seizure types.

For all major motor seizures we found a significant decrease in the parasympathetic activity and increase in the sympathetic activity in the postictal period. Increase in postictal sympathetic activity was significantly higher for GTCS compared with non-GTCS. Peri-ictal decrease in parasympathetic activity and increase in sympathetic activity were correlated with long PGES (≥20s), seizure duration and the intensity of ictal muscle activity (ZC-above). In conclusion: peri-ictal changes in HRV are potential biomarkers for seizure severity. Further studies on ultra-long term outpatient recordings are needed to elucidate the role of MRV measurement in seizure characterization and their potential in preventing SUDEP.

OC06 Automated seizure detection based on heart rate variability using a wearable ECG device

Jesper JEPPESEN (1), Anders FUGLSANG-FREDERIKSEN (1), Peter JOHANSEN (2), Jakob CHRISTENSEN (3), Sandor BENICZKY (1)
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Non-invasive devices for detection of convulsive seizures (generalized tonic-clonic and focal-to-bilateral tonic-clonic seizures) have been validated in phase 2 and 3 studies. However, detection of non-convulsive seizures still needs further research, since currently available methods have either low sensitivity or extremely high false alarm rate (FAR). We sought to assess the feasibility and accuracy of seizure detection based on heart rate variability (HRV) using a wearable electrocardiography (ECG) device.

In this phase-2 study, we prospectively recruited patients admitted to long-term video-EEG monitoring (LTM). ECG was recorded using a dedicated wearable device, hidden under the patients´ clothes. Seizures were automatically detected using HRV-parameters computed off-line. Seizure detection was done blIndiad to all other data. We compared the performance of twenty-six automated algorithms with the seizure time-points marked by experts who reviewed the LTM recordings. Patients were classified as responders if >66% of their seizures were detected.

We recruited 100 patients, and we analyzed 126 seizures (108 non-convulsive and 18 convulsive) from 43 patients who had seizures during monitoring. The best performing HRV-algorithm identified 53.5% of the patients as responders. Among responders, detection sensitivity was 93.1% for all seizures and 90.5% for non-convulsive seizures. FAR was 1.1 / 24 hours (0.11/night). Median seizure detection latency was 30 seconds. Typically, patients with prominent autonomic nervous system changes were responders: an ictal change of >50 heartbeats per minute predicted who would be responder with a positive predictive value of 87% and a negative predictive value of 90%. The automated HRV-algorithm, using ECG recorded with a wearable device has high sensitivity for detecting seizures, including the non-convulsive ones. FAR was low during the night. This approach is feasible in patients who have prominent ictal autonomic changes.

OC07 Detection of Epileptic Seizures using Hybrid Artificial Intelligence Techniques based Wavelet Transforms and Information Criteria

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Epilepsy is a central nervous system disorder, so the patients suffer from recurrent seizures that occur at unpredictable times and usually without warning. This study introduces an efficient procedure that provides an accurate classification of Electroencephalogram (EEG) signals for the detection of epileptic seizure. Essentially, this procedure can be adapted to various artificial intelligence (AI) techniques based on the discrete wavelet transforms (DWT) and feature selection methods.

To figure out the systematic behaviors of epileptic seizures, a proposed automated multi-resolution signal processing technique splits EEG signals into the detailed sub-series with different window-widths, and then carry out an efficient feature extraction framework by means of DWT. The complexity included by the feature matrix is reduced by the various feature selection methods and information criteria. In analysis, to improve the accurate classification rates of the epileptic seizures in EEG signals, the performances of many AI techniques such as deep neural networks, support vector machines, decision trees, nearest neighbor classifiers and ensemble learning are compared with each other over the benchmark and clinical datasets.

According to analysis results, the estimated models are able to achieve 99% accuracy ratios over test data sets in terms of classifying the epileptic signals. As a result, the proposed procedure not only allows making an efficient analysis of EEG signals for detection of epilepsy, but also provides the best model configurations for different detection methods in the context of reliability and complexity.

OC08 Computer-assisted diagnostic review for epilepsy

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Epilepsy diagnosis is costly, time-consuming and often inaccurate. The gold standard diagnostic monitoring test is continuous video-EEG monitoring for up to one week. Automating EEG data review would save time and resources, thus enabling more people to receive gold-standard monitoring and improving diagnostic outcomes in epilepsy. There has been decades of research into automated detection of seizures and epileptic activity from EEG. However, automated detection software is not widely used in diagnostic review for epilepsy; and, despite thousands of published algorithms, there remains just one FDA approved method for detecting epileptic activity from EEG. Diagnostic review is particularly challenging as scalp recordings contain artefacts, and signals vary between individuals with different epilepsy syndromes. A common approach in clinical settings is computer-assisted review, where an algorithm first analyses all the data and flags suspect activity. Computer detections are then reviewed by a human neurologist who ultimately makes the diagnosis.

This study reports on a deep learning algorithm for computer-assisted EEG review. The presented algorithm has been applied to review data from over 1000 patients in a clinical setting for at-home video-EEG diagnostic monitoring. Here, we report on results from a subset of 103 patients with idiopathic generalized epilepsy (IGE).

The automated detection algorithm outperforms the current state-of-the-art for detecting epileptic activity from clinical EEG, with sensitivity ranging from 90%-99% and corresponding false positive rates of 0.1 - 1.1 detections per minute. Importantly, we show through diagnostic case studies how the presented algorithm reduces human review time by an order of 10x, without misdiagnosing confirmed IGE compared to psychogenic non-epileptic seizures. Computer-assisted review can increase the speed and accuracy of epilepsy diagnosis, and has the potential to greatly improve treatment outcomes.

OC09 Personalized multimodal detection of focal impaired awareness seizures using behind-the-ear EEG and heart rate

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Multiple studies have shown the potential usage of seizure detection devices for motoric seizures. Currently, however, the detection of focal impaired awareness seizures (FIAS) has not been thoroughly investigated for usage in practice. These seizures can typically only be detected by electroencephalography (EEG) and heart rate. A full EEG system for seizure detection at home is found to be unpractical by the patients. Therefore, two EEG sensors were placed behind both ears of the patient in this study. The information of these EEG sensors was combined with heart rate information, which can be easily extracted using wearables and could further increase the performance in a multimodal system. The aim of this study was to find an optimal combination of behind-the-ear EEG and heart rate information for the automated detection of FIAS.

Two EEG sensors were placed behind each ear, leading to three bipolar EEG channels of which features were extracted using a 2 s window-based approach. The heart rate was extracted from the electrocardiogram. Heart rate increases were detected using gradient analysis, and characteristic features of this heart rate increase were extracted. Both EEG and heart rate features were classified using a support vector machine classifier. The information from both modalities was then combined using a personalized weighted late integration approach. A late integration approach was used as it allows a more efficient personalization than early integration. The algorithm was evaluated on a dataset of 2848 hours acquired at UZ Leuven containing 24 patients with 129 FIAS.

An average performance of 78% sensitivity and 2.9 false alarms per day was achieved using our multimodal approach. It leads to a decrease of 80% in false alarm rate compared to the unimodal EEG-based seizure detection. An algorithm combining information from behind-the-ear EEG and heart rate can accurately detect subtle FIAS.

OC10 Technical Validation of Sensor Dot: a Multimodal Wearable for Ambulatory Monitoring of Epileptic Seizures

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To improve our understanding of epilepsy and its comorbidities on the level of the individual, and to devise novel evidence-based treatments, devices that can accurately monitor epileptic seizures with minimal influence on a person's daily routine are crucial. Wearable devices tailored towards people with epilepsy need to strike a balance between data quality (i.e. clinical usefulness) vs. wearability and unobtrusiveness. We present technical and clinical validation data collected under ambulatory conditions for Byteflies Sensor Dot, a multimodal wearable device that can record many physiologic signals, including EEG.

Nine people with refractory absence seizures were sent home with 2 Sensor Dots (one recorded EEG and activity, the other heart rate and activity) and a Medatec BrainWalker 3 for 24 h. The latter is a portable but much bulkier EEG (10-20 configuration) recording device and was used as a reference. On the collected data, various types of artifacts were counted and similarity of the waveform data between the two devices was quantified using Dynamic Time Warping (DTW). Absence seizures were annotated on the Medatec reference data which established the ground truth. Next, seizures were annotated on a 3-channel configuration (post-auricular (PA) left (PAL), PA right (PAR) and PAL-PAR).

The occurrence of EEG (motion) artifacts was low for both the EEG Sensor Dot and reference device (< 2.5%). Signal similarity assessed by DTW was 89.7%. The recall of absence seizures on the 3-channel configuration (PAL, PAR, PAL-PAR) was 92% compared to the ground truth. We performed an initial validation of Byteflies Sensor Dot for ambulatory monitoring of epileptic seizures. Excellent artifact and signal similarity properties, compared to a portable reference EEG device, were achieved under ambulatory conditions. Furthermore, recall of absence seizures on a 3-channel PA montage was high.

OC11 Novel algorithm for seizure detection in wearable electroencephalography

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Advances in EEG equipment allow monitoring of patients with epilepsy at home. This produces large volumes of data that require novel algorithms to process the recordings on board of the device to identify and log or transmit only relevant data epochs. Existing seizure-detection algorithms are generally designed for post-processing purposes, so that memory and computing power are rarely considered as constraints. We propose a novel seizure detection method which is specifically designed to run on a microcontroller with minimal memory and processing power.

Data were collected from 7 patients with refractory absence seizures recruited at UZ Leuven hospital. The study was approved by the local ethical committee and written informed consent obtained. Patients were equipped with a 20-channel mobile EEG unit (Medatec BrainWalker3) for 24h-home recording. The algorithm is based on a patient-specific filter that is precomputed offline. Let $\boldsymbol{x}(t) \in \mathbb{R}^N$ denote an N-dimensional vector containing the sample at time t collected at N EEG channels. A data vector $\boldsymbol{y}(t) \in \mathbb{R}^{N.T}$ is constructed by taking lagged copies of $\boldsymbol{x}(t)$; $\boldsymbol{y}(t) = \{\boldsymbol{x}(t); \boldsymbol{x}(t+1); \ldots; \boldsymbol{x}(t+T-1)\}$. We combine the N EEG channels with T delays into a single-channel output $o(t)$ using a linear model $o(t) = \boldsymbol{w}^T\boldsymbol{y}(t)$. The weight vector $\boldsymbol{w}$ is optimized in a data-driven fashion to maximize signal-to-noise ratio of $o(t)$ over a training set, solving $max_{\boldsymbol{w}} \frac{E\{(\boldsymbol{w}^T\boldsymbol{s}(t))^2\}}{E\{(\boldsymbol{w}^T\boldsymbol{n}(t))^2\}}$ where $E\{.\}$ is the expectation operator, $\boldsymbol{s}(t) \in \mathbb{R}^{N.T}$ the observation of $\boldsymbol{y}(t)$ during seizure epochs and $\boldsymbol{n}(t) \in \mathbb{R}^{N.T}$ during non-seizure epochs. To identify seizures, a threshold is applied to the average power of the output signal $o(t)$ over a 3s sliding window.

Median false detections per hour is 0.1 for 90% sensitivity. The algorith requires only 6.4 kilobytes memory for storing $\boldsymbol{y}$, $\boldsymbol{w}$ and 3s of o^2 (T=20, 2 bytes/sample, sampled at 50Hz); and 400 additions and 400 multiplications per sample. This algorithm provides a practical solution for real-time seizure detection in a home environment. To our knowledge it is the first seizure detection algorithm that is designed to run on a microcontroller in an ambulatory setting.

OC12 Automated video-based detection of nocturnal motor seizures in children.

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Automated real-time seizure detection systems (SDDs) can improve epilepsy care, but wearable devices are not always tolerated. In a previous study, we demonstrated good performance of real-time video-based detection of nocturnal convulsive seizures in adults in a residential care setting.1 The present study examines the performance of this remote SDD in children.

The algorithm calculates power in the 2-6 Hz range relative to 0.5-12.5 Hz range of group velocity signals derived from video-sequence optical flow. Two major changes were made to the previously reported algorithm.1 First, the optical flow calculation was extended from one channel (grey-scale intensity truncated image) to multichannel (color level) to obtain the full spectral information contained in the images. Second, the real-time calculation speed was improved using a novel algorithm, GloriA.2 Relevant global group transformation velocities (translations, rotations, dilatations and shear deformations) were directly reconstructed from the image sequences. The performance was tested on 1661 full recorded nights of 22 children (age 4-17years) from the LICSENSE trial.3 The video footages of all events (nursing reports, alarms from NightWatch, a wearable SDD) were reviewed and 10% of all nights screened. Major motor seizures were defined as tonic-clonic and hyperkinetic seizures. The video algorithm was analyzed retrospectively.

The video algorithm detected 253 out of 260 major motor seizures (97% sensitivity) and identified 51 additional, previously unreported major motor seizures. Positive predictive value was 66% with a mean false alarm rate of 0.15 per night (range 0-1). Most false alarms were clustered in four children. This phase II study demonstrated a good performance of remote, video-based SDD. Future home- based studies are planned to assess prospective performance.

Geertsema et al. Epilepsia. 2018;59(S1):53-60
Kalitzin et al. 2018;310:290–301
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OC13 Real-Time Epileptic Seizure Detection Based on Cardiorespiratory Response

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Epilepsy is one of the most common chronic neurological disorders affecting more than 65 million people worldwide. Although the gold standard in epilepsy monitoring is video-Electroencephalogram (EEG), it is unacceptable to the majority of the patients for real-time monitoring, due to its intrusive and stigmatizing nature. An alternative is using electrocardiogram (ECG) for epilepsy monitoring and seizure detection. The cardiac and respiratory responses can be captured from the ECG signal using the features extracted from the R-peak to R-peak interval (RRI) and respiration (RSP) time series, respectively. These features can then be used to train machine learning models to detect epileptic seizures.

We have proposed an epilepsy detection system with three main phases: (1) a preprocessing phase to remove the noise and artifacts, (2) a feature extraction phase in which the RRI and ECG-drived RSP time series are extracted, and then the cardiac (hearth-rate variation, Lorenz plot and multi-fractality) and respiratory features (Plomb transform and entropy) are calculated, and (3) a machine learning phase to train a detection model on the aforementioned features using the Random forest (RF) learning algorithm.

We evaluate the performance of our proposed system based on an epilepsy database of more than 211 hours of recording, provided by the Lausanne University Hospital (CHUV), on the INYU wearable sensor. Using the aforementioned set of features for cardiorespiratory system, we achieve specificity and sensitivity of 85.65% and 88.66% and the system can work for 50.15 days with single battery charge. Our proposed approach based on combining both cardiac and respiratory responses outperforms the state-of-the-art techniques, which only use cardiac responses, by more than 10.79% and 12.63% in terms of specificity and sensitivity, respectively.

OC14 A multimodal garment with integrated sensors - the next step in the development

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We have previously reported the development of a prototype of a multimodal sensor garment for continuous monitoring of movements and other physiological variables (e.g. pulse, heart rate variability and changes in blood pressure) in epilepsy, Parkinson's disease and stroke. We here describe the development process for the latest prototype of the multimodal garment.

The improved features from the first prototype include: technical stability and more accurate synchronization for multiple modalities, practical features for garment usability and feasibility. A dedicated PC-program for handling and upload of data was developed. The identified needs for improvement were evaluated from both professionals and patients with experience of the garment and also through regular meetings, task groups and hands-on workshops in the multidisciplinary collaboration which involves researchers from medical, engineering, material and textile science.

An add-on sensor modality for measuring electrodermal activity was integrated in the latest prototype of the garment. The quality of ECG signals collected with the garment was improved with use of an in-house developed and patented biocompatible glue. No wearable sensors showed any deterioration in performance or any sign of electrical failure after ten repeated washing cycles. Usability was improved by allowing start and stop of a measurement by connection and disconnection of the battery, and adjustable pressure for textile electrodes were incorporated in the latest prototype. Fitness and comfort were also improved with the garment design. Technical and practical improvements enhance the clinical utility of the multimodal sensor garment. The cross-scientific competence is useful to overcome potential challenges during the development process for delivering clinical promise while maintaining feasibility and comfort for long-term monitoring with the sensor garment.

OC15 Detection of nonconvulsive seizures using limited montage EEG

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Pre-fabricated arrays with a limited number of EEG electrodes offer an opportunity to hasten diagnosis of seizures; however, their accuracy to detect seizures is unknown. In this retrospective study, we examined the utility of two electronically-configured limited montage EEG setups for the detection of nonconvulsive seizures.

Thirty previously interpreted EEG segments with nonconvulsive seizures and 43 segments with non-ictal patterns acquired with standard 21 electrode 10-20 arrays were rendered in a full bipolar montage, a "neonatal" montage with double electrode distances, and a "hatband" circumferential montage with 19, 9, and 10 electrodes, respectively. Participants proficient in interpretation of EEG reviewed the clips, collated in a series, to determine whether seizures were present and if the EEG data provided in the limited montage clips were sufficient to make a decision on escalation of clinical care such as ordering a full montage EEG or anticonvulsants.

Three board-certified epileptologists and two neurophysiologists completed the survey. When assessed against the confirmed clinical diagnosis, the sensitivities for seizure of the 'neonatal' and 'hatband' montages were 0.85 (CI = 0.78 - 0.90) and 0.68 (CI = 0.60 - 0.76), respectively, while the specificities were 0.99 (CI = 0.97 - 1.0) and 0.99 (CI 0.97 - 1.0), respectively. Inter-rater reliability in diagnosis of seizure was substantial for both montages (0.77 and 0.74). Inappropriate escalation of care was suggested for 23% and 36% of occurrences of non-seizure patterns in "neonatal" and "hatband" montages, respectively. Nonconvulsive seizures can be detected with modest accuracy using the limited electrode configuration in the "neonatal" and "hatband" montages. The sensitivity of the "neonatal" montage EEG in detecting seizures was superior to that of a "hatband" montage.

OC16 Epileptic Seizure Prediction Using EMU Data and Personalized Deep Learning

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We hypothesized that Electroencephalography (EEG) data and key nonEEG biometrics (heart rate, blood oxygen saturation, etc.), collected in Epilepsy Monitoring Units (EMUs), hold invaluable insight by which we can predict seizures. We have explored this hypothesis by extracting personalized features from EEG and nonEEG data and then constructing a patient-specific machine learning model that, upon training, can identify the pre-ictal period at least one minute before occurrence.

We first calculate the power spectral density of the EEG signal per window per channel for all five standard frequency bands. These spectral features are then used to train a deep neural network (DNN) that has been personalized, i.e. patient-specific modeling and configuration. Our method offers three key metrics for time-accuracy tradeoffs: data processing window (W), learning window (S), and desired time-to-seizure prediction (T). In general, larger values of W and S improve accuracy but reduce T and increase overall processing time, which may be critical in real time alert systems. Our technique visualizes the tradeoffs in a box-and-whisker plot by which an informed decision can be made. The user can choose the settings that best accommodate the individual patient, thereby yielding the highest prediction accuracy that allows a reasonable time to react before seizure onset.

We are currently testing our hypothesis by collecting clinical data from patients admitted to the adult EMU at the University Hospital in Dallas. So far for five patients, the data-driven personalized model for each patient has been validated based on an epileptologist's conventional EEG assessment. Our preliminary results indicate efficiency of DNN model in providing prediction accuracy vs. alert time settings to user to choose from. For example, predicting seizures with F-Measure (a harmonic mean of precision and sensitivity) of 91% and T=90 sec may be preferred over F=96% and T=40 sec.

OC17 Nonlinear brain-heart interactions in children with focal epilepsy assessed by mutual information of EEG and heart rate variability

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Network physiology is a recent approach describing the human body as an integrated network composed of several organ systems which continuously interact to produce healthy and diseased states. In this work, we apply the network physiology paradigm to study dynamical interactions between EEG activity and heart rate variability in children suffering from focal epilepsy. We aim to study the characteristics of brain-heart coupling between, before, and after seizures to better understand the physiological mechanisms underlying seizure onset in the pre-ictal phase and the recovery of normal autonomic function in the post-ictal phase. In perspective, linking the dynamic information of brain-heart can provide useful information for a better seizure prediction.

EEG and ECG data were recorded in 10 patients with focal epilepsy. After removal of baseline drift and muscle artifacts, the variability of heart rate and brain activity were measured extracting R-R intervals from the ECG and computing the spectral power of the EEG. 143 synchronous time series of 300 points were obtained in 4 different time windows (10 min and 10 sec before and after the seizure) and analyzed computing the cross-correlation coefficient (CC) and the mutual information (MI).

A statistically significant increase of MI was observed just after seizure episodes (p-value equal to 0.04, 10s before vs 10s after distributions, electrode O2), while a recovery of the baseline value was obtained 10 minutes after the episodes. This trend was found for several other EEG electrodes (Fp2, F3, F8, T3, C4, T4). On the contrary, CC did not change significantly across time windows. These results suggest that focal seizures are associated with an increased brain-heart coupling which is noticeable after seizure termination only in terms of mutual information. We conclude that focal epilepsy in childhood is associated with nonlinear brain-heart interaction mechanisms.

OC18 My Seizure Gauge: Seizure detection and prediction with noninvasive wearable devices

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Noninvasive wearable biosensors may be capable of forecasting the probability of seizures. However, rigorous testing with EEG-based seizure records is needed to develop such a system.

This three-year project is organized into three phases. In year 1, commercially available wearable sensors are evaluated for signal quality, patient acceptability, and potential to detect and predict seizures in patients undergoing invasive or scalp EEG. In year two, patients trialing sub-scalp EEG monitoring devices (UNEEG SubQ, or MIndiar subscalp) or an ambulatory intracranial EEG device (Medtronic RC+S) will wear sensors for multiple months to correlate biosignal records with EEG seizure annotations. In year three, a machine learning competition to develop forecasting algorithms on biosignals will be conducted. Biosignals evaluated in year 1 include photoplethysmography, accelerometry, electrodermal activity, EMG, scalp EEG, heart rate, and biosensors include the Empatica E4 watch, GeneActiv actigraphy watch, EpiLog scalp EEG sensor, ByteFlies dots, the Biovotion Everion armband, and the Equivital TnR vest. Surveys of mood and premonitory symptoms will be evaluated as possible seizure predictors in years 1 and 2 of the project.

We have enrolled 55 patients and recorded 115 seizures over a total of 296 days. The enrolled cohort is 53% female with median age 32 years. Sixteen patients (29%) were undergoing stereotactic EEG, 38 (69%) scalp EEG, and 1 (2%) subdural invasive EEG. Seven patients enrolled (13%) were pediatric. Subjects' seizure localizations were wide ranging, including left temporal (4, 7%), right temporal (3, 5%), right frontal (1, 2%), right occipital (2, 4%), and generalized or non-localized (8, 15%). Twenty six patients (47%) did not have seizures with a clear EEG correlate during monitoring. In total 16 seizures have been recorded with EMG, 9 with wireless scalp EEG, 30 with wrist PPG, 37 with chest PPG, 58 with wrist ACC, 53 with chest ACC, and 30 with EDA.

OC19 Non-invasive seizure forecasting

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Epileptic seizures may be modulated by a range of patient-specific, environmental and physiological factors. However, it has recently become clear that there are some generalisable patterns that modulate seizure onset. For instance, a majority of people show a circadian rhythm in their seizure times. Most people (over 50%) also show a slower, multi day rhythm of one week or longer (Karoly et al. 2018). Seizure cycles can be captured from a range of recording modalities, including self-reported seizure diaries. Other factors known to modulate seizure times can also be measured non-invasively, such as weather conditions, sleep quality, stress/mood, medication and physiological data.

This study presents a mobile app and web-based framework to generate real-time forecasts that combine data recorded from wearable devices and user inputs from a mobile app. We provide a proof-of-concept for the performance accuracy of non-invasive seizure forecasting using an existing database of long-term, individual seizure records (Cook et al. 2013). Seizure forecasts based on circadian and multiday seizure cycles were also tested in a pseudo-prospective manner using data recorded from mobile seizure tracking apps (with over 1000 users).

Forecasts allowed seizure diary users to spend an average of over half (58%) of their time in a low-risk state, with 21% of their time in a high-risk warning. On average, 54% of seizures occurred in the high risk state. These results show that forecasts based on self-reported data can provide personalized information about users' seizure likelihood. Warnings based on seizure cycles alone may not provide sufficient precision for a standalone forecast; however, our results also demonstrate potential for mobile diaries to be combined with other non-invasive measures to provide a more accurate forecast of seizure likelihood. This information can give people with epilepsy greater confidence to go about their everyday lives.

OC20 Predicting epileptic seizures using machine learning and a novel wearable device

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Autonomic changes in persons with epilepsy (PWE) can be investigated and ascertained by the continuous and combined study of their Heart Rate Variability (HRV) and skin conductance. HRV data can be obtained using a Photoplethysmography (PPG) sensor and skin conductance measurements can be obtained with Electrodermal Activity (EDA) sensors. Such data can form the basis of a machine learning-based seizure prediction system that could be further deployed on a wearable device.

 We collected Photoplethysmogram (PPG) and Electrodermal (EDA) data from 30 subjects with 50 CPS. After pre-processing, we created a dataset using pre-seizure segments of 1-hour duration and interictal segments consisting of the actual seizure duration of the subjects. This dataset consisting of 42 features was divided into 6 groups using 10 minute windows. We used a principal component analysis on the HRV and the EDA features to derive the percentage of variance between features. After the initial steps, proprietary algorithms using Heart Rate, Breathing Rate, HRV and EDA features were used to identify the 'point of seizure arousal'. The period from the point of seizure arousal to the point of clinical onset of seizure was measured to identify the seizure prediction window.

We used a Support Vector Machine (SVM) classifier for predictive analysis. It showed both HRV and EDA changes occur near or before the earliest electrographic changes. In the pre-ictal HRV and EDA analysis, 46 out of 50 seizures (92%) and 28 out of 30 subjects (93%) showed significant (p-value < 0.005) difference between the 6 groups of preictal data using Kruskal-Wallis test. The 6th group (10 minutes preictal) showed significant (p-value < 0.005) mean difference from every other group using Tukey's test. We found significant changes in HRV and EDA in the pre-ictal (2-10 minutes before seizure) data segment, which suggests this is the minimum horizon for developing early seizure prediction algorithms.

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POSTERS

P01	Tracking and detecting epileptic seizures with portable technologies: Protocol for a systematic review *Élisabeth BEAUCHAMP-CHALIFOUR (1,2), Marie-Pierre GAGNON (1), Tamara HERRERA FORTIN (3), Elie BOU ASSI (3), Dang Khoa NGUYEN (3) - (1)Université Laval, Canada, (2)CHU de Québec – Université Laval, Canada, (3)Université de Montréal, Canada*
P02	Biometric Healthcare Research Platform: preliminary results using wearable sensors for multi-modal monitoring in epilepsy *Ivan ZIBRANDTSEN (1), Paolo MASULLI (2), Steven JEURIS (3), Tobias ANDERSEN (2), Troels KJAER (1) - (1)Zealand's University Hospital, Denmark, (2)Department of Applied Mathematics and Computer Science DTU Compute, Technical University of Denmark, Denmark, (3)Department of Health Technology. Technical University of Denmark, Denmark*
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P06	Detection of hypermotor seizures using accelerometry *Jan WIPENMYR (1), Fredrik OHLSSON (2), Sofie WÅLLBERG (1), David KRYSL (3), Kristina MALMGREN (4) - (1)RISE Research Institutes of Sweden AB, Sweden, (2)Chalmers University of Technology and University of Gothenburg, Sweden, (3)Department of Clinical Neuroscience, Institute of Neuroscience and Physiology, Sahlgrenska Academy, University of Gothenburg, Sweden, (4)Department of Neurosurgery, Sahlgrenska University Hospital, Sweden*
P07	Classification of tonic–clonic seizures using wearable accelerometer sensors *Sare ABBASPOUR (1), David KRÝSL (2,3), Fredrik OHLSSON (1), Jan WIPENMYR (1), Kristina MALMGREN (2,4) - (1)RISE Acreo AB, Sweden, (2)Department of Clinical Neuroscience, Institute of Neuroscience and Physiology, Sahlgrenska Academy, University of Gothenburg, Sweden, (3)Department of Clinical Neurophysiology, Sahlgrenska University Hospital, Sweden, (4)Department of Neurology, Sahlgrenska University Hospital, Sweden*
P08	A personalized seizure detection algorithm using behind-the-ear EEG data *Kaat VANDECASTEELE (1), Thomas DE COOMAN (1), Evy CLEEREN (2), Wim VAN PAESSCHEN (2), Borbála HUNYADI (3) - (1)Department of Electrical Engineering (ESAT), KU Leuven, Belgium, (2)Department of Neurology, UZ Leuven, Belgium, (3)Department of Microelectronics, TUDelft, Netherlands*
P09	Myoclonic seizures in different human body signals recorded with wearable devices *Nicolas ZABLER, Friedrich GAUGER, Wilhelm STORK - (1)FZI Forschungszentrum Informatik, Germany*
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P17	In hospital patients' experience of wearing multimodal devices for remote measurement and recording of epileptic seizures: a qualitative analysis. *Andrea BIONDI (1), Sara SIMBLETT (2), Sebastian BÖTTCHER (3), Andreas SCHULZE-BONHAGE (3), Mark RICHARDSON (1) - (1)King's College London, United Kingdom, (2)Institute of Psychiatry, Psychology & Neuroscience (IoPPN), United Kingdom, (3)University Medical Center Freiburg, Germany*
P18	Digital holistic decision support system for neurologists & PWE: A report from field usability tests *Jonathan SCHREIBER (1), Ludovic AMPE (1), Peter DEDEKEN (2) - (1) Epione BVBA, Brussels, Belgium, (2) Heilig Hart Ziekenhuis Lier, Lier, Belgium*

P01 Tracking and detecting epileptic seizures with portable technologies: Protocol for a systematic review

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Epilepsy is a chronic neurological disease characterized by recurrent seizures caused by excessive and abnormal neuronal discharges. According to World Health Organization, fifty million people worldwide are affected by this medical condition. The causes of epilepsy are multiple: malformations of cortical development, genetic mutations, tumors, etc. While 70% of epileptics respond to medication, a third are drug-resistant. Uncontrolled epilepsy is associated with cognitive impairment, seizure-related injuries and a higher risk of sudden unexpected death in epilepsy. Electroencephalography is the most common technique to detect epileptic seizures. It requires healthcare resources for its installation and interpretation. Various portable health technologies have recently been developed to detect and monitor seizures at home. However, most appear to have not been adequately validated; thus, scientific evidence is limited regarding their effectiveness.

The aim of this systematic review is to gather evidence about the safety, effectiveness, validity, acceptability and impact of portable technologies used to track seizures. We will use the methods of the Cochrane Collaboration for conducting the systematic review. All empirical studies evaluating portable technologies will be considered for any type of seizures and outcomes evaluated. The primary outcomes are the technology effects on health and quality life of epileptic patients. Secondary outcomes include knowledge, attitudes and perceptions about these technologies, as well as their cost and impact on the health system. Systematic searches are conducted in Medline, Embase and CINAHL. The review protocol has been registered in PROSPERO. Preliminary results will be presented.

This systematic review will contribute to improving knowledge on the effectiveness of portable technologies and provide information for developing personalized tools for detecting seizures on the basis of the best available scientific evidence.

P02 Biometric Healthcare Research Platform: preliminary results using wearable sensors for multi-modal monitoring in epilepsy

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Seizures may affect different functional brain areas to produce varied clinical manifestations that have measurable correlates in multiple periodic biological signals originating from the heart and brain. The Biometric Healthcare Research Platform (BHRP) is a software architecture suited for collection and analysis of multiple biosignals recorded in different environments. We analyze heart rate and body acceleration from preliminary results of multi-modal monitoring in epilepsy from an epilepsy monitoring unit (EMU).

Data from one of four patients monitored by ECG, EEG and accelerometry in the epilepsy monitoring unit is presented here. During anti-epileptic-drug (AED) tapering, the patient had an accumulating burden of generalized spike-wave paroxysms, increasing over hours from brief transient activity to a continuous epileptiform pattern, clinically manifesting as non-convulsive status epilepticus. We compare accelerometry and ECG measurements from seizure intervals to non-seizure intervals on subsequent days when the patient was normal.

There was a significant difference in HR [$F(4, 29.21) = 103.45$, $p < 10\text{-}6$] between seizure intervals and non-seizure intervals. The Games-Howell post-hoc test shows a significant increase in HR between seizure vs non-seizure intervals ($D = 32.2$ BPM (CI 26.8-37.6), $p < 0.01$) but not between seizure compared to seizure or non-seizure compared to non-seizure. Tests of the acceleration magnitude differences across seizure and non-seizure intervals did not show significance in all comparisons, excluding the possibility that the variation in HR is caused by physical exertion. These preliminary results show the potential of the BHRP platform in allowing the collection of multi-modal data in epilepsy research, which can shed light on the connections between sensor data and ictal activity. Furthermore, that BHRP will be able to operate not only in an EMU setting, but also in a home environment and outdoors.

P03 Seizure onset detection for responsive stimulation in the sensorimotor cortex

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In refractory epilepsy patients, large parts of the pericentral gyri are considered inoperable without permanent functional deficits, due to their key role in sensorimotor processing. Responsive cortical electrical stimulation (CES) may be a promising alternative to surgery1 due to presumed closed-loop early seizure suppression. Improved approaches for specific and fast seizure detection, validated on central lobe epilepsy (CLE) patients, are required for the development of a next generation of implantable responsive CES devices. This study aims to employ a combination of machine learning methods, which have demonstrated sensitive and specific real-time classification of the ictal and non-ictal electrocorticogram (ECoG), and compare performance of the combined algorithm with algorithms used in existing responsive CES devices.

Recordings of ten CLE patients, who presented at least three seizures with similar onset characteristics during invasive presurgical evaluation were used. Six bipolar ECoG channels were selected for each patient to represent cortical areas inside and outside the clinically identified seizure onset zone. A patient-specific Random Forest (RF) classifier was trained using a 138-dimensional feature space, consisting of cross-correlation features and a set of per-channel time and frequency domain features. For every patient, performances were evaluated based on early detection sensitivity using leave-one-out cross-validation, and on false detection rate on a 24h test set.

On our data, the algorithm demonstrates improved performance as compared to existing responsive CES device algorithms. The used feature set and patient-specific RF classifier may be employed to achieve closed-loop suppression in future responsive CES implants for CLE treatment.

1. Vassileva, A., van Blooijs, D., et al. Neocortical electrical stimulation for epilepsy: Closed-loop versus open-loop. Epilepsy Res. 141, 95–101 (2018)

P04 Prospective evaluation of seizure detection performance of the Embrace wristband on pediatric patients in the epilepsy monitoring unit

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Embrace is a wrist-worn device that senses accelerometry (ACM) and electrodermal activity (EDA) to detect patterns likely associated with generalized tonic-clonic seizures (GTCSs). A multi-center retrospective study on 69 EMU patients (4-60 yo) showed the potential of a machine learning algorithm to recognize GTCSs from sensor data, with a sensitivity (Sens) higher than 94% and false alarm rate per day (FAR) lower than 0.25 (Onorati et al 2017, Epilepsia). A successive prospective analysis reported Sens of 98% and FAR of 0.94 on a larger cohort (141 EMU patients, 6-63 yo), which led to FDA clearance of Embrace. Higher FAR was ascribed to the prevalence of pediatrics, who are naturally more prone to engage in activities involving repetitive movements (e.g. clapping). Here we report additional analyses on a pediatric population, which was part of a phase III prospective trial of Embrace in EMUs.

Between October 2017 and January 2019, 40 pediatric patients at risk of having GTCSs were admitted to the EMU at Bambino Gesù Children's Hospital and monitored with video-EEG (vEEG) and Embrace. VEEG-based seizures annotation was Indiapendently performed by 3 board-certified neurologists blIndiad to sensors, and used as ground truth for performance evaluation. Embrace alerts were logged in a separate database.

Eleven subjects were discarded from the analysis due to lack of compliance or age lower than 2 yo. On the 29 patients left, the overall number of days of data collected was 36.2 (mean of 30 hours/patient). No device deficiency or adverse event were recorded. Embrace detected 12 GTCSs out of 14 in 5 patients (overall Sens = 86%, CI: [70%-90%]; avg. patient-level Sens = 92%). The mean detection latency with respect to the start of the generalized phase was 30 s (range: 15-49 s). The overall FAR was 0.8 (CI: [0.48-1.18]). 52% of patients experiences 0 FA, while 48% experienced 29 false alarms. These results confirm the effectiveness of the Embrace as a GTCS alerting device.

P05 Algorithmic modelling of nocturnal epileptic episodes

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Proper seizure documentation is an important tool to evaluate treatment outcomes and risks associated with epileptic seizures. In the case of nocturnal seizures, the rate of documentation and proper characterization can be as low as 10% [0]. Here, we propose an algorithmic method to aid in the accuracy and scalability of nocturnal seizure detection using an existing low-cost video-based monitoring system. [0] Peciola et al. Under-reporting of nocturnal seizures using video-based home monitoring: a case study on the evaluation of the effect of vagal nerve stimulation. Epileptic Disorders. 2018 Dec 1;20(6):535-540.

For each type of motor seizure, we have developed separate models derived from a common set of extracted video and audio features. By using a classical machine learning-based method with a sample size of at least 10 patients / 15 seizures per seizure type, each model is trained in a cross-validated manner appropriate to the Phase II validation requirements set by [1]. The vision features are based on background segmentation and optical flow path reconstruction tuned for ictal movement patterns. The audio features are extracted by a convolutional neural network trained on ictal sound samples such as screaming. [1] Beniczky S., Ryvlin P. Standards for testing and clinical validation of seizure detection devices. Epilepsia. 2018 Jun.

While we continue to amass a larger data set for full validation, our preliminary results achieve 100% sensitivity in detecting nocturnal motor seizures, both prominent (tonic-clonic, clonic, tonic, hyperkinetic) and subtle (automatisms, myoclonic). Specificity ranges from 30% to 100% depending on seizure type. In the context of a seizure monitoring service, this model holds promise to improve accuracy and scalability by reducing fatigue of human annotators. We anticipate future iterations to prove useful in building a system for automated, online seizure detection and classification.

P06 Detection of hypermotor seizures using accelerometry

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Hypermotor seizures (HMS) display great variability both in semiology and duration, making the construction of general algorithms for seizure detection challenging. In this study, we aim to investigate several techniques for detecting HMS in the context of low background activity but not restricted to sleep.

Accelerometers were attached to both wrists of patients undergoing video-electroencephalography (vEEG) monitoring at the Sahlgrenska University hospital. A total of 37 HMS in four patients were identified during the accelerometry recording. The accelerometer signal was pre-processed and used to identify a low-activity data set comprising 127 h. Due to the small number of HMS, seizures occurring in a high activity background were manually included in the low-activity dataset. Several common features were computed, a primary classification stage using kernel density estimation (KDE) was employed, and feature selection performed using forward selection or a custom overlap integral. Subsequently, several secondary binary classifiers were used to generate classifications with a 1 second resolution and a threshold based post-processing was implemented to generate seizure detection events. Both general and individual models were investigated. In eight of the HMS, the duration and/or characteristic of the motor manifestations made them impossible to distinguish from voluntary movements, both in terms of accelerometry signatures and video recordings. False negatives (FN) associated with these seizures were considered acceptable during the model evaluation.

Cross-validation showed that general models were sufficient in two patients while the other two required individualized models. Application of the KDE resulted in substantial false positive (FP) reduction, but at the cost of a moderate increase in FN. The best overall FP rates at 100% sensitivity obtained were 1,3 FP/h for general models and 1,0 FP/h for individual models.

P07 Classification of tonic-clonic seizures using wearable accelerometer sensors

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Onset of tonic-clonic seizures (TCS) can be focal (FBTCS), generalized (GTCS) or unknown. Analysis of movement pattern in TCS helps in classification and management of epilepsy. This study aims at developing algorithms for classification of TCS based on movement patterns detected by accelerometer sensors.

Two accelerometer sensors were placed on the wrists of 11 patients with TCS during electroencephalography and video monitoring (VEEG) at the hospital environment (in total 36 TCS: 34 FBTCS and 2 GTCS). Movement patterns in different phases of TCS, as well as relevant lateralizing semiological signs were considered for the analysis. Continuous wavelet transform was applied to the accelerometer data to investigate the patterns in time-frequency domain. Maximum values of the square of the wavelet coefficients in each scale were selected for further analysis. The obtained vector was segmented using windows of one second (100 samples). Ratio of sum (RS) was calculated (sum of samples in each window from left / right wrist). Level of asymmetry between movement patterns in the right and left wrist was obtained by applying a predefined threshold to RS. To estimate onset-side, RS was divided into 3 windows: 20 s at onset, 20 s at the end (EW), and the remaining samples in the middle (MW). The average values of the samples in EW and MW were then calculated (MEW and MMW, respectively). If MMW<1 or MEW>1, FBTCS was classified as left, and if MMW>1 and MEW<1, FBTCS was classified as right.

FBTCS were correctly identified in 31/34 cases (91.2%). The two GTCS were detected correctly. Onset-side was correctly identified in 29/31 FBTCS (93.5%). Our results demonstrate that accelerometer sensors provide useful data for TCS classification. In many FBTCS, information about onset-side can be given with considerable reliability. Considering the uneven availability of VEEG. This kind of analysis may help in early planning of further investigations and treatment.

P08 A personalized seizure detection algorithm using behind-the-ear EEG data

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Objective seizure logging requires a device with an automated seizure detection algorithm. Current devices are able to detect mainly motor seizures. Non-motor seizures can be detected using electroencephalography (EEG). However, recording full EEG outside the hospital is cumbersome and stigmatizing. We are developing a new wearable device which is able to record EEG behind the ears. In this study, two EEG electrodes were placed behind both ears, which were used for the seizure detection during longterm videoEEG recording. On one hand, a model can be constructed using non-patient-specific data, which result in mediocre performance since the ictal EEG patterns are patient-specific. On the other hand, a model can be constructed using patient-specific data, which has the limitation that only a low amount of seizure data is available. The aim of this study was to improve the detection performance by personalizing the non-patient-specific model in an optimal and efficient way.

Behind-the-ear EEG features were classified into either epileptic or non-epileptic activity using a support vector machine. This classifier was trained in three different ways. Firstly, the classifier was trained using non-patient-specific data. Secondly, the model was constructed using only patient-specific data. Lastly, the non-patient-specific model was improved by adding patient-specific data. The algorithm was evaluated on a dataset of 3473 hours acquired at UZ Leuven containing 34 patients with 175 focal seizures, ranging from 2 to 23 seizures per patient.

The non-patient-specific model resulted in an average performance of 64% sensitivity and 2.6 false alarms per hour, whereas the patient-specific model achieves 73% sensitivity and 0.9 false alarms per hour. The improved patient-specific model outperformed the results with 78% sensitivity and 0.6 false alarms per hour. Personalizing an EEG-based non-patient-specific algorithm improved seizure detection sensitivity with fewer false alarms.

P09 Myoclonic seizures in different human body signals recorded with wearable devices

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Patients with Juvenile Myoclonic Epilepsy (JME) show a tendency to discontinue medication on their own, often without professional assistance. Studies suggest that some of these patients stand a good chance to remain free from seizures, even after discontinuation of their medication. Unfortunately, these studies lack any objective criteria to prove the absence of seizures. Particularly for JME, no tools are available for the objective monitoring and guidance of pharmacotherapy discontinuation / titration in the ambulatory setting. Currently available, wearable seizure detection systems are restricted to a narrow range of seizure types and typically do not cover JME, mainly manifested by myoclonic seizures. We thus aimed to explore a multitude of different measuring channels of human body signals in a real-world setup, which eventually could be used for the detection of myoclonic seizures in a future wearable detection system.

A single, 22-year old male JME patient not taking any medication was object of the study. Myoclonic seizures were recorded for 7 days continuously during daily activities. 24 different channels were recorded to 4 mobile measurement devices including two ECG, thirteen EMG, two EEG, one EDA and two 3D-ACC channels. During the recording and after each occurence of a myoclonic seizure, approximate time of occurence was manually logged to a smartphone app along with additional information. After recording, signals were analysed and characteristics of individual events were described.

104 myoclonic seizures were perceived and annotated by the patient. Of these, 86 could be found and identified in at least one of the 24 different measurement channels. Features of myoclonic seizures, as described in the current literature, were observed. A statistical comparison of all channels regarding to their potential of usage for a wearable detection system was made. 3D-ACC sensors on arm, head or torso, sEMG on biceps and EEG are suggested for further research.

P10 Improvement of generalized tonic-clonic seizure detection by Embrace wristband on outpatient data

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Embrace is an FDA-cleared wrist-worn device that senses accelerometry and electrodermal activity to detect and alert for generalized tonic-clonic seizures (GTCSs). Tests of real-time algorithms on inpatients have shown sensitivity (Sens) higher than 90% with low false alarm rates (FAR = 0.2-1/day). On more active outpatients, the FAR have been decreased towards levels tolerable for the majority of patients and caregivers (Regalia et al., 2019, Epilepsy Research). Beyond the primary alerting function, a GTCSs detection algorithm is clinically useful also to automatically fill a digital diary, which can be further reviewed by clinicians for diagnostic and treatment management. With offline processing, it may be possible to further reduce the FAR. Here, we report the latest results for FAR reduction in outpatients.

The test set consists of 2,136 hours of Embrace data recorded from 32 users (avg 66.75 hours/user). The GTCSs were reported by users and successively reviewed by 2 data experts. A variety of real-life activities prone to generate false alarms are present in the test set, which was completely separated from the data used to train the different versions of the GTCS detection algorithm (DA). Data were analyzed offline by 3 DAs: (I) a real-time/embedded DA which formerly showed promising long-term ambulatory performances (Onorati et al., 2018, European Congress on Epileptology); (II) a real-time/embedded DA that obtained FDA clearance for monitoring GTCSs during rest periods for ages >=6 in Dec 2018; and (III) a novel offline DA, developed using more training data and adding advanced new features.

The test data contained 55 GTCSs reported by 8 out of 32 users. DA1 yielded Sens = 91% and FAR = 1.15/day; DA2 yielded Sens = 91% and FAR = 0.83/day; DA3 yielded Sens = 91% and FAR = 0.25/day. Keeping high Sens levels, it was possible to further reduce the FAR on outpatient data for offline review, by increasing the quantity and the quality of the information.

P11 Wrist accelerometry-based detection of nocturnal myoclonic seizures

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There is a growing need for non-EEG wearable devices to automatically monitor epileptic seizures in ambulatory and outpatient settings. Efforts in this field have previously focused on detecting generalized tonic-clonic seizures (GTCSs), such as by using accelerometry (ACM) and electrodermal activity (Onorati et al., Epilepsia 2017). Myoclonic seizures (MS) are motor seizures characterized by short sudden jerk-like movements, which can disrupt sleep and precede other more severe motor seizures. Current detection devices developed for GTCS are unable to detect MS. State-of-the-art algorithms based on ACM for MS detection report sensitivity (Sens) as high as 80% but with false alarm rates (FAR) as high as 100 per hour (Nijsen et al., IEEE Trans Inf Technol Biomed 2010). Here, we present preliminary results of a new automated nocturnal MS detection algorithm.

Data include EMU inpatient data and outpatient data. Inpatient data are from 4 epilepsy patients undergoing video-EEG (vEEG) monitoring at Boston Childrens' Hospital wearing an Empatica E4 wristband with 3-axis ACM. Seizure annotation from vEEG was performed by one board certified clinical neurophysiologist blIndiad to sensor data, and used as ground truth. Outpatient data included continuous ACM recordings from Empatica Embrace from 4 healthy subjects. ACM data were analyzed using a proprietary classification algorithm. Due to the limited number of patients with epilepsy, a leave-three-seizures-out cross-validation approach was employed. Performances were computed as Sens and FAR during sleep periods, which were identified by a proprietary algorithm.

432 hours (avg 108 hrs/patient) of inpatient data and 314 hours (avg 78 hrs/patient) of outpatient data were analyzed. Overall, 34 MS were recorded from the 4 EMU patients. The algorithm detected 23 MS (Sens = 73%), with avg FAR of 1.13 per night. These preliminary results are promising for the automating nocturnal MS detection with a high Sens and bearable FAR.

P12 A modular, generalized time series seizure detection algorithm using deep neural networks

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The rapid growth of wirelessly connected physiological monitors is expanding possibilities in ambulatory EEG monitoring and responsive neuromodulation in epilepsy. With increases in mobile computational power comes the ability to run more complex algorithms for seizure diaries and closed-loop neuromodulation.

Our aim is to develop a generalized seizure detection algorithm trained using signals from selected subjects and tested in other subjects. We are using iEEG signals recorded with the NeuroVista Seizure Advisory System device (SAS, Neuro Vista Inc.) from 4 canines and 4 human subjects. The iEEG was acquired from a sixteen-electrode configuration and was recorded in ambulatory subjects via wireless telemetry. A Long Short-Term Memory (LSTM) Recurrent Neural Network (RNN) algorithm was designed and was trained on 1-second iEEG segments. The algorithm was tested in pseudo-prospective mode on all the future data available.

The algorithm was first run individually on each canine subject's data training on the initial portion of the recording and testing on subsequent data. The algorithm was trained on 2 dogs and tested on 2 different dogs to assess inter-subject performance. The classifier was then trained on data from all 4 dogs and tested on the human iEEG seizures to assess inter-species performance. To compensate for the unbalanced ictal/interictal data ratio in training, noise-added copies of ictal data segments were generated. In all experiments algorithm performance was evaluated using the area under the ROC curve (AUC). The average AUC for intra-subject training and testing for the 4 dogs was 0.96. The AUC across the test data of the 2 dogs using a classifier which was trained on 2 other dogs was 0.93. Using the canine-trained algorithm for human iEEG data resulted in mean AUC of 0.66.

P13 Detecting focal seizures in multimodal biosignal data from wearables

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In Epilepsy research, wearables have been considered to detect and log seizures of patients with epilepsy (PwE) in their day-to-day environment. These are most commonly smartwatch-like devices or fitness trackers recording biosignals such as accelerometry (ACC), electrodermal activity (EDA), and blood pulse via photoplethysmography (PPG). These biosignals have been shown to give sufficient indication towards epileptic seizures, with research focusing on monomodal and multimodal detection of generalized tonic-clonic seizures (GTCS) [Kusmakar 2017, Cogan 2017].

Here, a first look is offered into a possible multimodal approach to detect focal seizures (FS), which is a relatively new and unexplored avenue in epileptic seizure detection. A new and extensive data set of biosignal data from wearables worn by PwE during video-EEG monitoring was recorded. A multimodal seizure detection pipeline for variable types of seizures was implemented, and a large feature set was calculated from biosignals like ACC, EDA and PPG. The feature set specifically mixes features from all biosignal modalities, and at multiple feature window lengths. This allows for a comprehensive feature selection particularly for different types of FS.

Preliminary tests of the detection pipeline on individual patients that have multiple FS with motor components recorded show promising results. For example, in an event-based leave-one-seizure-out cross-validation on three select patients with varying levels of motor components in FS, a simple Random Forest model could detect 100%, 78%, and 57% of seizures respectively. While one patient had multiple characteristic FS with tonic and clonic components that were robustly detectable, the patient with the worst detection rate showed mainly pedal, manual and oral automatisms. In the future, the cross-patient behavior of such a system needs to be evaluated, as well as the performance on different types of seizures like autonomic or dyscognitive FS.

P14 The Dravet Syndrome SCN1A/A1783V mouse model shows temperature-dependent brain hyperexcitability that ultimately leads to heat induced seizures

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Dravet Syndrome (DS) is an epileptic encephalopathy characterized by drug-resistant seizures (often triggered by hyperthermia) accompanied by cognitive and motor deficits and high risk of sudden unexpected death in epilepsy. In up to 90% of cases DS is caused by happloinsufficiency of the SCN1A gene encoding the alpha subunit of a voltage-dependent sodium channel (Nav1.1). Here we aim at understanding the mechanisms underlying fever induction of seizures in DS by performing electrophysiological recordings in the Scn1aWT/A1783V DS mouse model under a thermal challenge.

5 Scn1aWT/A1783V and 5 Scn1aWT/WT littermates (~10 weeks of age) were implanted with deep electrodes across different layers of the hippocampus and prefrontal cortex. Simultaneous video recordings were used to assess behavioural state of the animals and the presence of (clinical) seizures. Sessions began with 30 minutes of awake, freely moving recordings at room temperature followed by a thermal challenge where activity was obtained at increasing temperatures (max. 42°C) or the appearance of seizures. Electrophysiological activity was inspected to detect abnormal activities (interictal epileptiform discharges, IEDs) or electrical seizures. IEDs were then semi-automatically detected by means of a supervised Supported Vector Machine. Video recordings were also reviewed to obtain a semiologycal description of the seizures.

IEDs were observed in all Scn1aWT/A1783V in basal conditions and increased in a temperature-dependent manner until seizure appearance. Seizures were multifocal, with different origins within and across individuals. They showed intra/inter-hemispheric propagation and often resulted in generalized tonic-clonic seizures. Altogether, our results suggest that the A1783V mutation in the Scn1a gene alters brain thermal regulation and precipitate seizures during temperature elevations. This sensitivity seems to be associated with the neural hyperexcitability observed at room temperature.

P15 Fitting Hawkes processes to multi-unit activity of an epileptic patient

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Hawkes process is a general framework of self-excitation regarding point processes. Here the dynamics of the MUA of epileptic patients is modeled using this particular class of point processes with a feedback effect, in which the intensity is

$$\lambda_t = \mu + \int_{-\infty}^{t} g(t-s)\,\mathrm{d}N_s$$

affected by past events (Hawkes processes): In the special case of exponential core function self-excitation is characterized by two parameters, volatility and friction. These control the length and density of trains of events (bursts) to occur, but it can be shown that imbalance of these two parameters may lead to the explosion of the process. This feature, the stability of the system is denoted by c,

$$c = \int_0^{\infty} g(s)\,\mathrm{d}s$$

where The system is stable only if $c < 1$. We note that an additional parameter – mean firing rate – is used. Our aim was to investigate how processes fitted to human multi-unit activity (MUA) change during epileptic activity.

We recorded MUA from a patient with therapy refractory epilepsy using laminar microelectrodes. After applying a band pass filter (500-3000Hz) the signal was thresholded using a median based filter in order to derive series of events from the continuous signal. Hawkes processes were fitted to distinct epochs of the data using maximum likelihood estimation (MLE). Epochs were represented with their parameters acquired during the MLE. Significance of the results was determined by computing the confidence ellipsoid of a given estimate.

We found clear separation between epochs recorded during interictal periods and seizure in the parameter-space. Also, we observed that processes fitted to seizure-containing epochs drifted towards unstable regimes.

P16 Information flow in EEG source networks in epileptic children with focal seizure activity

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Scalp electroencephalographic (EEG) signals are influenced by several factors, including volume conduction and low spatial resolution, which can jeopardize the validity of brain connectivity analysis performed on the raw recordings. One possible solution is to identify, starting from scalp EEG signals, the underlying cortical source activations, and to apply connectivity metrics on the reconstructed source time series. In this work, the dynamics of information flow between cortical EEG signals obtained after source reconstruction were assessed in children suffering from focal epilepsy.

In a group of 10 children with focal seizures, 5-second windows of the 19-channel EEG were obtained in the baseline, pre-ictal, and post-ictal phases. After filtering and artifact removal, 19 baseline, 19 pre-ictal, and 12 post-ictal stationary trials were selected for the analysis. Source reconstruction was performed combining a common spatial pattern algorithm with linear modeling and Indiapendent component analysis. Finally, linear measures of functional connectivity (information storage, total and conditional information transfer) were obtained from vector autoregressive models of the source signals.

While the average information stored in the nodes of the source EEG network did not change significantly across conditions, the total information transferred to each node increased significantly just before the seizure onset ($p=0.001$) and remained high after the seizure ($p=0.009$). The number of directed links in the network (statistically significant values of the conditional information transfer) also increased comparing the pre-ictal and post-ictal phases with the baseline period ($p=0.134$, $p=0.109$). These results indicate that a reorganization of the source EEG network, characterized by dense topology and increased information transfer, occurs before the onset of focal seizures, which is promising for seizure prediction algorithms.

P17 In hospital patients' experience of wearing multimodal devices for remote measurement and recording of epileptic seizures: a qualitative analysis.

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The capability of wearable devices to detect epileptic seizures is being investigated; however, developing a device acceptable and usable from the stakeholders' viewpoint is crucial. In previous studies feedback from people with epilepsy (PWE) has largely stemmed from discussing theoretical devices [1]. The aim of this study is to assess for the first time how the priorities and concerns of PWE interact with specific wearable devices.

Adults with a diagnosis of epilepsy admitted for scalp video-EEG were asked to wear one or a combination of wearable biosensors. Selected wearables are CE or FDA marked, or "prototype" designed for real-time acquisition of bio-signals. Semi-structured interviews were conducted by a psychologist on people having worn one or more devices for at least 24hours. A systematic thematic analysis extracted themes focusing on acceptability and usability.

Twenty-one PWE took part in the interview. PWE described their experience as convenient but highlighted problems such as the presence of wires, support and discomfort. Their motivation was strongly influenced by the device functions (i.e. efficiency in detecting bio-signals related to seizures). PWE were interested in wearing additional devices and sharing their data with professionals and were open to the possibility of wearing devices at home. Willingness to use an additional smartphone app to gather self-reported information varied between participants depending on the frequency and amount of questions. We also found that some devices were more tolerable than others. Comfort, efficacy, flexibility and appearance of the device were considered most important. Feedback from PWE based on a direct and prolonged experience should be the guidance to inform the design of feasible and acceptable future studies using wearable devices in hospital and home settings.

[1] Ozanne, A. et al. (2018) 'Wearables in epilepsy and Parkinson ' s disease - A focus group study', pp. 188–194. doi: 10.1111/ane.12798.

P18 Digital holistic decision support system for neurologists & PWE: A report from field usability tests

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Epilepsy is a heavy chronic disease: People with epilepsy (PWE) often live with comorbidities, the epilepsy is often uncontrolled and the social impact is undeniable. Moreover, there is a lack of data and insights in the epilepsy of patients. Finally, doctor-patient communication is often frustrating. On the other side, new technologies and findings in sensors, data science, digital tools and behavioral science are bringing opportunities to streamline the care of chronic disorders like epilepsy. The objective of this field usability testing was to evaluate the relevance of a holistic monitoring & management platform for PWE and neurologists.

A holistic digital platform was built (Helpilepsy), based on literature research and field observations. This platform is a mobile app for PWE (optionally with seizure-detection device) through which PWE monitor their epilepsy with standardized forms and PRO's. The app also features managing tools for PWE, like appointment preparation and medication reminders. For neurologists, the platform provides a dynamic dashboard and reports with data insights of each patient. This study was a field usability test with as goal to assess the potential benefits.

More than 35k seizures & 3k side effects were monitored through the platform, and it was used in >300 appointments.
The reported benefits: Patient empowerment (e.g. >80% of PWE reported Helpilepsy as very useful during the appointment), care efficiency (e.g. significant time gain during the anamnesis), care quality (e.g. when used correctly, could lead to >10x more data), clinician satisfaction (e.g. when used correctly, physicians reported it as helpful). Other key insights were gained (e.g. how to increase data quality), providing valuable inputs for improvements.
These usability tests have shown potential benefits of a holistic monitoring & managing platform like Helpilepsy. COHORT studies are needed to show the quantifiable effect on a larger population group.

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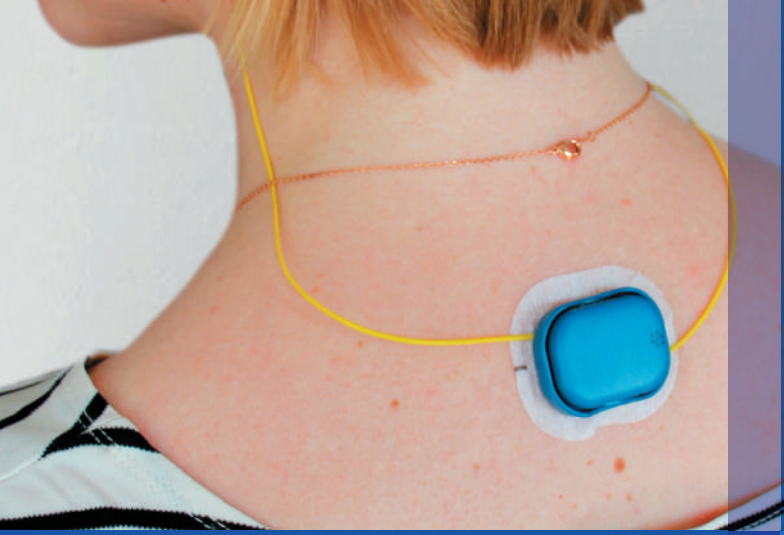

This discreet wearable device monitors several biosignals to allow a more precise quantitative analysis of seizure activity.

SeizeIT2 – Discreet personalised epileptic seizure detection device

SeizeIT2 is a clinically accurate seizure detection system for people with epilepsy, currently in development.

- 70–90% accuracy,[1] compared to the accuracy level of less than 50% that is typical for a seizure diary[2]
- Optimised treatment for a patient's specific condition
- Improved patient experience

For more information visit:
https://www.eithealth.eu/innovation_projects

1. Gu Y, *et al.* 2018. Comparison between scalp eeg and behind-the-ear eeg for development of a wearable seizure detection system for patients with focal epilepsy. *Sensors,* 18(1), p.29.

2. Elger, C.E. and Hoppe, C. 2018. Diagnostic challenges in epilepsy: seizure under-reporting and seizure detection. *The Lancet Neurology*, 17(3), pp.279–288.

SEIZEIT

SeizeIT2 is a joint development project involving:

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