Improving convulsive seizure detection by exploiting data from outpatient settings using the Embrace wristband

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Purpose

Embrace (http://www.empatica.com/product-embrace) is a wearable convulsive seizure detector and alert system (Figure 1, Top) currently under evaluation in an IRB-approved clinical trial. The system relies on wristband-embedded accelerometer sensors and skin conductance sensors able to detect the electrodermal activity triggered by the sympathetic autonomic response during a seizure (Figure 1, Bottom).

Data collected in Epilepsy Monitoring Unit (EMU) settings do not mimic the real-life environment where Embrace is intended for use. In home settings people are engaged in very different physical activities, such as sports and physical labor, which are likely to trigger more false alarms.

Here we show the effectiveness of adding home subjects' data to train the convulsive seizure detector, compared to the performances of seizure detectors trained solely with dataset collected inside EMUs.

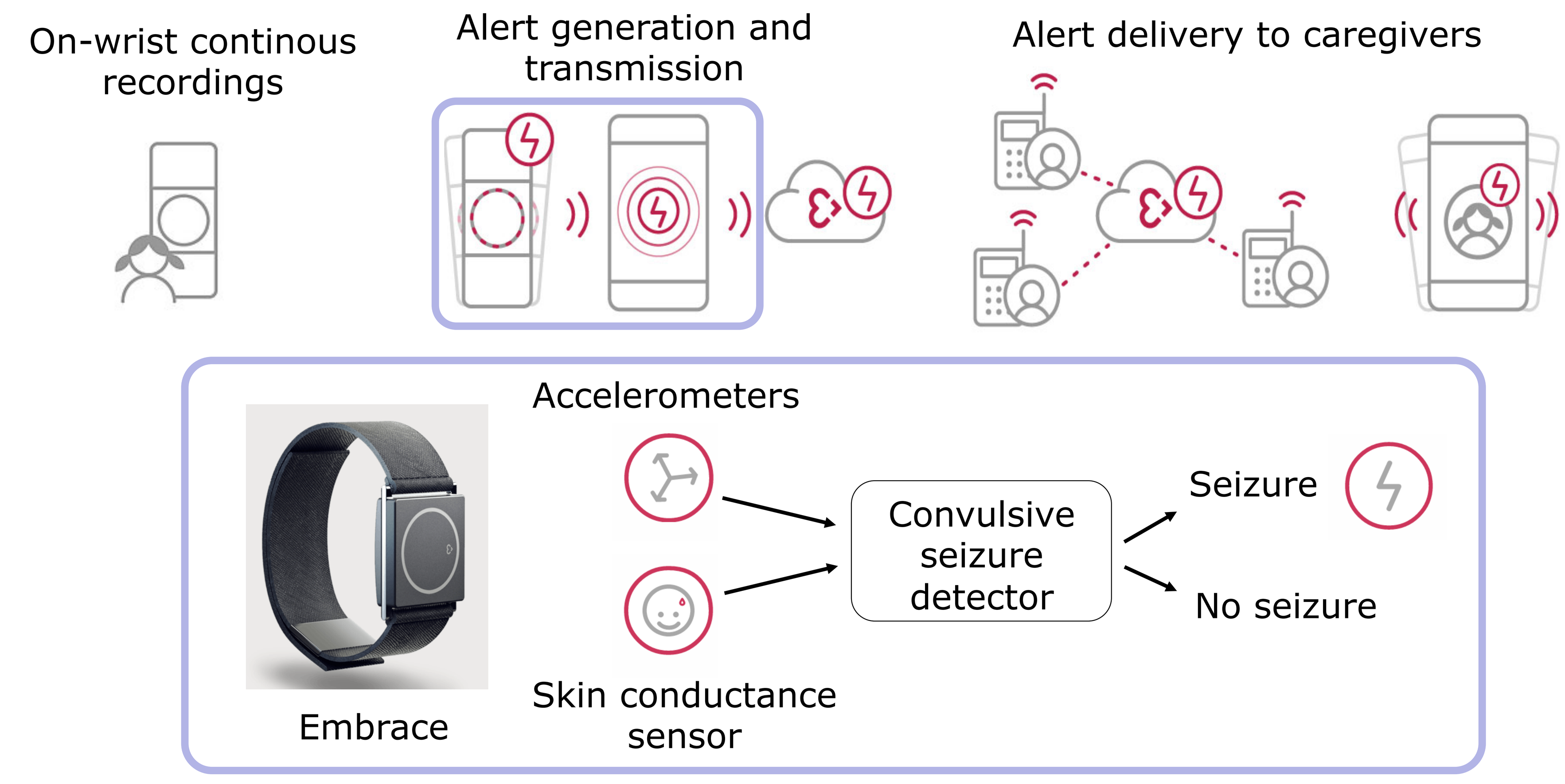

Figure 1. *Top*: Schematic representation of the Embrace seizure detection and alert system, composed of a wristband which transmits alerts to the patient's smartphone, which in turn delivers it to the cloud. Caregivers are then alerted through a phone call. *Bottom*: Schematic workflow of the convulsive seizure detector wristband.

Methods

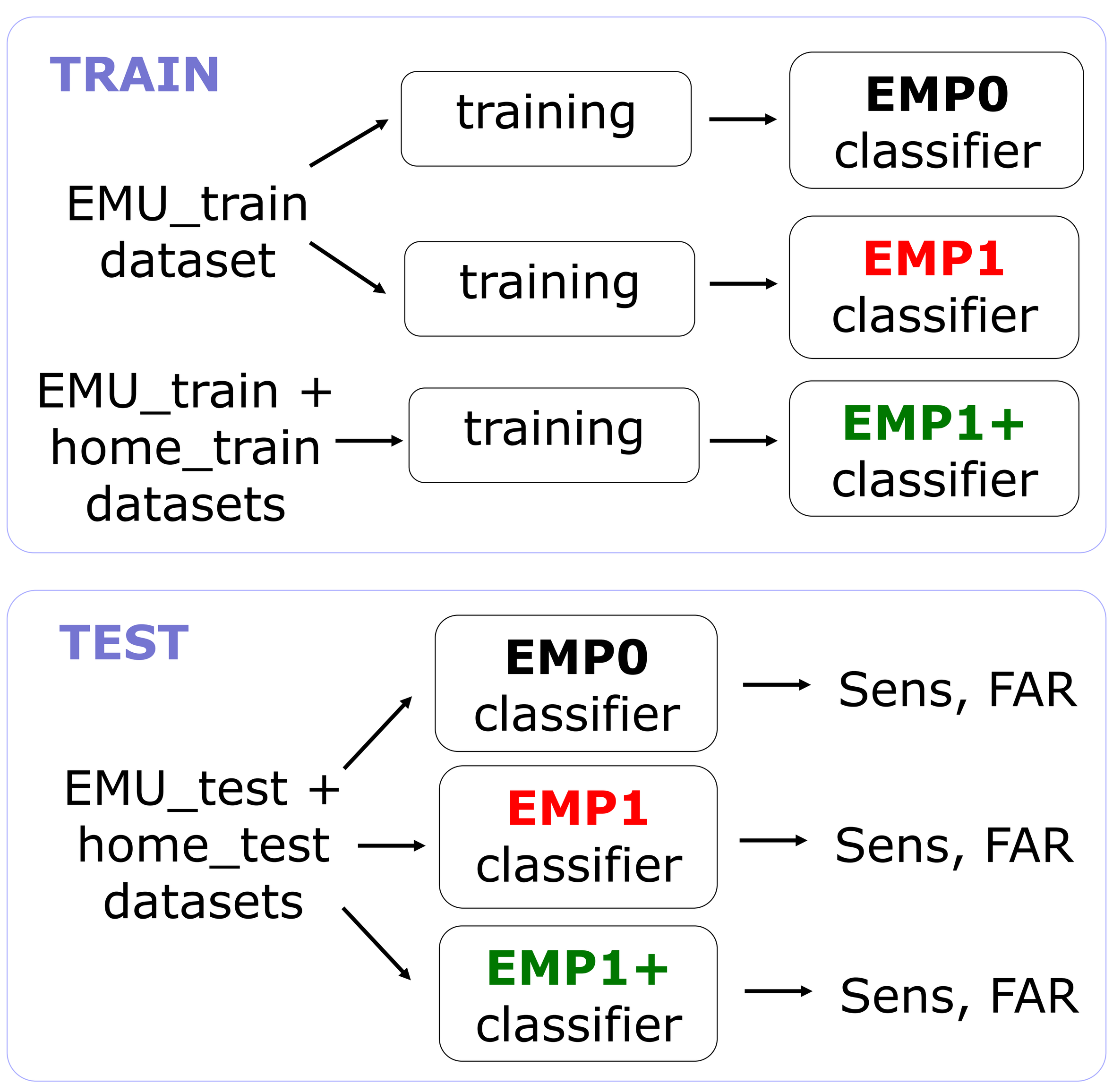

Figure 2. Schematic representation of the training (top) and testing (bottom) phases of the 3 seizure detectors under comparison.

Three seizure detectors (i.e., classifiers), namely EMP0, EMP1 and EMP1+, have been trained and tested as shown in Figure 2.

EMP0, based on a pilot classifier (Poh et al. Epilepsia 2012,53(5),93-7), and EMP1, an improved version of EMP0, were trained on an EMU dataset (EMU_train) consisting of recordings from 69 patients (5,918 hours) including 55 convulsive seizures (CSs) from 22 patients.

EMP1+ is based on EMP1, but was trained on a larger dataset recorded from 92 subjects (6,495 hours), including EMU_train and home subjects' data from 23 subjects (27 CSs from 4 patients, home_train). Home recordings with no seizures were included to represent confounding motor activities (e.g. sports, brushing teeth).

Performance was evaluated on a separate testing set from 36 subjects (2,210 hours) including EMU data from 5 patients (2 CSs from 2 patients, EMU_test) and home subjects' data from 31 subjects (53 CSs from 8 patients, home_test). Ground truth for EMU CSs was assigned through video-EEG examination, while ground truth for home subjects' CSs was derived from patient/caregivers-reported information. The sensitivity (Sens), i.e. percentage of recognized seizures, and False Alarm Rate (FAR), i.e. number of false alarms per 24 hours, where computed at different values of the decision threshold on classifiers output.

Results

Figure 3 shows an example of accelerometry (ACM) and electrodermal activity (EDA) signals recorded by Embrace wristband during a CS occurred in outpatient setting.

- EMP1+ classifier outperforms both EMP1 and EMP0, being the only one able to yield acceptable Sens and comfortable FAR values (top-left area in Figure 4) on the test dataset.
- For low (Sens=85%), mid (Sens=90%) and high (Sens=95%) sensitivity, EMP1+ shows respectively FAR=0.85, FAR=1.05 and FAR=2, while EMP1 shows respectively FAR=4.5, FAR=4.85 and FAR=6.1, and EMP0 shows respectively FAR=10.37, FAR=11.35 and FAR=20.48.
- Only EMP1+ classifier is able to reach Sens=100%, at cost of FAR=5.72.

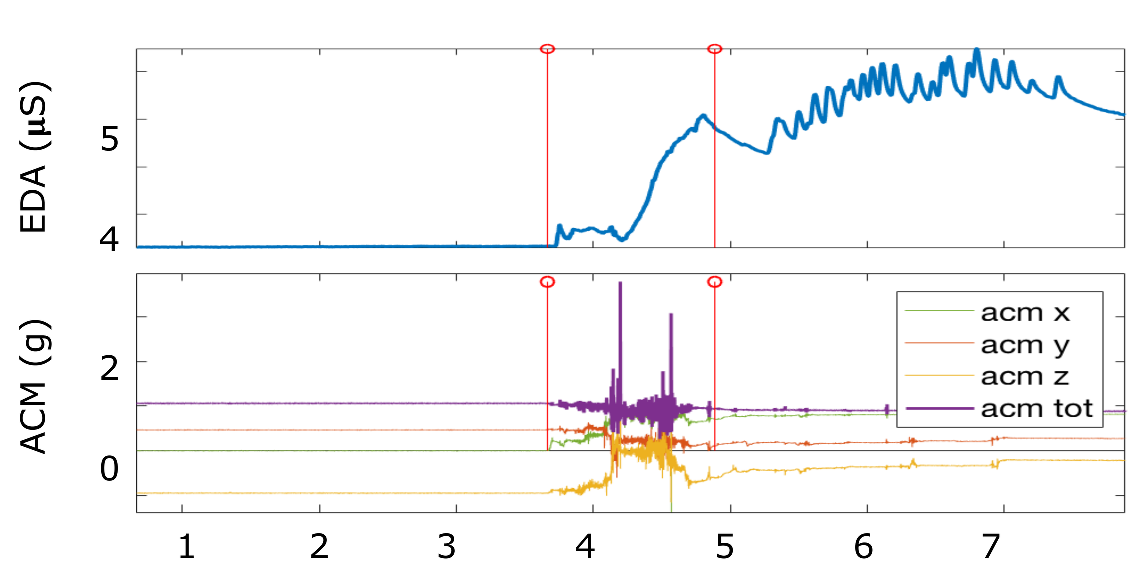

Figure 3. EDA (top) and ACM (bottom) signals of one patient recorded during a generalized convulsive seizure (CS) with Embrace. The red bars mark the seizure.

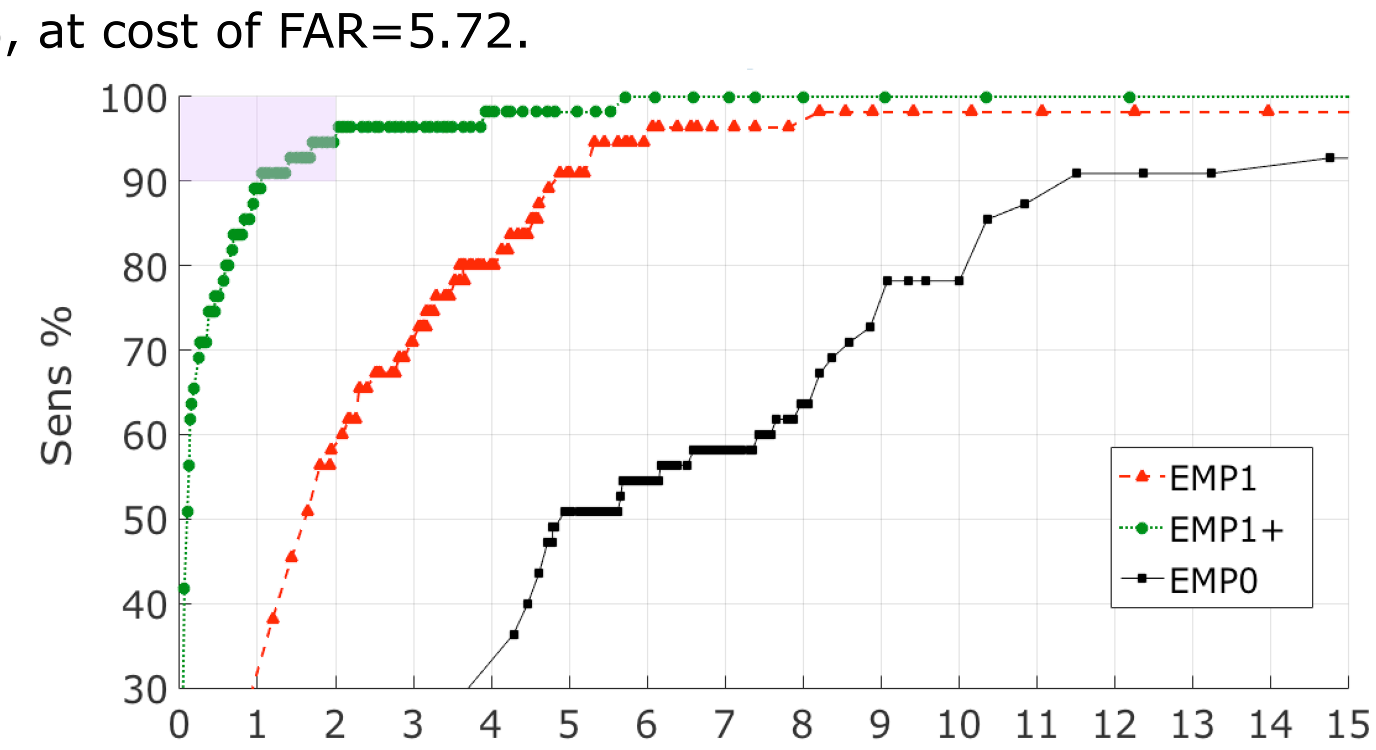

Figure 4. Performance comparison of the three seizure detectors on the test dataset. Each point of the curves represents the number of false alarms per day and the percentage of CSs correctly recognized at a specific value of the decision threshold. The colored area in the top-left corner represents the targeted performances (Sens>90% and FAR<2 false alarms per day).

Conclusions

- We have here shown that having access to home data can dramatically improve the performance of a portable convulsive seizure detector, taking advantage of a more comprehensive pool of human daily activities which can affect the performance of a classifier trained only on EMU data.
- The sensitivity on detection of convulsive seizures reached by EMP1+ classifier is significantly higher than published rates from patient-reported diaries, while maintaining a comfortably low rate of false alarms, which is being made even lower by means of algorithm's optimization.

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