Electrodermal activity asymmetry in sleep - a case study for migraine detection

H. Mönttinen[1], H. Koskimäki[1], P. Siirtola[1] and J. Röning[1]

[1] Biomimetics and Intelligent Systems Group, University of Oulu, Oulu, Finland

Abstract— **Migraine is a poorly understood disease and it is estimated that 15% of people in Europe alone are affected by it. In this study skin electrodermal activity (EDA) signals of left and right wrists were collected from a migraine patient to see if the asymmetry associated with EDA signals will affect to migraine detection based on wearable sensors. In the study, nighttime EDA storm epochs were detected and visual inspection on total time of EDA storm epochs and timing of EDA storms between wrists were done. Also filtered EDA signals of nights that preceded migraine attacks were visually checked. According to the results, EDA measurements from one wrist are enough to detect changes before a migraine attack because the EDA asymmetry measured between wrists might play not a significant role in migraine prediction.**

Keywords— **EDA storms, sleep, migraine, wearable sensors**

I. Introduction

Migraine is a complex disease that is insufficiently understood. However, it is estimated that it affects 15% of people in developed countries and is one of the most disabling and costly neurological disorders [1]. The two most common types of migraine are migraine without aura and migraine with aura. They share otherwise similar symptoms (headache phase with a severe or moderate headache with nausea or phono or photo phobia) but in migraine with aura the headache phase is preceded by an aura phase, which may include visual, sensory or cognitive symptoms lasting approximately from 5 to 60 minutes. Occasionally, the aura phase may also appear without a headache. These two phases of migraine event may be preceded with a prodromal phase, which may have a wide variety of subtle symptoms like fatigue and food cravings. The headache phase is followed by resolution and recovery phases, during which the pain wanes but the overall condition is not yet normal and one might feel tired or other symptoms. Hence, in total, one migraine episode can affect for days.

In order to reverse or at least attenuate and shorten in length an upcoming migraine attack, a preventive medication should be taken on time. Unfortunately, for many patients, the recognition of upcoming migraine attack is difficult and medication is avoided until they are certain that the attack is really coming. However, it might be too late then, and hence, they have to suffer from attacks that could have been prevented with a medication taken on time. In addition with worsening of life quality, migraine attacks are an economical burden due to reduced working ability and absences from work [1]. Thus, early migraine detection would be a valuable addition to the patients and the society. In this study, some grounds needed for migraine detection based on wearable sensors are defined, namely related to EDA signals.

In earlier studies [2, 3], migraine attacks are tried to be predicted by using different combinations of SpO2, skin temperature, heart rate and electrodermal activity data. Despite of the promising results, the number of subjects is small and the suggested solution might be quite difficult to adapt in practice. Another study [4] used EEG data to classify migraine episodes into categories of inter-ictal, pre-ictal, ictal and post-ictal. By analyzing resting-state EEGs, they got promising results and were able to classify all stages user-independently with over 60% accuracy. In other study where resting state EEG were analyzed also [5], they discovered differences in EEG power and effective connectivity between patients and health controls, as well as between different migraine stages.

Electrodermal activity is used as the indicator of sympathetic nervous system activity in psychophysiology. Usually, the outermost layer of skin has a low conductivity but when sweat is conveyed to the skin surface due to sympathetic nerve activation, the conductivity increases. Normally, EDA has been measured in a palm with Ag/AgCl electrodes attached on the skin.[6] However, dry electrode measurements are also done in a wrist that is a much more convenient place in long term measurements [7] and is shown to correlate with the palm readings [8].

It is observed that skin EDA may be useful to use in detection of epileptic seizures due to the activation of sympathetic nervous system [9]. There is also some evidence that there exists asymmetry between EDA signals due to the activation of different brain regions [10].Nevertheless, there are no studies indicating if the same asymmetry exists during sleep or with migraine patients, and if it affects the possibility to recognize a migraine attack using the wearable sensors based on EDA signal. Hence, in this study, the aim is to see if there is a significant difference between wrists when measuring the electrodermal activity during sleep and with a migraine patient.

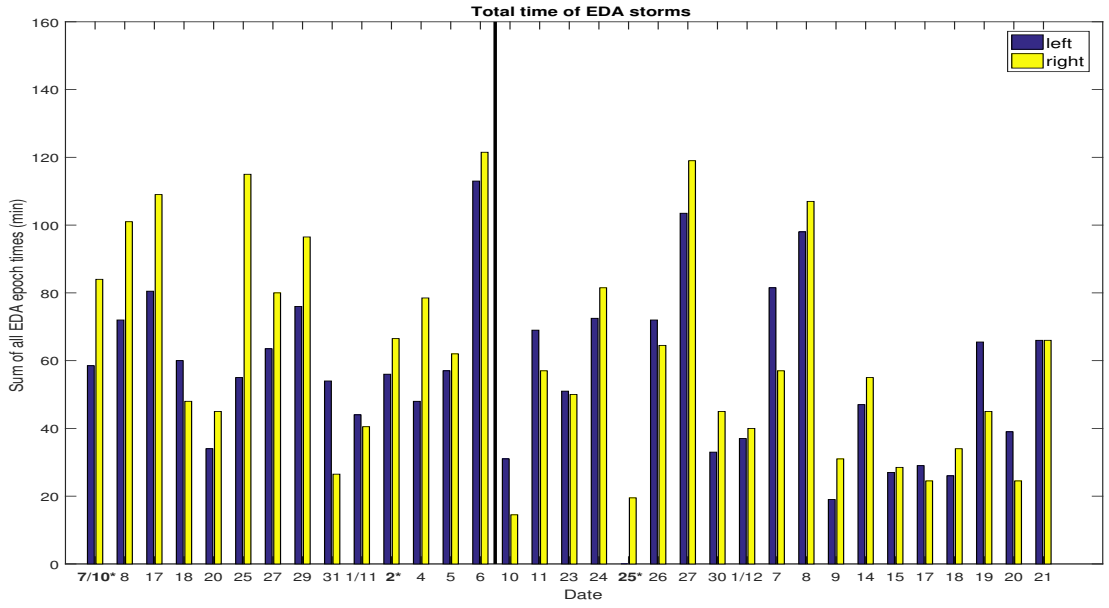


Fig. 1: The total time of EDA storm epochs during a night. A left hand is in blue and a right hand is in yellow. The black line in the figure shows the time when wristbands were switched from one hand to another. Nights that preceded migraine attacks are marked with asterisks.

Firstly, the level of asymmetry is studied by inspecting differences in EDA storm times detected during a night. Secondly, it is checked if there is detectable differences in the timing of EDA episodes during the night. Thirdly, it is checked if there is found some differences in EDA storms in a night before a migraine attack.

II. Materials and Methods

A. Collected data

A period for data collection lasted from October 2016 to December 2016 and altogether data from 33 nights were used. The data were collected from a right-handed 45-year-old female subject who suffered from migraine without aura. She did not take any preventive medication and only Burana or Panadol occasionally during migraine attacks. Within the 33 nights there were three recorded migraine attacks.

The data were collected by using two Empatica E4 wristbands, which were worn on both wrists. The wristband measured EDA (sampling frequency, fs = 4 Hz, resolution = 0.9 nS), skin temperature (fs = 4 Hz, resolution = 0.02 °C), acceleration (3-axis, fs = 32 Hz, resolution = 0.0156 g) and blood volume pulse (BVP) (by photoplethysmograph, fs = 64 Hz, resolution = 0.9 nW). By using BVP, inter-beat-interval (IBI) and heart rate (fs = 1 Hz) were calculated and provided by the wristband. In order to check if wristbands did not cause the seen differences on EDA level, the wristbands were changed on different hands within the data set after first 14 nights.

B. Data analysis

In this study, only EDA is studied. In preprocessing stage, nights were manually selected by using accelerometer and heart rate data to select times when the subject had been still and heart rate was lowered. The selected EDA night data were low pass filtered (cut off frequency 0.4 Hz) with a 32-order FIR filter. After low pass filtering, poor contact data were removed (EDA values were lower than 0.05 μS). EDA storms were automatically found in a similar way as in article [7], the threshold of the first derivative that was considered as an EDA peak was 0.05 μS / s. Also, the peak had to be separated at least by one second from the other peaks. Peaks were counted in 30-second intervals with no overlap. As in article [7], an EDA storm was detected if at least one EDA peak was found in two subsequent windows.

For comparing the differences between right and left wrists, a total time of EDA storms detected per night were calculated by summing together all 30 second windows that were labeled as being a part of EDA storm. As nights had different length, it was chosen to analyze approximately only first four hours of nights according to the length of the short-

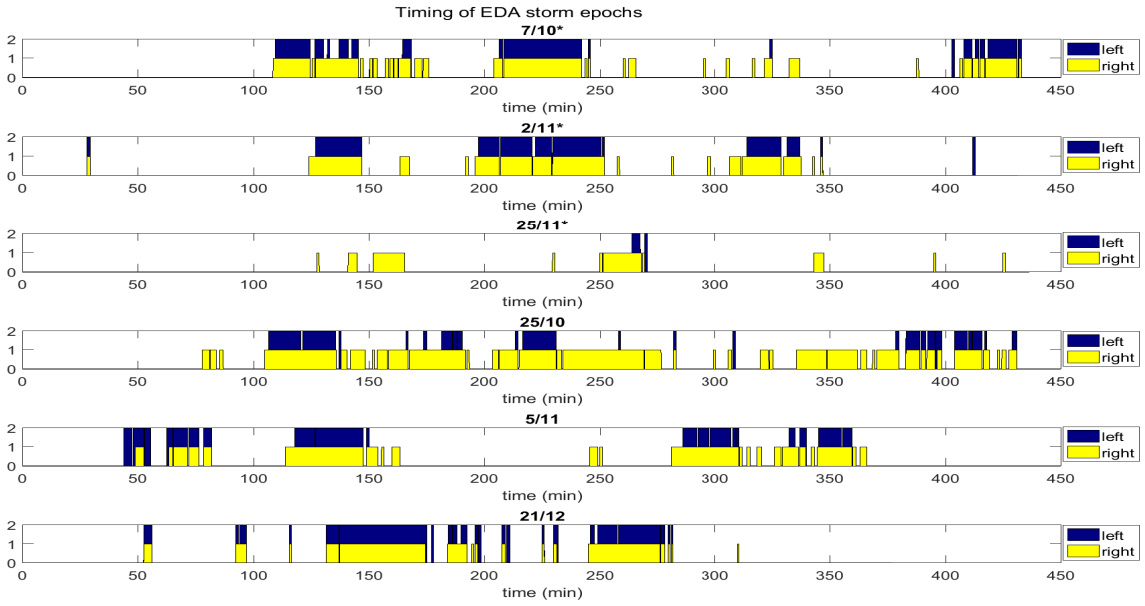


Fig. 2: EDA storm epochs marked with blocks. A left hand is in blue and a right hand is in yellow. Date times marked with asterisks are nights that preceded migraine attacks.

est recorded night. Secondly, to study the differences in the timing of EDA storms between the hands, all labeled EDA storm epochs from left and right wrists were plotted against each other. All migraine preceding nights and three healthy nights were chosen to be presented in this article. Finally, for studying if there are some visible similarities in EDA signals before migraine attacks, the three EDA signals from migraine preceding nights were drawn.

III. Results

A. Total time of EDA storms

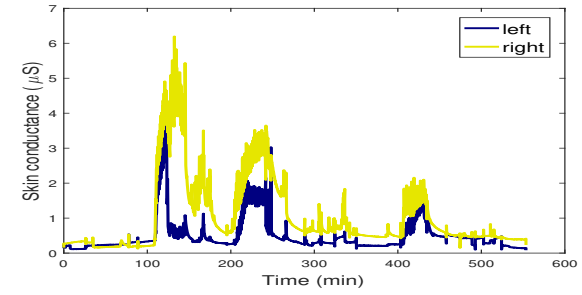
In Figure 1, it is shown a bar plot, in which the total time of EDA storm epochs is presented. The left wrist is in blue and the right wrist in yellow. The time when wristbands were switched is marked with the long black line and the three nights that preceded migraine attacks are marked with asterisks. When summing the total EDA storm time, it was noticed that most of the time right wrist had longer EDA storm times when compared to the left wrist. Also, it can be noticed that there was not any significant change when wristbands were switched from one wrist to another. However, there might have been some overall decrease during EDA storms in late December as they seem to be somewhat lower than during the rest of the measurement. Interestingly, in one night that preceded a migraine attack, there is clear decrease in EDA storms in the right wrist and EDA storms from the left wrist are absent.

B. Timing of EDA storms

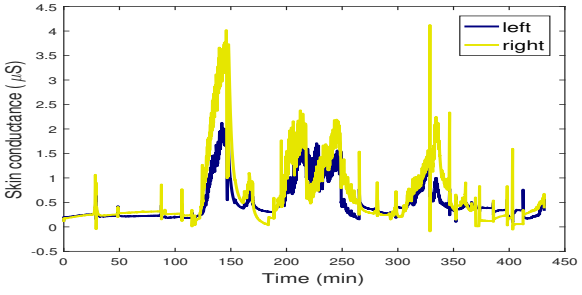
In Figure 2, is presented EDA storm epochs from different nights. The first three subfigures that are marked with asterisks are the three nights that preceded migraine attacks and the other three are healthy nights. The left hand is in blue and right hand in yellow. If timing of EDA storm epochs is compared, they quite often appear at the same time on both hands. There is clearly less EDA events on the left side, which do not appear on the right side. In some nights, almost all detected EDA storms on the right side also appear on the left side and the difference between wrists is small. In other nights, there is a clear difference in EDA storms but even then the storms usually appear at the same time when an EDA storm is detected on the wrist which is less active.

C. Prediction of upcoming migraine

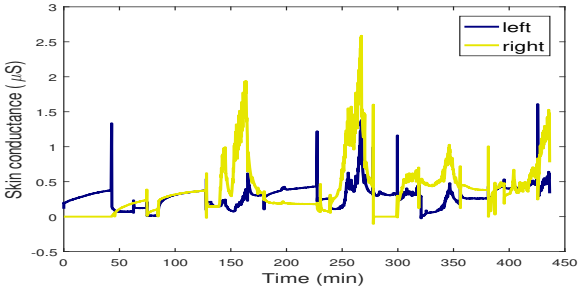
In Figure 3, is presented EDA signals form the three nights that preceded migraine attacks. The left wrist is in blue and the right wrist is in yellow. When looking at the signals, it



(a) October 7th.



(b) November 2nd.



(c) November 25th.

Fig. 3: Elecrodermal activity signals of three nights preceding a migraine attack. Blue is signal from the left hand and yellow is from the right hand.

can be said that in the first two nights before migraine, EDA signals are rather similar although the left hand has a lower level of conductance than the right hand. The third night, in which the differences were highest in previous figures, the skin conductance of the left hand is otherwise similar than in the right hand except for its EDA storm epochs (the higher parts of signal from the right wrist) are smaller. However, as there can be seen quite many quick transitions due to poor contact compared to the other two nights, it may have affected the results.

Overall, according to inspections done in the previous subsections, it seems that EDA asymmetry between wrists might not have any significant role in migraine prediction. Nevertheless, while the clear changes that are detected have been on the left side, it could be stated that if a wrist can be predefined for future EDA measurement, the left hand or non-dominant hand could be slightly favored in case of migraine prediction.

IV. Conclusion

In this study, a visual inspection was done on skin EDA data collected during 33 nights from one subject. There was some asymmetry detected between wrists but it seemed that the differences are not necessarily related to migraine. The only significant change was detected on the left hand hinting that asymmetry might play a minor role in migraine prediction and the left hand or non-dominant hand could be favored for EDA measurements. However, only one subject was studied and hence as a future research the results should be checked with a larger number of participants.

Acknowledgements

We are thankful for Tekes and Infotech Oulu for funding the study. We also want to thank Markku Nissilä for his time to answer our questions. In addition, we thank the Finnish migraine society for their help.

References

1. Linde M, Gustavsson A, et. al . The cost of headache disorders in Europe: the Eurolight project. *European Journal of Neurology.* 2012;19:703–711.
2. Pagan J, De Orbe M, Gago A, et al. . Robust and Accurate Modeling Approaches for Migraine Per-Patient Prediction from Ambulatory Data *Sensors.* 2015;15:15419–15442.
3. Pagan J, Risco-Marin J.L., et al . Grammatical Evolutionary Techniques for Prompt Migraine Prediction in *GECCO Genetic and Evolutionary Computation Conference. ACM*(Killarney, Ireland):1–5 2016.
4. Cao Z.-H., Ko L.-W., et al . Classification of Migraine Stages based on Resting-State EEG Power in *IJCNN International Joint Conference on Neural Networks*;4(Denver, USA):973–980 2015.
5. Cao Z.-H., Lin C.-T., et al . Resting-state EEG power and coherence vary between migraine phases *The Journal of Headache and Pain.* 2016;17.
6. Boucsein W. *Electrodermal Activity*. New York: Springer 2012.
7. Sano A, Picard R, Stickgold R. Quantitative analysis of wrist electrodermal activity during sleep *International Journal of Psychophysiology.* 2014;94:382–389.
8. van Dooren M, de Vries J, Janssen J. Emotional sweating across the body: Comparing 16 different skin conductance measurement locations *Physiology & Behavior.* 2012;106:298-304.
9. Poh M. Z., Loddenkemper T, et. al . Continuous Monitoring of Electrodermal Activity During Epileptic Seizures Using a Wearable Sensor in *IEEE 32nd Annual International Conference of the IEEE EMBS*(Buenos Aires, Argentina):1–5 2010.
10. Picard R, Fedor S, Ayzenberg Y. Multiple Arousal Theory and Daily-Life Electrodermal Activity Asymmetry *Emotion Review.* 2015;8:62–75.