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Technological considerations in measuring weather-derived epileptic seizures of dogs

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***Abstract*—As in every technical discipline, the objective, reproducible instrumental measurements are indispensable. It is no different at investigating the effect of weather on living organism. The parallel measurement of the atmospheric environment and the physiological parameters is novel and individual, as well as the investigation of epileptic seizures depending on weather situations. Several questions came up in connection with our equipment designed for studying dogs epileptic phenomenon, such as fixing, water resistant,- and robust implementation, the problem of data storage, measurement schedule or the power supply for instance. Keeping these in mind during the development process we got an apparatus, which since is an integral part of our further researches.**

Keywords—effects of weather, epilepsy, instrumental measurements

I. State of the Art

As demonstrated in our previous papers [1][2], the scientific world pays close attention to investigate the physiological effects of the weather, but still not aware or any equipment – besides our devices – which measures parallely the physiological characteristics of an individual and the individual's atmospheric microenvironment. In addition, in such a way to examine the impact of weather on epileptic seizures are completely novel [3][4]. This paper discusses experimental instrument development problems related to this research area.

II. Introduction

Today it is accepted as a fact that the weather – and its changes – has a significant impact on living organisms, as both international literature [5-8] and our previous publications [3][4] pointed out. In these publications we discussed some measuring technology questions as recurring problems, such as the schedule of the measurement, the sampling frequency, or the wearability and comfort of the equipments. We have performed measurements both on human and animal (especially dogs) individuals – from which mutually useful research results can be hoped due to the high degree on analogy [9] –, but the implementation of the measurements raise very different kinds of problems. In this paper we focus on dogs' epileptic seizure measurement difficulties.

It is necessary to discuss briefly the background of epileptic symptomatology, so it can be seen, that studies should be performed only with individualized characteristics, and individual assessment should be applied in every case. Dogs' epileptic seizures show a high degree of correlation with the human's, and seizure classification is based on a similar manner provided by the ILAE (International League Against Epilepsy) [10]. In the perspective of this paper – and also the developed test equipment – it is relevant to point out that an epileptic seizure can be partial (focal) or generalized, and in the majority of cases, months or even years before a grand mal seizure – involving loss of consciousness and generalized convulsions – focal symptoms may show. In addition, seizures may not affect only the musculoskeletal system, there are also seizures affecting visceral (with autonomous symptoms) and sensory system (eg. stinging, burning, tingling sensations etc.), or they result the impairment of consciousness (eg. hallucinations and temporary attention deficit disorders). The objective assessment can be achieved in these cases usually only with proper video-EEG monitoring. Consequently our study is primarily aimed at animals whose seizures induce motoric movement changes (i.e. seizures effecting muscle movement, thus easier to detect instrumentally): these can be tonic fits – with continuous contraction –, muscle contractions with grater or less frequency (myoclonus, either locally or spreading over the whole body), mixed (tonic-clonic) or atonic seizures as well.

III. Quasi-time-point events – Epilepsy

Our discussed research area is to examine the epileptic seizures in dogs generated by atmospheric micro and macro-environmental impact. Previous results have demonstrated the existence of this relationship [3][4]. It is important that each animal have individual seizure-pattern: an animal may have only one kind of seizure, but it often happens that is shows several focal symptoms beside generalized convulsion, and the temporal distribution of these seizures are different. In long-term epilepsy treatment one of the most important factor is the seizure frequency, i.e. how frequently epileptic fits occur (=how long is the seizure-free or interictal period). An epileptic event generally follows the next order: changes in behavior before the seizure (prodroma sign eg. changes in activity), then the epileptic fit (ictal signs), and after that postictal period. In some case the latter is much longer in time compared to the fit than the effective seizure (it could take hours or even days), so it could be easily mistaken with the actual seizure, since vast majority of epileptic events last only for minutes (or just 10-15 seconds), so owner of the animal only could notice – if they exist (eg. aggression, fear, psychosis, compulsive disorders, etc) – the postictal signs, not the fit itself. Another challenge in constructing a device which is capable to register these events in correlation with weather activity while meteorological changes takes place through several days (or weeks) we have to look for epileptic fits with minutes or even seconds (and thus resulting only a small fraction in the observation period).

To solve the problem of management and storage of the big output data of long-term measurements the predictability of weather changes can be very helpful. In case of a given individual – possess sufficient knowledge – we can determine what type of weather situation we should start our measurements or increase the sampling frequency. In the first phase of the examination for a selected animal, when we do not have prior knowledge about the individual yet, it is necessary to collect information covering the entire spectrum of weather.

Figure 2. Occurrence of an examined animal's epileptic seizures in 2013 (together with the identified meteorological fronts in those periods)

IV. Complex, inegrated measurements

As several physiological, environmental, meteorological parameters have to be measured in sync, a high degree of integration is required, which raises a number of difficulties. Because of the mainly long-term and high-resolution measurements, transmission and storage of large amounts of data is required. The wireless implementation – see below – sends the data through a 2.4 [GHz] communication channel to the docking unit so the amount of data to be transmitted is increased in proportion to the communication traffic, and that means extra energy needs. The storage and the processing of the big amount of data is an additional problem in case of month-term study of numerous individuals. The local data-processing could be a solution to this, but the studied meteorological processes can not be considered point-like and also not independent from each other, thus it would need serious memory and computing capacity, which is too energy intensive. For as much as the measurement of the activity[1] (as one of the physiological parameters) is quasi-continuous, while the weather parameters are enough to measure in minute intervals, we need to focus on this parameter at the solution of data amount problem. The following solution strategy has been developed (schematically):

- We find the lowest sampling frequency – based on Shannon's theorem [11] –, which does not distort the useful signal more than a threshold we define. For this, apart from the extreme movements a 25 [Hz] sampling frequency is satisfactory;

- A *scalar* software has been developed, which, under a given level of activity keeps the microcontroller in the ultra-low-power mode, then as the movement amount grows – what we detect with hardware interrupts – is sets the measurement dynamic range to the level of activity, and after a reduction in the activity is switches back to the IDLE state;

- Other sensors during normal behavior are turned on only with small time duty ratio and after the measurement series (which happen at the same time) they switches back to standby;

- In case of abnormal activity detection or a drastic change in the measured parameters – depending on the settings – measure frequency can be increase automatically.

These solutions can optimize the use of energy – which has an important role in wearability through reducing the necessary size of the battery – and reduces the amount of data as well. Data downloaded from the docking unit is then subjected to further processing – for example we can store movement-pattern information or activity level instead of acceleration values – to reduce the amount of data to be

[1] three-axis gyroscope and absolute acceleration

stored. The far most amount of output data arises on that version of the device which records ECG-signal as well, especially in continuous operation mode. In this case the most important is to determine the required measurement sections, which is currently under development.

It also posed a serious challenge to design the device – with energy sources, a number of sensors, wireless module and central microcontroller unit – in such a degree of integration level that is still should be small and comfortable to wear. To this, beside serious technical experience, the use of smallest size components in the industry contributed. We used:

- 0402 size code passive components;
- QFN package microcontroller unit;
- Surface Mount (SMD) 2.4 [GHz] antenna;
- multi-level PCB implementation at MEMS sensor modules;
- Li-Polymer battery.

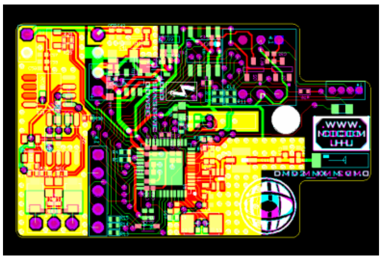

Figure 4. ECG mobile device's main PCB

The use of these technologies is clearly requires oven reflow soldering, what – being a small product series – we did ourselves using the apparatus of ICI Interactive Co. Ltd.

V. FIXING, ERGONOMICS AND SIGNAL LEAD

Since in case of dogs we can not expect that the wearer of the device pays particular attention to its safety, the implementation and the fixing must be robust. In addition, it is an equally important aspect that the device does not impede the animal in the normal way of living, nor to disturb the individual with its presence even in case of a long-term use. Various technological aspects arose during the design and testing (schematically):

- In the acceleration measurement – if we are interested also in the movement pattern – the direction of the sensor (so that we know which way is "up") is important, and to determine the correct amount of movement is essential that the sensor move together with the animal's mass center. It is obvious that the animal will produce quite different accelerometer data when the sensor is located on its back or on one of the lower legs;
- Measuring the ambient temperature it is important that the lead of the temperature sensor probe point the outside as more as it is possible to avoid measuring the body temperature of the animal. The temperature sensors must be located on the mobile device, as the docking unit is almost always being indoor, while the dog is not necessarily, and we need the atmospheric microenvironment of the animal, as its organism exposed directly to that;
- Measuring the ambient light – which is also important in epilepsy examinations [12][13] – stands similar to the criteria above;
- In case of the ECG version the chest electrodes should be protected against major shift, otherwise the quality of the signal lead drastically deteriorates.

Beside these the following general criteria should be considered:

- The device need to be placed so the dog can not reach it and for example not able to chew it;
- The device must be water-resistant, with water-resistant recharging ability. The former we solved with epoxy molding, the latter with gilt, corrosion-free connectors;
- Due to the large amount of data the mobile unit should send the data through wireless communication to the docking unit so the device fixed on the animal can be really *mobile* while the data can observed in *real-time*. These two features are very important, so during the design process were maintained with a high priority.

Based on the demands above using harness seemed to be an obvious solution. It is the most stabile way of fixing a device on a dog. This way, we have the chance to set the sensors in the best possible location (this influences most the ECG electrodes' position-stability), considering also the factors occurs in the animal's activity.

The latter not only helps to filter the noise, but also – taking into account the specific characteristics of the particular animal's epileptic symptoms – may help to find the best location where to place the accelerometer (eg. in the case of focal convulsions of head and neck muscles it can be placed on neck ring, or in case of limb movement the proper side of the animal)

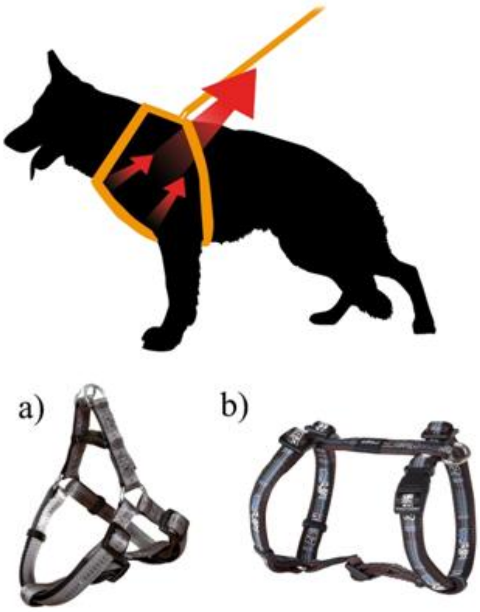

Figure 5. Two often used harness type
source: http://www.petdream.hu

VI. RESULTS

As a result of the technical considerations outlined above we get an easily wearable instrument, which – besides it is capable for several days of continuous operation with a single charge – provides reliable measurement results. The measurements of the ambient light and temperature are satisfactory, the activity measurement is excellent. The ECG signal's lead during series of tests on animals in resting position brought very good results, but in case of moving, active animals further improvements are needed to increase the stability of the electrodes. Our further goal is to create an experimental tool can gain data more efficiently and accurately, thus also suitable for clear identification of the type of epileptic seizures.

Figure 6. Mobile device (ECG type) and docking unit

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