

Spatial ECG of the Rat During Spatial Navigation

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ABSTRACT

In the present study our aim was to spatially characterize the electrocardiogram (ECG) during the free navigation of rats in an open space via 2D maps. The development of the necessary tools (hardware, analytical) to carry out this mapping should allow us in the future to obtain a physiological correlate of different behaviours. With that purpose, we recorded the ECG from Lister Hooded rats with three superficial electrodes while the rat was being tracked during free navigation in an 80x80 open field. The heart rate and heart rate variability were represented on relation to the spatial position in the field. These physiological measures provide information about the internal state of the animal during the performance of a particular task. In this presentation, we present analytical techniques to treat the ECG signal and to obtain heart rate variability and to represent it in 2D. A similar approach can be applied to the spatial representation of other physiological signals.

Author Keywords

ECG, stress, free movement, home base, behaviour measurement, behaviour analysis, 2D maps, navigation.

INTRODUCTION

Willem Einthoven developed, in the early 1900's, tools to observe and measure electrocardiogram (ECG) [1]. He received Nobel Prize in 1924 for his work. Since this time, ECG is a commonly recorded physiological measure. The calculation of heart rate variability (HRV), a measure of the variability of the interval between heart beats, provides information about the stress level, which is relevant

information during behavioural tasks [2, 3]. On the other hand, cardiovascular rhythms have been described to determine the time of motor acts initiation [4, 5]. Therefore, it should be possible to find temporal correlations between heart rate changes and behaviour. Our aim here was to detect the possible correlation between physiological values and behaviour by characterizing the parameters of the ECG spatial map during the free navigation of rats in an open space.

DATA RECORDING

The electrocardiogram data (ECG) was recorded from the surface of the thorax of Lister Hooded rats ($n=5$) with 3 electrodes attached to the skin and held by a vest. Rats were cared for and treated in accordance with the Spanish regulatory laws (BOE 256; 25-10-1990) which comply with the EU guidelines on protection of vertebrates used for experimentation (Strasbourg 3/18/1986). To increase the contact between the skin and electrodes, we use a conductive paste, a high-chloride abrasive electrolyte gel (Abralyt HiCl 1000 gr., EASYCAP GmbH). The animal was placed in a square maze (80x80cm) and allowed to freely navigate, being motivated by randomly delivered pellets. A camera synchronized with the ECG signal recorded the movement of animal in the maze. Data of the tracking (X; Y position) and data of ECG (raw ECG data) were acquired. In our study, we used two different acquisition systems to record ECG data, one from *Axona Ltd*, England (complete solution recording and video tracking) and the other one from *g.tec*, Austria (*g.USBamp* –recording-, *g.ANTS* – tracking-) in order to compare the performance of both systems available in our laboratory and to improve the compatibility of the analysis on different formats of datasets.

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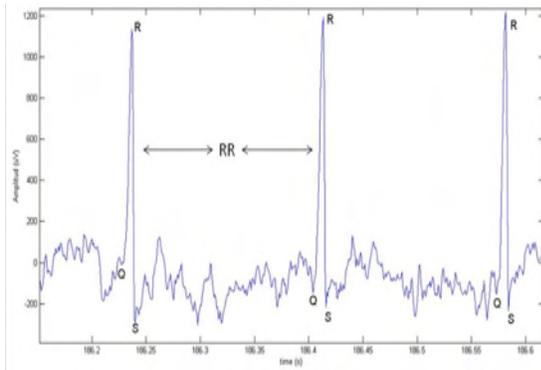


Figure 1. Recording of heart activity. QRS complex and the RR interval are visible.

TEMPORAL ANALYSIS

From the ECG recorded along time we extract several parameters which in turn are temporal signals. First of all, the RR interval (interval between consecutive QRS complexes) was obtained.

For calculating the RR intervals, QRS complexes have to be detected. For that, we used an algorithm developed by *GTEC* in Matlab. This software includes a preliminary automatic detection of the QRS, which was supervised later by an experimenter. From RR intervals we obtained heart rate and different definitions of heart rate variability (HRV) over 5 seconds windows [3]:

- Heart Rate $\rightarrow HR = \frac{1}{RR}$
- Root Mean Square of the Mean Squared Difference of successive RR (RMSSD)

$$RMSSD = \sqrt{\frac{1}{\#samp} \sum_{i=1}^{\#samp} (RR_{i-1} - RR_i)^2}$$

- The proportion of the number of pairs of successive RRs that differ by more than 0.05 ms (pNN0.05)

$$pNN0.05 = \sum_{i=1}^{\#samp} \begin{cases} 0 & \text{if } |RR_{i+1} - RR_i| < 0.05ms \\ 1 & \text{if } |RR_{i+1} - RR_i| \geq 0.05ms \end{cases}$$

(#samp \rightarrow number of samples fitting in 5sec. windows)

Those variables of HRV reflect the stress of the animal doing a behaviour task [2].

2D MAPS

In order to study the relation of heart activity with position we transformed data from the time domain to the spatial domain (2D). As a first step, we drew raw data recorded by the tracking system to examine the trajectory of the animal (Figure 2).

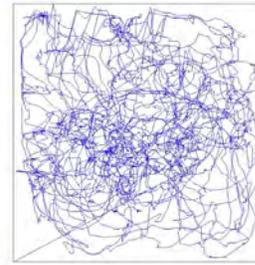


Figure 2. Rat's trajectory (80x80cm).

Then, we divided the space into square bins (1x1cm) represented by positions in a matrix object. This matrix could board any kind of data to be represented in the space. Next, the time spent by the animal in every spatial bin was represented (Figure 3). This was constructed with tracking data, by summing up all the periods elapsed in the same bin (dwell time map).

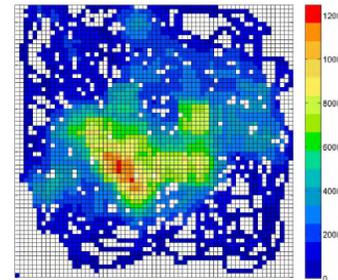


Figure 3. Dwell time map in ms (80x80cm).

Afterwards, the physiological signals that we had previously obtained in the temporal analysis (see above): HR, RMSSD, and pNN0.05 were represented (Figure 4). For this purpose, we aligned in time the position signal with the physiological signal, taking into account the difference in the number of samples, and upsampling or downsampling if necessary. From this alignment, we can know which the position of the rat for every value of the desired signal is, and we can assign this value to the corresponding position of the matrix object. Besides, it is common that the animal goes through the same place (bin) more than once.

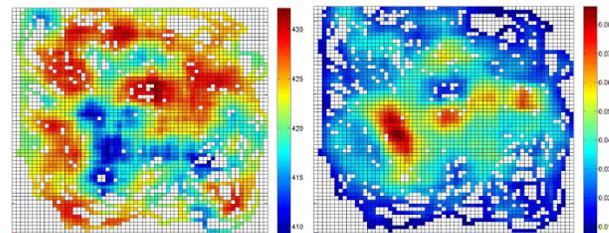


Figure 4. Heart rate map in bpm (right, 80x80cm) RMSSD map (left, 80x80cm).

Further manipulation of this 2D data lead to correlation maps between them.

CONCLUSION

We describe here a technique to acquire and analyze ECG to obtain the spatial mapping of the heart activity, and thus a measure of the internal state of the animal during navigation. The novelty of this technique is the 2D representation of heart rate and heart rate variability. Several protocols were carried out in our laboratory in order to study ECG and animal's spatial behaviour. The results show changes in different ECG parameters depending on the navigational pattern and position. The next step should be to carry out the analysis on real time in order to be able to modify stimulation depending on the animal's internal state. Real time would also allow feedback protocols based on ECG analysis. We plan to continue using the aforementioned techniques during the performance of different spatial behavioural protocols. Eventually, a third dimension (time) could be added to have a better

understanding of the physiological and behavioural correlations.

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