ON SOME ASPECTS IN ACQUISITION OF BRAIN ELECTRICAL ACTIVITY

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Abstract

We give a description of a portable system for acquisition of the brain electrical activity and discuss some problems which arise while developing, implementing, and fine-tuning the system.

We developed, implemented, and fine-tuned a portable system for acquisition of the electrical activity of a brain, which was successfully utilised to acquire the electroencephalogram and nociceptive evoked potentials (EPs) in the somatosensory S_1HL and the anterior cingulate Cg areas of cerebral cortex in the right hemisphere in rats.

The heart of the system is either an Intel Pentium IV-based portable computer (an IBM ThinkPad G40 in our study) or a Raspberry Pi 2 ARM Cortex-A7-based microcomputer loaded with Linux. So the analogue-to-digital converter is selected from amongst those supported by the `COMEDI` project [7] which develops open-source drivers, tools, and libraries for data acquisition implemented as a core Linux kernel module suitable for real-time tasks. We choose the 16-channel analogue-to-digital converter `usbdux-fast` coupled with 4-channel amplifier modules assembled to the open specifications provided by Incite Technology Ltd., Computing & Maths Dept., University of Stirling, United Kingdom (see [5, 6]); the amplifier was originally developed for teaching ECG at the Medical Faculty of the Ruhr University Bochum. The full schematic diagrams of the converter and the amplifier can be found in [3, 5, 6]. We make use of readily-available electronic components which inhabit custom printed circuit boards. Since the libraries and the firmwares source codes are in public domain, in our experiments we succeeded in implementing necessary corrections and revisions of the software in minimal time. The generation of the stimulus routed to the tail of an experimental animal (a male Wistar rat) via a constant current isolator unit (we used the isolator unit A365 produced by World Precision Instruments, Inc.), as well as that of the synchronising stimulus which triggered the start of acquisition, were carried out with the use of either the IEEE-1284 parallel port of the Intel-based computer or the general purpose input-output ports of the Raspberry box. Both of the electrophysiological data acquisition and stimuli generation tasks can also be executed concurrently on dedicated computers of the above architectures.

The key features of the system consist of the following: high sensitivity (μV); high-resolution measurement (discretisation up to a hundred kHz per channel); presence of no filters of the input signal in both the analogue-to-digital converter and amplifier modules; this results in the near absence of analogue data loss while acquiring the real

time brain bioelectrical activity. The system can perform a software filtering of the input data flow when needed.

The complex problem to prevent garbling of the input data due to intense electromagnetic pollution of the environment was solved by making use of a multilayer shielding of the analogue part of the system (the laboratory animal, cables, and the amplifier) and by using an autonomous direct current source to feed the whole system.

If one takes the laboratory animal as a 'black box' whose input is some external stimulus while the output yields a high-volume data flow, then the goal of the experiment consists of separating the response to the input stimulus in the output data flow. The start of acquisition of the electrical activity of the rat brain is triggered by the synchronising impulse issued at a fixed (maybe zero) time interval before the leading front of the stimulating impulse.

The input electroencephalogram is conveniently observed in the real time with the use of `xoscope 1.12` [8]. In order to capture the data, we use `ktimetrace 0.2.37` [2]; it permits to capture samples from desired channels of our data acquisition device in a given time interval starting either from an arbitrary time instant or from that governed by the external synchronising signal and to save it to a file while providing a real-time graphing display. The data thus obtained form a text file whose each row consists of numerical values captured from the channels at the corresponding time instants. The size of the file can grow to a very large value, so we decide to use the appropriate file system (`ext4` in our study).

We investigate the role which the brain cortex plays in formation of the nociceptive reactions by means of analysis of the evoked potentials acquired in the somatosensory S_1HL and the anterior cingulate Cg areas of cerebral cortex in the right hemisphere in immobilised Wistar male rats before the intraperitoneal injection of a lipopolysaccharide (LPS) and at the 1st, 3rd and 7th days after it upon an electrocutaneous stimulation of the tail. The stimulation of the rat tail is by single rectangular current impulses of 80% of the initial vocalisation threshold. The EPs are averaged over 36 trials. The changes of the late components of the EPs, which reflect the emotional component of the nociceptive reaction, were analysed by their peak-to-peak amplitudes (A) and the areas of the secondary negative responses (S). In [4, 3], we give an example of dynamics of nociceptive evoked potentials registered in the somatosensory area of the rat's cerebral cortex before the intraperitoneal injection of the lipopolysaccharide and at the first and the seventh days after it. We thus came to the classical biostatistics problem to find whether there was an effect of a single administration of a drug or not (see, e.g., [1]); to solve it, we made use of the non-parametric Wilcoxon test; this test uses only the information on the differences between values of the parameters and their signs, and there is no need to make assumptions concerning the laws of distribution of the differences of the parameters under investigation upon the action of the drug. The parametric tests based on the normal approximations appear to be of little use in our case.

The battery of solutions we have used while developing and setting up this system are pioneering and allow us to deal with a wide range of problems of electrophysiology including electromyography, electrocardiography, electroencephalography, and record-

ing of neuronal activity in the brain.

All investigations on the laboratory animals were carried out in full compliance with the GLP principles.

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