NEUROPHYSIOLOGICAL LONG-TERM RECORDINGS IN SPACE:
EXPERIMENTS SCORPI AND SCORPI-T
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The International Space Station ISS offers the opportunity for physiological long-term observations in microgravity in awake animals. The 3-month period of experimentation favours heredity, development and physiological adaptation as scientific fields that can profit from those long-term exposures to microgravity. However, the most complicating problems are (i) the lack of proper animal habitats, and (ii) the available crew time. These facts dramatically decrease the types of experiments and, in particular, the animal species that can be used for long-term studies.

From the methodological point of view, automatic working recording devices are the most suitable techniques. Experience with neurophysiological long-term recordings based on ground studies, in particular in insects (cf. Miller, 1979), favours the study of central integration of neuronal, sensory and muscular activity of the organisms and, in particular, its adaptation to the microgravity environment. The lack of proper animal habitats on ISS favours the use of animals that are adapted to a life in extreme environmental conditions with rare food supply. Only those animals can be used that are adapted to a life in extreme environmental conditions and that are able to starve for long periods of their life due to limited access to food and water. Desert animals such as beetles and scorpions are species of first choice.

In 2001, an experiment with scorpions titled SCORPI was selected for flight on ISS mounted in the European research facility BIOLAB. Its main purpose is to analyse the adaptation of coordinating mechanisms between vegetative and sensorimotor activities to microgravity by means of neurophysiological recordings.

Among the basic coordinating principles of physiological mechanisms common in most organisms are biological clocks and their synchronization with external Zeitgebers such as the daily light-dark rhythm and other geophysical fields. In humans, desynchronisation of these rhythmic events during space flights (Gundel et al., 1997; Dinges, 2001) or microgravity simulation such as bed rest head-down tilt (Samel et al. 1993) can cause physiological, behavioral and psychological disturbances. Studies in animals and lower organisms revealed that circadian rhythms may be altered, but do not disappear during space flights of rhesus macaques (Fuller et al., 1996), the beetle Trigonoceles gigas (Alpatov et al., 1994), Chlamydomonas and Neurospora (Ferraro et al., 1995).

The project SCORPI includes two important objectives, the hardware and the science objective. In particular, SCORPI has to demonstrate the reliability of a continuous neurophysiological multi-channel recording technique in the restrained animals during a long-term space flight. Furthermore, it has to analyze the integration of motor, neuronal and sensory signals and its long-term adaptation to microgravity with specific consideration of the biological clock system.

The first challenge for SCORPI was the development of a proper immobilization technique. A 3-point immobilization seems to be the most suitable one (Fig. 1), but a multi-point fixation at the base segment of each leg will be tested during the precursor space flight experiment SCORPI-T on the Russian satellite FOTON-M2 in 2005.

Figure 1. A 3-point immobilization of scorpions for neurophysiological long-term recordings in space. Pedipalps and opisthosoma base are fixed by aluminium clamps (C). The tail is connected to a thread (TF) that restricts the extent of tail movements protecting the electrodes from damage by the sting. Electrodes are inserted at eye, leg, opisthosoma, and brain. Despite of this immobilization, animals catch prey actively that is a necessary condition for feeding. Animals survive in this harness for months.

The second challenge was to develop the fully automated equipment that allow recordings of the visually elicited activity (electroretinogram, ERG), the muscular activity (electromyogram, EMG), the arousal of the brain (spontaneous cerebral electrical activity, SEA) and the heart beat frequency (electrocardiogram, ECG) (Fig. 2).

Figure 2. Implantation sites of the electrodes for the neurophysiological multi-channel long-term recordings.
The ERG is induced by short light pulses. Its basic shape is bipolar; in the case of rapid repetition of the stimulus, adaptation occurs (Fig. 3). For SCORPI, this is not critical because the individual test light stimuli are presented 10 to 20 min apart from each other. The parameters EMG, SEA and ECG are recorded during spontaneous activity. In general, during motor activity the motor signal (EMG) overwhelms all traces (Fig. 4); however, high- and low-pass filtering facilitates easy detection of all other activities such as ECG (Fig. 5) and SEA (Fig. 6, upper trace). For the low frequent signals such as ERG and ECG, low pass filtering is necessary while for the SEA, a specific filtering window is used.

The techniques developed to date for immobilization and electrode implantation allow to record physiological parameters for several months. Thus it will be possible to study the stability of sensory, motor and neuronal integration in the long-term range in orbit and on ground. This technique can also be applied to long-term studies of ecological adaptation to extreme environmental conditions such as high temperatures, low humidity, or drought.

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REFERENCES


