Quantification of manual dexterity in adult macaque monkey tested during a reach and grasp drawer task

Fregosi M., Kaeser M., Savidan J, Gindrat A.-D., Chatagny P., Badoud S., Moret V., Roulin C., Rouiller E.M. & Schmidlin E.
Department of Medicine, Unit of Physiology, University of Fribourg, Switzerland

Introduction

- Manual dexterity is a complex motor behavior common to non-human primates and human beings. It is mainly controlled by superior motor centers of the central nervous system (CNS), particularly by the primary motor cortex (M1).
- The quantification of manual dexterity allows to detect and assess precisely functional recovery after brain injury affecting M1 and to differentiate the effects on distal muscles of the forelimb (hand) and more proximal muscles (arm and shoulder).
- We are interested in the precision grip movement which is the opposition between the index finger and the thumb, aiming particularly at measuring the forces developed and the time intervals to perform the task.
- The aim of the present work is to quantify the motor performance in a reach and grasp drawer task before and after the lesion of the hand area in the primary motor cortex in *Macaca fascicularis*.

Methods

- We trained eight adult macaque monkeys (2 males and 6 female) to perform the reach and grasp drawer task in which the animals had to pull a drawer against adjustable levels of resistance and to grasp a food pellet inside the drawer, using one or the other hand.
- The pulling phase of the drawer was quantitatively assessed by measuring: 1) the grip force to grasp and hold the knob; 2) the load force exerted by the arm to pull and open the drawer.
- The drawer is connected to a computer which records three different parameters in time: first the displacement of the drawer, second the force needed to grasp the knob of the drawer and, finally, the force needed to open the drawer (load force) during the task.
- Data presented here were derived from 5 behavioral sessions for each level resistance for each animal tested for both hands.

Results

- Our results have shown that maximal grip force and maximal load force increase as a function of the increase of the resistance to the pulling of the drawer.
- In general we can observe a statistical difference between the different resistances tested. This is valid using both hands and for grip and load forces.
- The time needed to open the drawer increases in correlation with the increase of the resistance to the opening.

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Behavioral task: Description

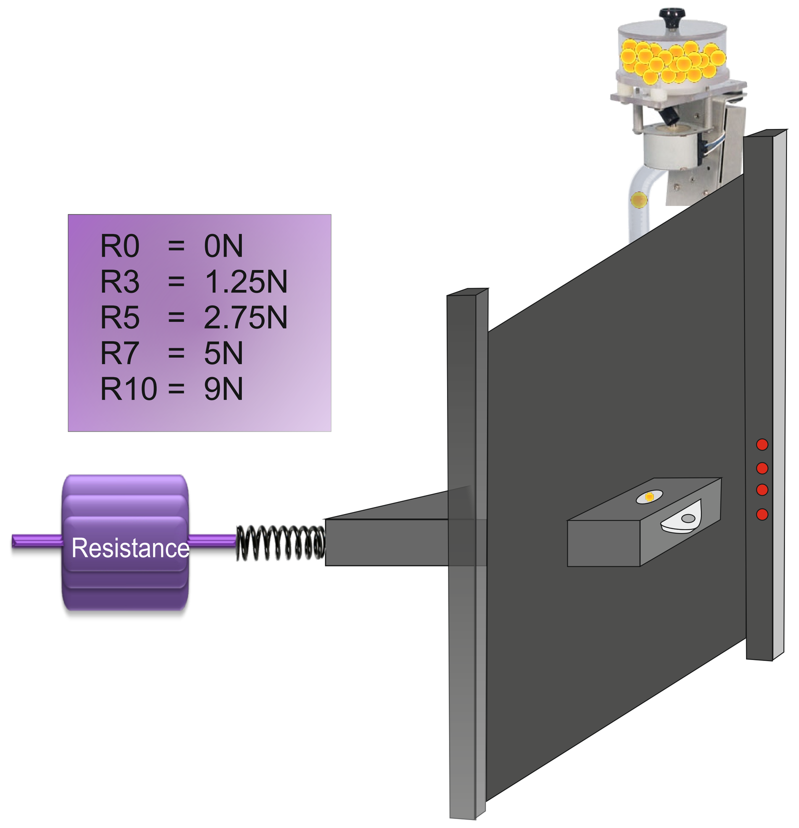

Figure 1: Drawing illustrating the reach and grasp drawer task setup with adjustable resistance (N). It is an extended version of a previous set-up (Kazennikar et al, 2004, EJN), providing now quantification of forces exerted by the monkey.

Analysis

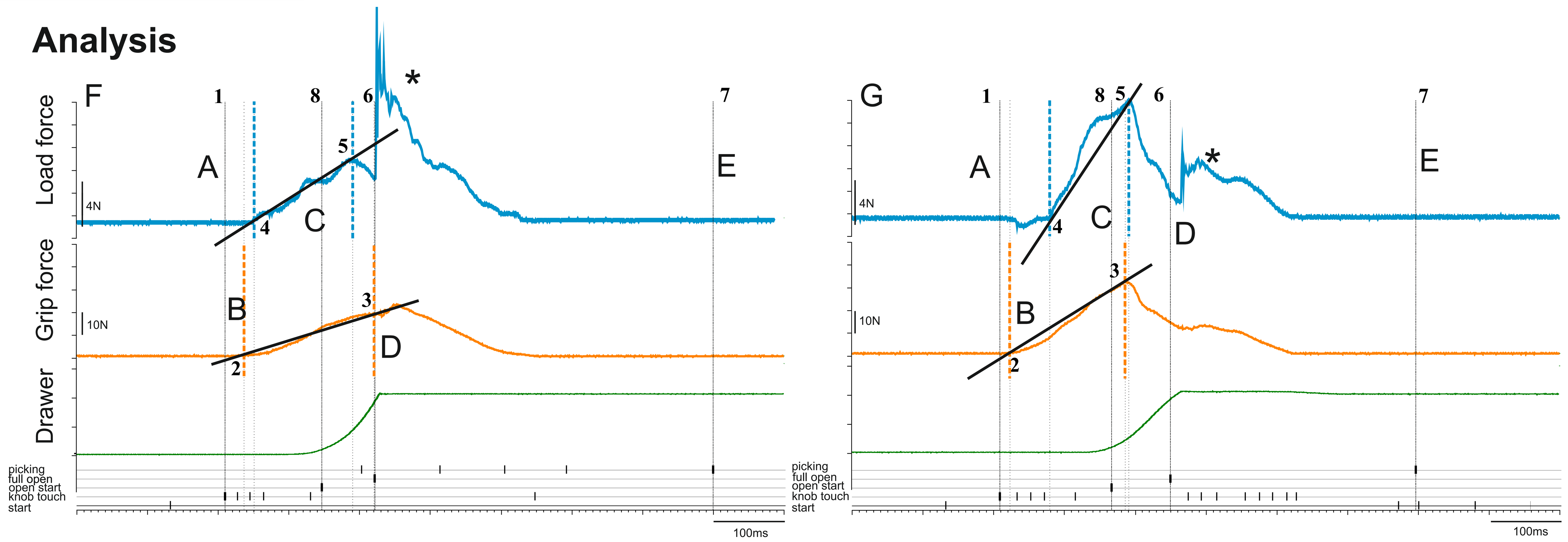

Figure 2: unfolding of a trial during a session of the reach and grasp drawer task performed by a monkey with the right hand. A-E : Five photographs showing key moments during the task. They correspond to: A knob touch, B onset grip force, C onset of pulling of the drawer, D full open of the drawer and E picking of the pellet. F and G show the computer recording of a trial at resistance 0 (panel F) and at resistance 5 (panel G). Both graphs show three online recordings during one trial: the load force (red), the grip force (blue), and the drawer displacement (green). Discrete events are: #1 is the knob touch (A), #2 is the onset of grip force (B), #3 is the maximal grip force, #4 is the onset of load force, #5 is the maximal load force, #6 is the full open (D), #7 is the picking (E) and finally #8 is the pulling onset (C). Cursors #1,6,7 and 8 are placed on markers given by the sensors placed on the drawer setup; the other cursors are manually located. Artefacts (*) due to the blocking of the drawer in full open position were not taken into account. Time scale bar 100 ms.

Results

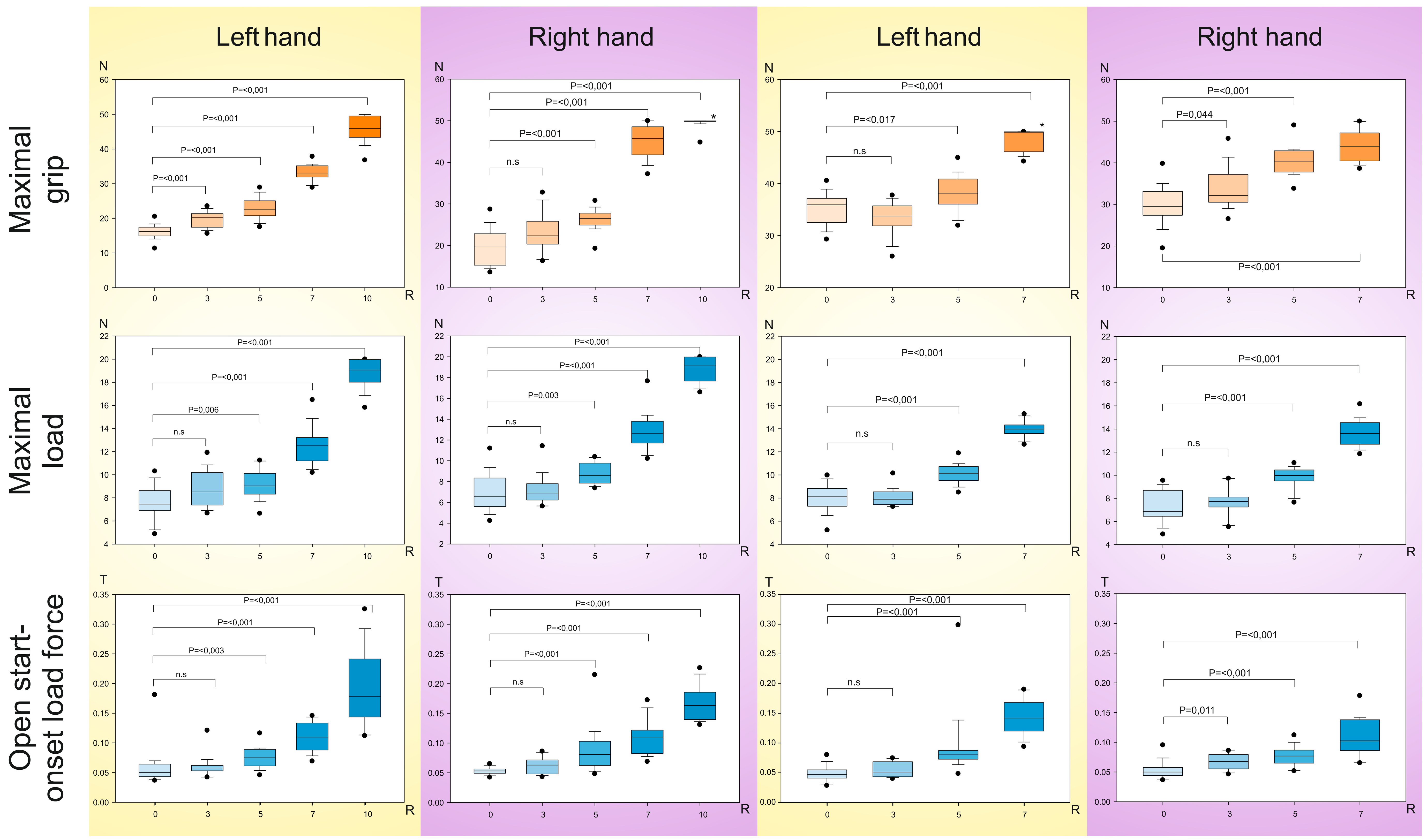

Figure 3: Box plots showing quantitative analyses of the recorded forces (load force in blue and grip force in orange) for both hands in two animals. The symbol (*) indicates that the acquisition system saturated.

Conclusions

- The reach and grasp drawer task appears to be a good behavioral model to study the movements coordination and the application of forces for the execution of fine hand movement (precision grip).
- After the lesion of M1 we expect dramatic changes in the forces applied and in temporal unfolding of the different sequences of the task.
- The increased level of resistance to the pulling resulted in strong changes in the forces needed to perform the task and the time interval between the different movement sequences.
- The difference between relative resistances 0 and 3 is less affected, possibly because the difference in Newton is not large enough.

Futures perspectives

- Cortical lesions of M1 hand area and subsequent analysis of pre- versus post-lesion differences, as well as assessment of functional recovery.
- Electromyogram (EMG) analysis on animals chronically implanted with subcutaneous electrodes.