Marked changes of motor strategy in a complex manual dexterity task after permanent lesion of the primary motor cortex hand area assessed by chronic EMG recordings in non-human primate

Camille Roux, Melanie Kaeser, Eric M. Rouiller and Eric Schmidlin
Department of Medicine and Fribourg Center for Cognition, University of Fribourg, Ch. du Musée 5, 1700 Fribourg, Switzerland

FNSNF Grant No:149643 Swiss National Science Foundation

UNI FR UNIVERSITÉ DE FRIBOURG UNIVERSITÄT FREIBURG

I Inactivation of M1

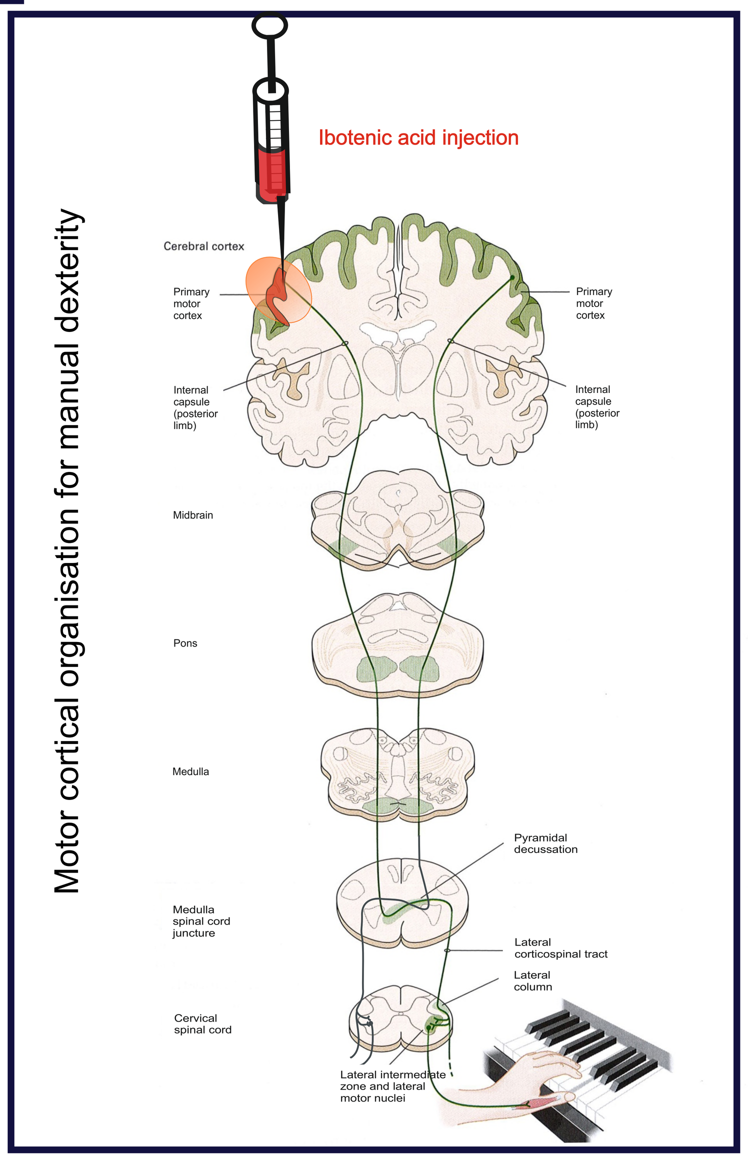

Fig. I: Schematic representation of the experimental paradigm, showing ibotenic acid lesion of the hand representation in the primary motor cortex (red).

II

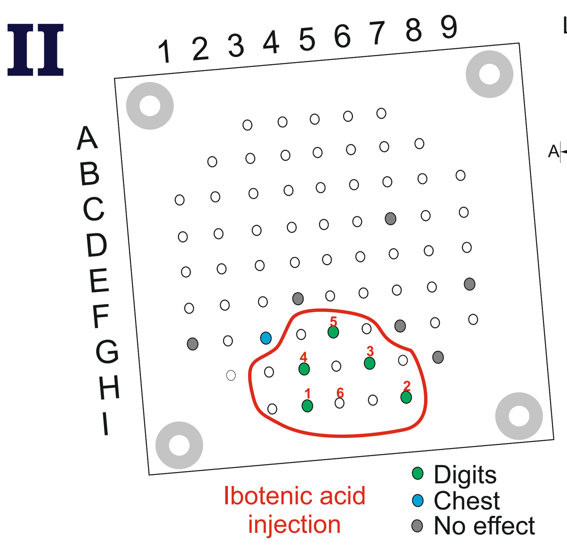

Fig. II: Mapping of M1 hand area showing sites where ICMS (grey, blue and green dots) and ibotenic acid injections (red numbers) were performed.

Introduction

Precise quantification of motor function is necessary to test the efficiency of possible treatments enhancing functional recovery after CNS lesion such as stroke. In addition, manual dexterity and precision grip express the highly specialised feature of cortical motor control via the corticomotoneuronal system, specific to primates. We therefore analysed and compared the muscular pattern needed to perform a complex manual dexterity task before and after a permanent lesion of the hand representation of the primary motor cortex in non-human primate.

Methods

Surgery:
Chronic implantation of a Tecapeek chamber containing **tecapeek grids** allowing penetration of tungsten microelectrodes to elicit **ICMS** or **ibotenic acid infusion in the primary motor (M1) cortex hand area** in one adult female macaca monkey.
Chronic implantation of **eight hand and arm muscles** showing modulation of electromyographic (EMG) activity during the different phases of the "reach and grasp drawer" task (**AbPB**: abductor pollicis brevis, **1DI**: one dorsal interosseous, **PL**: palmaris longus, **EDC**: extensor digitorum communis, **FCU**: flexor carpi ulnaris, **FDS**: flexor digitorum superficialis, **Tri** :triceps and **AD**: anterior deltoid).

Cortical inactivation (Fig.I and II):
Invasive permanent inactivation: microinfusion of excitotoxic **ibotenic acid** at multiple sites in **M1** (Fig. II) where ICMS elicited single joint finger movements (ICMS=intracortical microstimulation: train of 6 pulses 0.2 ms width at 333 Hz).

Behavioral assessement of manual dexterity (Fig.III):
A **"reach and grasp drawer" task** requiring opposition of thumb and index finger (precision grip) was used to **assess monkey´s manual dexterity**. It consists for the animal to pull a drawer against different levels of resistance to the opening and to retrieve a food pellet located inside the drawer.

III Unimanual "reach and grasp drawer" task

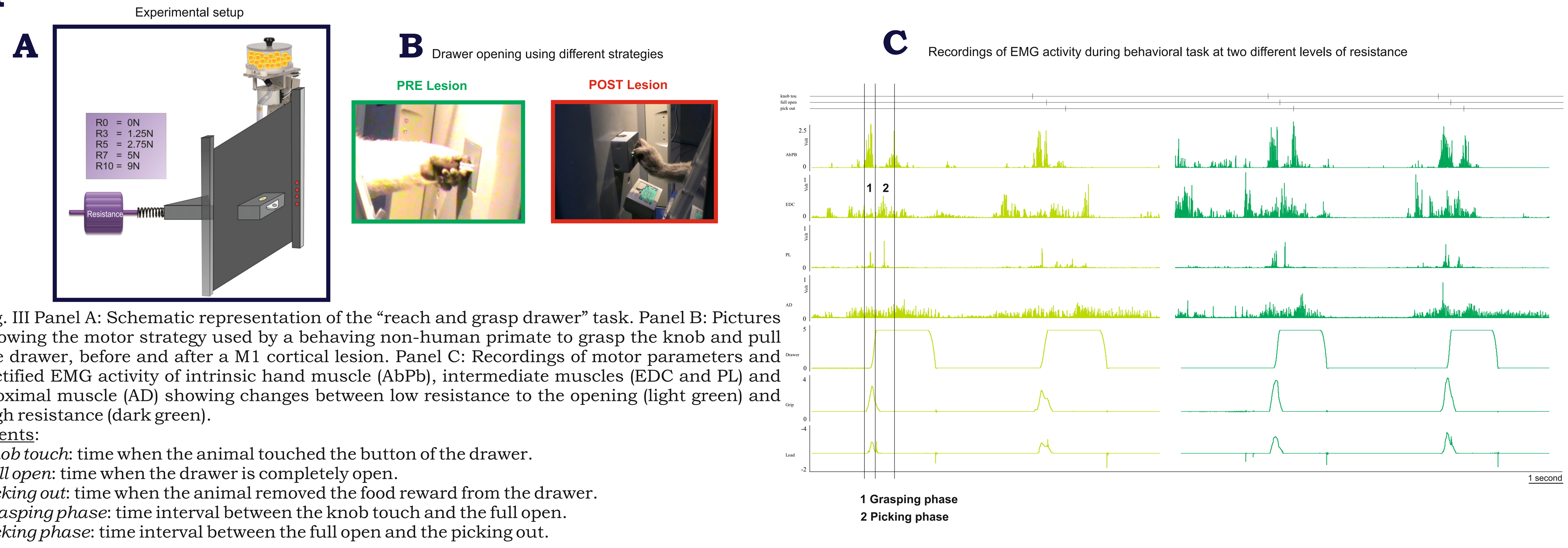

Fig. III Panel A: Schematic representation of the "reach and grasp drawer" task. Panel B: Pictures showing the motor strategy used by a behaving non-human primate to grasp the knob and pull the drawer, before and after a M1 cortical lesion. Panel C: Recordings of motor parameters and rectified EMG activity of intrinsic hand muscle (AbPc), intermediate muscles (EDC and PL) and proximal muscle (AD) showing changes between low resistance to the opening (light green) and high resistance (dark green).
Events:
Knob touch: time when the animal touched the button of the drawer.
Full open: time when the drawer is completely open.
Picking out: time when the animal removed the food reward from the drawer.
Grasping phase: time interval between the knob touch and the full open.
Picking phase: time interval between the full open and the picking out.

Results

Stability of EMG activity in the four presented muscles **before the cortical lesion** in the different phases of the behavioral task, such as the grasping phase and the picking phase, with a high success rate (total of attempt/ total of successfully retrieved pellets).
Increased EMG activity correlated with **increased level of resistance to the opening**, in particular in the grasping phase whereas the picking phase is less affected.
At the **lowest level of resistance** to the opening, the cortical lesion resulted in **marked changes of EMG activity in the ability of the animal to perform the "reach and grasp drawer" task** as shown by the very low rate of successful trials in the acute phase. A certain level of **functional recovery** was observed in the EMG activity as reflected by the higher rate of successful trials **in the chronic phase**.
In the **chronic phase**, despite a similar sequence pattern, the **EMG activity of the distal muscles** such as AbPB significantly **decreased**, partly **compensated by an increased EMG activity in the intermediate** muscles such as PL and EDC.
At a **higher level of resistance** to the opening, the animal was **unable to perform** the task in the acute phase and showed dramatic remaining impairments in the chronic phase.

IV Effects of ibotenic acid inactivation on EMG activity

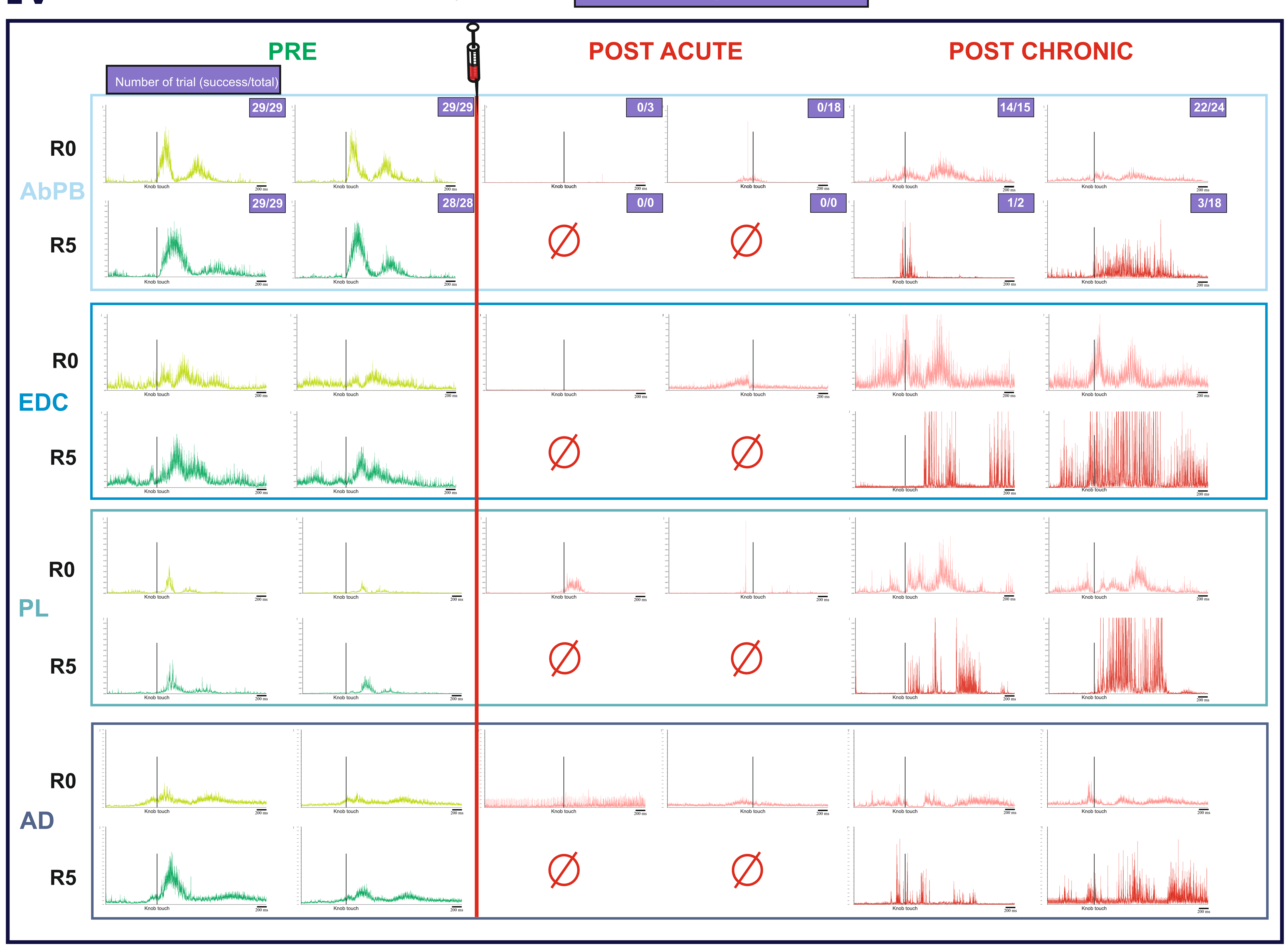

Fig. IV: Averaged rectified EMG activity of four hand and arm muscles chronically implanted and involved in "reach and grasp drawer" task, aligned on the knob touch instant (vertical black line, time =0), at low level (light colour) and high level (dark colour) of resistance to the opening of the drawer (AbPB: abductor pollicis brevis, EDC: extensor digitorum communis, PL: palmaris longus, AD: anterior part of the deltoid) in the pre-lesion period (the two green columns to the left), the immediate acute post-lesion period (1 day and 8 days post lesion respectively) and in the chronic phase at 2 time points. Red crossed circles mean that the animal was unable to perform the task.

V Effects of ibotenic acid inactivation on EMG activity at 2 time points

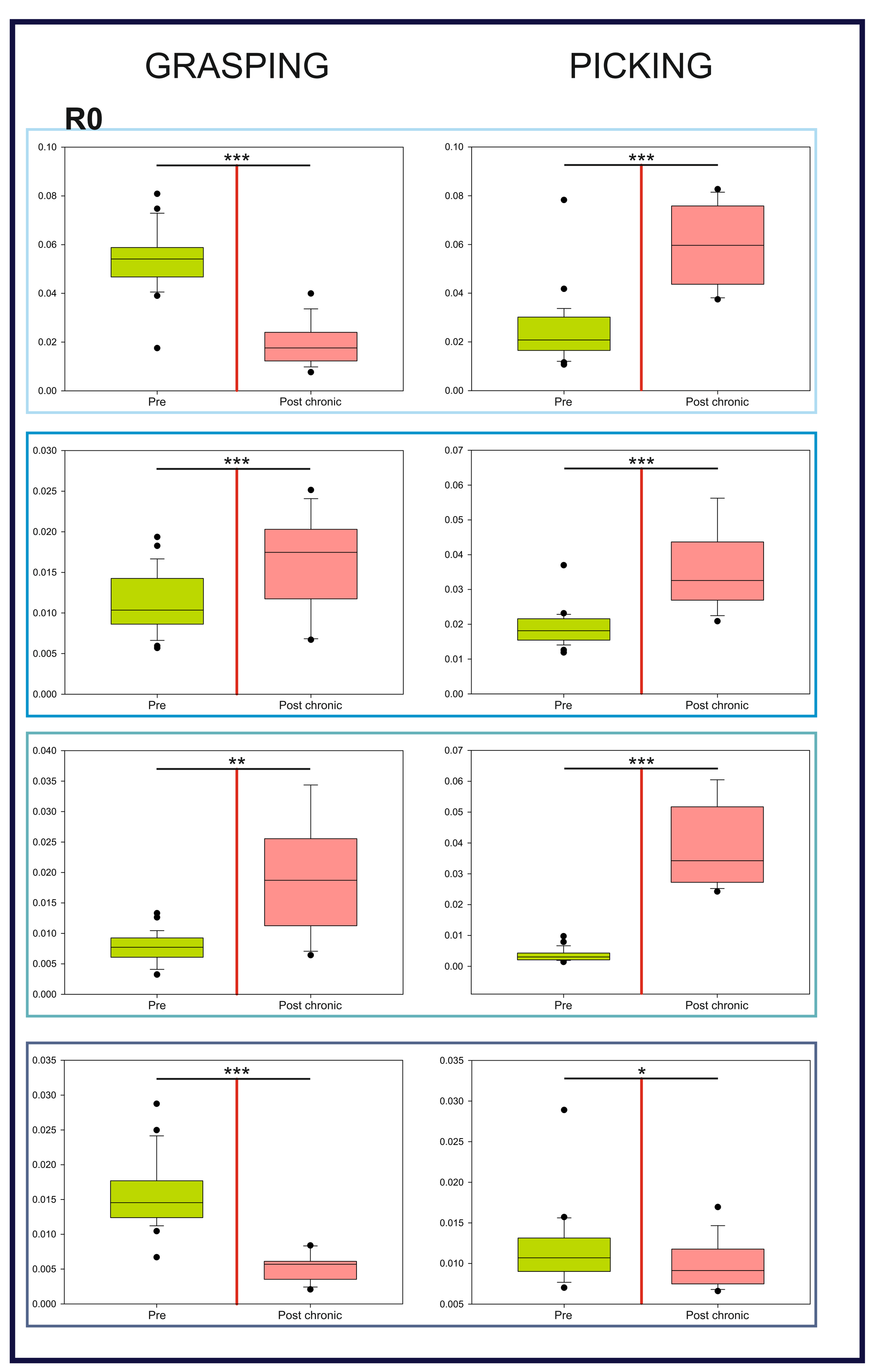

Fig. V: Box plots showing the quantification of the area under the curve of the rectified EMG activity in the two different phases of the behavioral task (grasping phase and picking phase) in one representative session before the cortical lesion (corresponding to the fisrt column of Fig.IV, green) and one representative session in the chronic period (corresponding to the fifth column of Fig. IV, red). Same muscles as in Fig. IV.

Conclusions and perspectives

The **"reach and grasp drawer" behavioral task** is an **adequate** behavioral task to **challenge manual dexterity** before and after cortical lesion involving hand representation of M1.
It allows a **correlation between chronic EMG recordings** of hand and arm muscles **in the different paradigms of behavior.**
Pattern of EMG recordings was stable during the two analysed prelesion sessions for all implanted muscles and linked to the different paradigms of behavior.
The **cortical lesion** targeting specifically the hand representation in **M1** resulted in **marked changes of EMG activity** and in success rate, in particular at high levels of resistance to the opening. There was a certain **functional recovery due to change of strategy**, as reflected by a **switch of activity from the distal muscle to more proximal muscles**.
Preshaping and adaptation in the reaching phase were **less affected** by the cortical lesion.
Further analysis is needed to assess different changes of distribution of activation network in the spinal cord, integrating the consequences of a sudden interruption of the supra-spinal influence over the motoneurons involved in manual dexterity, including the role of proprioception among others.