Encoding of Movement in Local Field Potentials from the Wall of Motor Cortical Lesions in Rats

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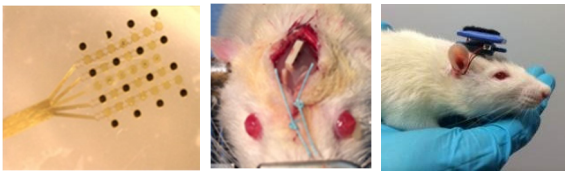
1 OBJECTIVES

The objective of the current study was to investigate if electrical oscillatory activity from within the cavity wall of a motor cortical lesion can be used as a biomarker in decoding movement. We show results from 3 rats with unilateral lesion in the forelimb area of the motor cortex, for which local field potential (LFP) spectra present significant modulation within the frequency bands of 6-10 Hz and 45-90 Hz, corresponding to movement episodes.

2 METHODS

Rats were anaesthetized with a mixture of ketamine (Nimatek®) and medetomidine hydrochloride (Narcostart®). A craniotomy over the forelimb area of the primary motor cortex was made (coordinates: 1.5 mm posterior to 5 mm anterior to bregma, and 0.5 mm to 4.5 mm lateral to bregma), after which the exposed brain tissue was aspirated to a depth of 1.5 mm. Three weeks later, a polyimide-based thin film electrode array (Ceyssens et al., 2013) containing 16 platinum electrode contacts, each with a diameter of 350 µm (Fig. 1.a.) was implanted against the cavity wall. The implant and connector (Omnetics) were secured in place with stainless steel screws in the skull and dental cement (Fig. 1.b.).

Open field tests were performed 1 month after electrode implantation. The rats were placed in metal cages (dimensions 36x38x35 cm), being free to move. They were monitored for ~30 min with a SONY HDR-AS15 camera (sample rate 30 Hz) placed laterally. Brain electrical activity was wirelessly recorded at the same time, using the W16 headstage model from Multichannel Systems (MCS GmbH, Reutlingen, Germany), (see Fig.1.c.). The LFPs were sampled at 10 kHz and preamplified in the range of 1Hz to 5 kHz within the headstage.



a). b). c).

Figure 1: a). Electrode array; b). Top view of the implantation site; c). View of the headstage.

Analyses of both video and LFP recordings were performed offline in MATLAB (version 2014b; The MathWorks). An automatic algorithm based on pixel intensity was implemented to discriminate between activity and resting intervals. The threshold was set empirically so as to capture activity such as walking, self-grooming, standing on hind limbs. Intervals when no movement of the limbs could be detected were labelled as part of the 'resting state'. The corresponding LFP intervals were then extracted and divided in 2-sec epochs. On average, 225 (± 55) epochs per rat were extracted for the active state and 335 (± 80) epochs, respectively, for the resting state.

The LFPs were low-pass filtered and down-sampled using an equiripple FIR decimator (300 Hz cutoff frequency, decimation factor of 10) so that final sampling rate was 1 kHz. We computed the power spectrum using the '*periodogram'* Matlab function (frequency resolution of 0.5 Hz) and we multiplied power at each frequency bin with squared frequency to account for the $1/f^2$ decay specific to brain signals (Miller *et al.*, 2009; Buszaki *et al.,* 2012). A peak in power ~8 Hz and ~50 Hz was observed on datasets from both behavioural states.

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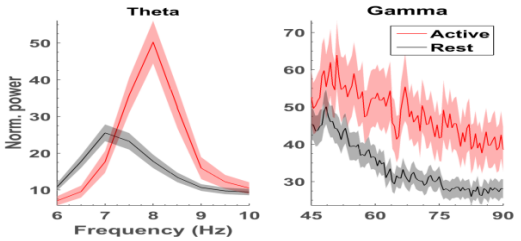
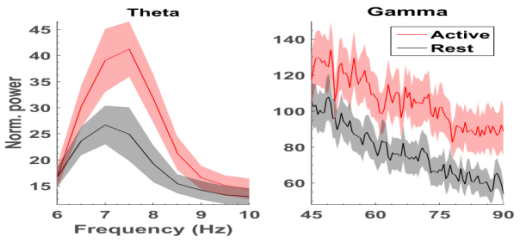
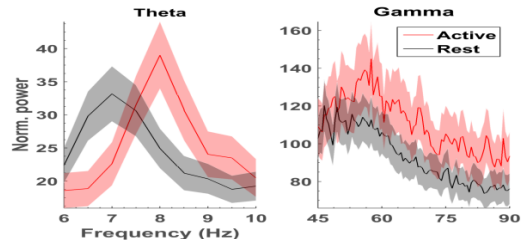


c) Rat 1



b) Rat 2



a) Rat 3

Figure 2: Mean normalized power between significant channels (± 95% confidence limits) for each animal.

3 RESULTS

We performed two-sample t-tests with unequal variances to test significant differences between two sets of features (mean power in theta (6-10 Hz) and high-gamma (45-90 Hz) band for all 16 electrodes), to investigate how well each feature discriminates activity from rest. For each rat, a subset of electrodes showed significant increases ($p<0.05$) in theta power (14 electrodes for rat 1, 9 for rat 2 and 6 for rat 3). High gamma power was significantly higher ($p<<0.01$) in active state on all electrodes.

4 DISCUSSION

We report prominent theta and gamma activity in the forelimb region of the rat motor cortex, on LFPs recorded from the wall of a lesion. We show that these oscillations are strongly linked to motor behaviour state, in an open-field experimental setup that required neither learning nor reward. Our results corroborate previous studies reported in literature on cortical LFPs from healthy rats, during treadmill running (von Nicolai *et al.,* 2014), or during reward-motivated forelimb movement (Igarashi *et al.* 2013).

Since the results revealed that specific subsets of electrodes are relevant for each subject, the robustness of these features could be investigated in a longitudinal test, while optimizing a decoder able to detect activity state on a single-trial basis.

Motor cortical lesions can induce various impairments, therefore it would be of interest to search for a correlation between theta-gamma activity and the type of deficit the subject exhibits.

In conclusion, our results suggest that informative signal features can be extracted from electrical activity generated in the wall of a motor cortical lesion. These features should be further investigated to test the hypothesis that LFPs can help parametrize state of impairment, on a subject-by-subject basis.

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