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Signal Characteristics of Cerebellar Activity Recorded with 2D Micro-Electrode Arrays

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Abstract—**Recordings were performed on the rat paramedian lobule of the cerebellum with a surface micro-electrode array during hand licking and quiet states. The Fast Fourier Transform (FFT) and average coherence both showed a change in the frequency distributions between active and quiet conditions. The signals were segregated into different frequency bands and the signal compositions were analyzed. In each of the bands an increase in neural activity was seen at the onset of activity. Frequency coherence analysis was performed between electrodes at two different separations for active and quiet conditions. The coherence analysis showed that there was an increase in coherence for shorter distances and during activity.**

I. INTRODUCTION

There is a growing evidence on the importance of the cerebellum. The cerebellum plays an integral role in motor learning and motor planning [1, 2, 3]. It has also been found that the cerebellum plays a role in the cognitive aspects of brain function [4, 5, 6].

Most studies to date have been performed on single unit activities in the Purkinje cells. The Purkinje cells have been shown to correlate with different motor parameters. Some Purkinje cells are correlated with the kinematic parameters such as position and velocity [7,8]. Purkinje cells may encode dynamic parameters of movement as well [9]. Only few studies have been performed on the field potentials and their spatial and temporal characteristics.

The signal characteristics of the field potentials and higher frequency oscillations are studied extensively in the cerebral cortex. In the motor and sensory areas of the cerebral cortex it has been demonstrated that these oscillations can predict the direction of movement [10, 11, 12]. It has also been found that the oscillations are capable of object selection [12].

Local field potential oscillations between 10 to 25Hz of the paramedian lobule are modulated by different states of awareness and expectation of movement and reward in primates [13, 14]. These field potentials show strong synchrony with the somatosensory cortex and less so with the primary motor cortex [15].

In this preliminary study, we investigated the characteristics of the signals recorded with surface micro-electrode arrays placed on the paramedian lobule of the rat cerebellum. These signals were recorded during both active (hand licking movements) and quiet (stationary) states. The oscillations were filtered at different frequency bands to analyze the characteristics in various frequency ranges.

II. METHODS

A. *Surgical Procedure*

Flexible, 2D multi-electrode arrays were chronically implanted in two Long Evans male rats (300-350g) using sterile surgical techniques. All procedures were approved and performed in accordance to the guidelines of the Animal Care and Use Committee, Rutgers University, Newark, NJ. The rats were anesthetized with sodium pentobarbital (30mg/kg, IP) and additional doses (6mg/kg) were administered as needed during the surgical procedure. A portion of the skull was removed exposing the paramedian lobule of the cerebellum. A 34 contact (6x6 matrix) polyimide substrate, 2D electrode array with 300μm contact separation (Multichannel Systems, Germany) was placed subdurally on the cerebellar cortex. The electrode was fixed in place using ocytal cyanoacrylate tissue adhesive (Nexaband, WPI, Inc., FL). The microconnector (Omnetics) was placed on top of the skull and fixed in place using dental acrylic. The rats were allowed to recover from surgery for a week before recordings started.

B. *Recording Procedures*

The recordings were performed with a 34 channel mini-Amplifier (TBSI) placed over the head (Gain 100). The recordings were sampled at 30kHz and were collected in 5 second episodes. Video was taken of the rat during the recordings to determine movement onset and duration.

The cerebellar signals were recorded during both active and quiet states. The active state chosen for analysis was the act of the rat licking its forepaw. Rats often perform this task naturally without training. The quiet states were times when the animal presented no observable movement.

C. *Data Analysis*

All data analysis was performed using Matlab. Fast Fourier Transforms (FFT) were performed over the entire length of the 5 s signal epochs for both active and quiet conditions. The coherence analysis was performed between adjacent and distant electrodes for both active and quiet conditions. The signals were band passed filtered at 2-13Hz, 13-30Hz, 30-90Hz, 90-150Hz, 150-500Hz, and 500-1000Hz.

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III. RESULTS

Figure 1 shows the FFT for quiet and active conditions. Analysis of the frequency distributions showed that for frequencies over 1000Hz the power was very low and so the frequency components above this point were not included in further analysis. Most of the power is contained in the band bellow 100Hz. Comparing the frequency spectra of active and quiet states, the active state recordings show a slight increase in magnitude over the entire range of analyzed frequencies.

The signals were filtered into different frequency bands for further comparison. Representative signals during activity are shown in Figure 2. The bar indicates the time interval when the animal was licking its forepaw, which started slightly before 1.5s. The largest modulation during the movement was seen in the 2-13Hz band in the top plot. The 13-30Hz band also showed modulation, however, the amplitude was much less. The 90-500Hz and 500-1000Hz bands contain activity modulation during the time of behavior usually following the large fluctuations in the 2-13Hz range. Note that each band presents a unique pattern of activity.

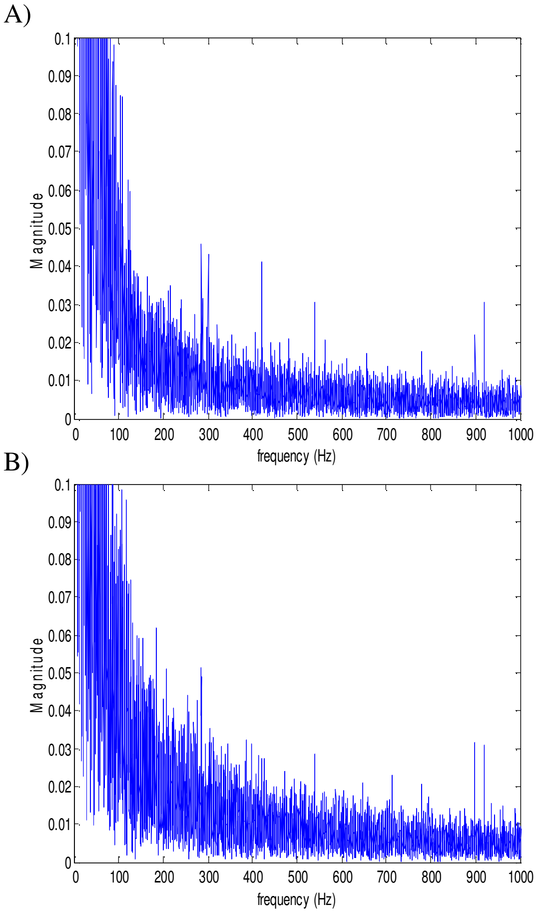

Fig. 1. The FFT of single channel signals recorded for A) the animal in a quiet state with no movement and B) while hand licking. In both FFTs the signals above 1000Hz had very little power. The hand licking FFT shows higher power for the entire spectrum frequencies as compared to the quiet recordings. These results can be generalized for other recording channels.

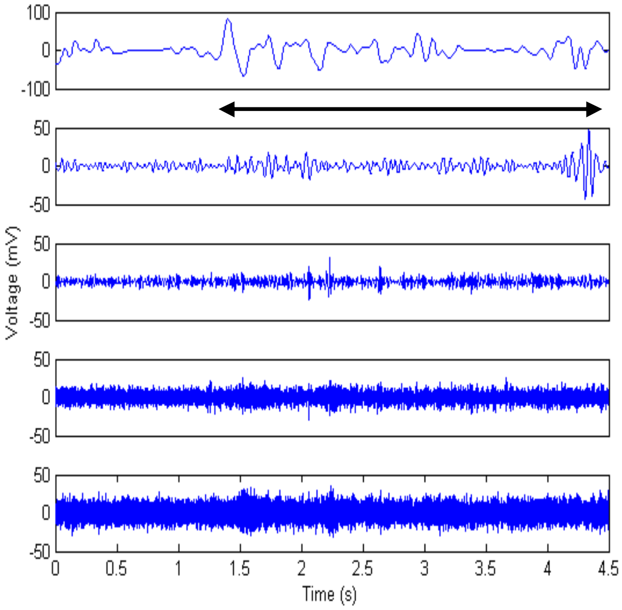

Fig. 2 Signals during activity sequenced into different frequency bands. The bar under the first plot indicates the time interval when the animal was performing hand licking. From top to bottom the signal segregated into the 2-13Hz, 13-30Hz, 30-90Hz, 90-500Hz, and 500-1000Hz bands.

Figure 3 shows the coherence between electrodes at two different electrode separations and for active and quiet conditions. The greatest coherence was contained in the frequencies less than 100Hz for all cases. There is a higher degree of coherence for the electrodes separated by 300µm than the electrodes separated by a distance of 1.5mm. The figures also indicate that there is an increase in the coherence between channels during activity.

IV. CONCLUSIONS

This work demonstrates that the signals recorded from the surface of the paramedian lobule of the rat cerebellum are modulated during motor behavior. An increase was observed in amplitude for the entire spectrum, but particularly at frequencies below 100Hz, during active conditions. The time plots contain neural activity patterns concurrent with the behavior. The coherence analysis suggests that there is an increase in coherence between channels during activation and that the correlation drops with distance between electrodes. Motor and sensory information contained in these surface recordings needs to be investigated further.

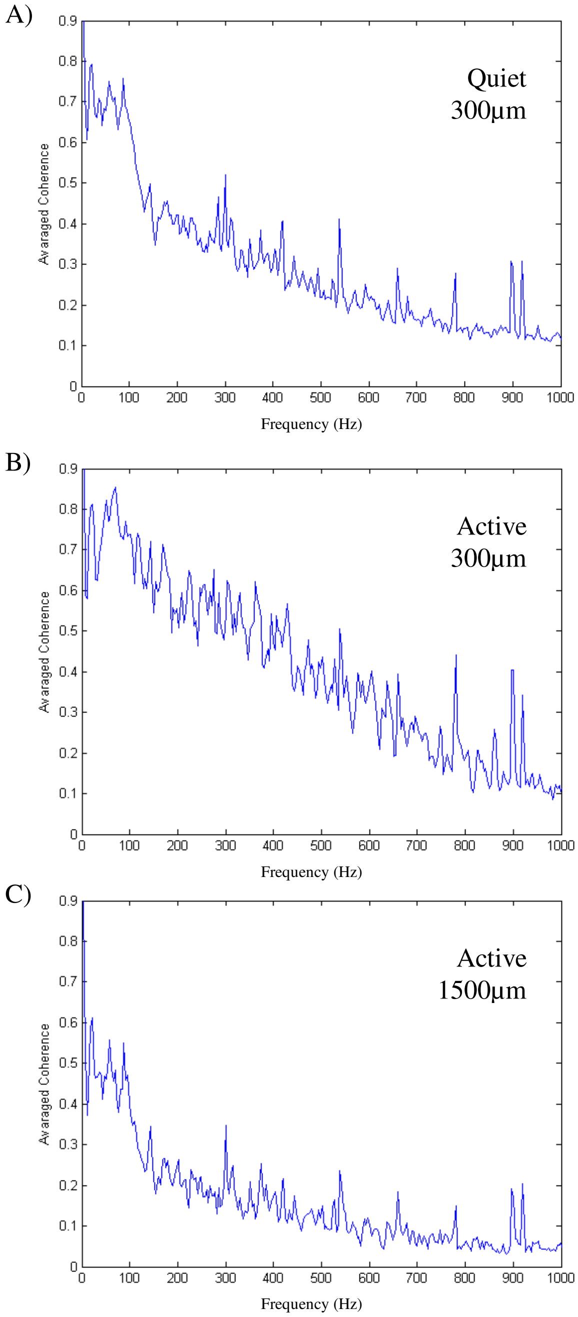

Fig. 3 Average coherence plots between all the electrodes contacts at a distance of A) 300µm for quiet condition, B) 300µm for active condition, C) 1.5mm for active condition.

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