Long-term Stability of Cortical Neural Ensemble Recordings between Different Microelectrode Array Types

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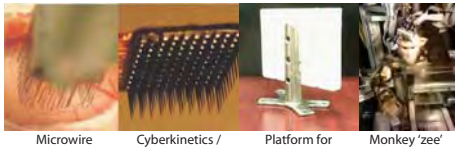
Introduction

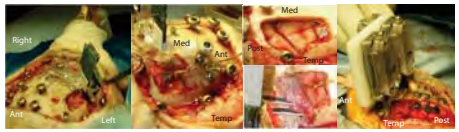
With technological advancements in the development of microelectrode arrays (MEAs) a multitude of MEAs are now commercially available, ranging from those made in the laboratory to industrially perfected arrays produced by various biomedical engineering companies. These electrodes vary in their physical, chemical and electrical properties which directly affect the recorded neural signal as well as immediate and late immunological responses. These factors ultimately contribute to the long-term quality of the recorded neural signals which tend to deteriorate over time either due to histological reactions or failure of the device. In addition, micro-stimulation through these arrays can affect tissue health, neural responses and the electrode properties. In the present study, we have compared the stability of cortical neural recordings from standard Microwire arrays (32 micro-electrodes per array, inter electrode spacing ~500 µm or ~1000 µm at the tip) and the Cyberkinetics array (100 micro-electrodes per array, inter-electrode spacing ~400 µm at tip, 1.0 mm or 1.5 mm shank length, Pt with/without IrOx coating) implanted in the somatosensory cortex (areas 3b, 1, 2). Recordings were acquired from 3 non-human primates (M. Radiata) implanted with either or both of these arrays, while the animal sat in a primate chair.

Surgical Implantation

Microelectrode implants were performed on Isoflurane-anesthetized monkeys in a sterile surgical environment. Monkey 'gol' was implanted with CK array in area 1-2 of right somatosensory cortex in the region representing left ear upto ulnar side of hand, and MW array in area 1 of left somatosensory cortex in the region representing right forearm and hand. Monkey 'gra' was implanted with CK array in area 1-2 of right somatosensory cortex representing left lower limb. Monkey 'zee' was implanted with CK arrays in S1 (IrOx) reprsenting right shoulder and elbow regions, M1 (Pt) and PMd (Pt) areas. Monkey 'pep' was implanted with MW arrays in area 2 of left somatosensory cortex and also in left dorsal premotor cortex. CK array shank length was 1 mm (gol, gra) or 1.5 mm (zee) and implanted using mechanical implant device. MW and KM arrays were implanted using stereotaxic device by guiding manually (~10 µm/sec) upto 0.9-1.1 mm and 1.8-2.3 mm depth, respectively.



Microwire Array - MW | Cyberkinetics / Utah Array - CK | Platform for ICS-96 (CK) | Monkey 'zee' with KinARM



Monkey 'gol' | Monkey 'gra' | Monkey 'zee'

Fig 1: Arrays and implants

Neural Recordings

All the recordings were made on awake, head-restrained animal sitting on a primate chair. The naive monkey would sit idle while recording is going on ('gol' and 'gra') or trained monkey working on reaching task with KinARM (BKin Technologies) robotic manipulandum on which the right hand is restrained ('pep' and 'zee'). The recordings were made with one or two externally synced 128-channel Multichannel Acquisition Processor units (Plexon Inc). To avoid the waveform sorting bias by operator, before the beginning of the first recording session for the day, all the channels are auto-configured using plexon-made algorithm which would set the gain and threshold according to the waveform quality for each channel and then collect 500-1000 waveform templates and define the units based on this template data. These settings are not changed manually unless the threshold is set very low automatically or missing of obvious unit by algorithm that appear following auto configuring.

Results

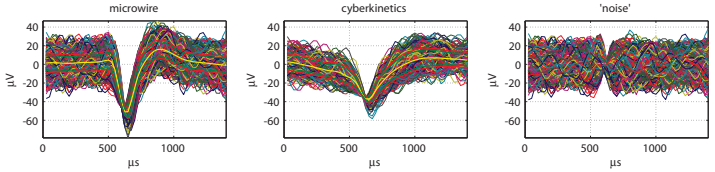


Fig 2: Typical waveforms

waveform width: 1400 µs, PreThreshold (waveform crossing point) at 600 µs

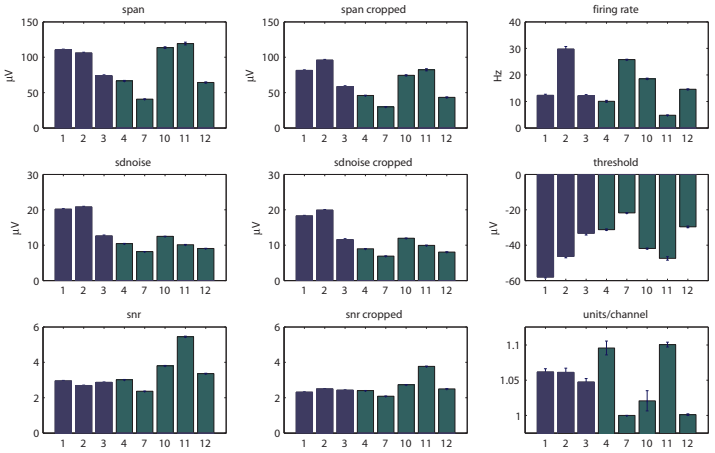


Fig 3: Comparison summary of different MEA performance

Monkey 'Pep': ***1:*** MW in left PMd, ***2:*** MW in left S1; Monkey 'Gol': ***3:*** MW in left S1, ***4:*** CK (Pt, 1.0 mm) in right S1

Monkey 'Gra': ***7:*** CK (Pt, 1.0 mm) in right S1; Monkey 'Zee': ***10:*** CK (pt, 1.5 mm) in left M1,

11: CK (pt, 1.5 mm) in left PMd, ***12:*** CK (IrOx, 1.5 mm) in left S1; Blue=MW, Green=CK

'cropped' is window of 200 µs before to 500 µs after the PreThreshold point

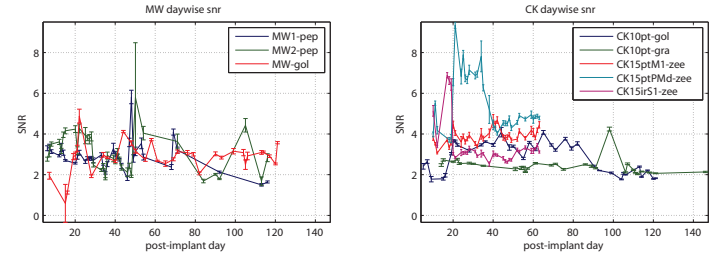


Fig 4: Long-term stability of Signal-to-Noise Ratio in different MEAs

Note that the signal quality of 1.5 mm CK is better than 1.0 mm CK and that there is no significant change in the signal quality with 1.5 mm IrOx coated CK array

Microstimulation and effects

Three out of 4 monkeys were given intracortical microstimulation at some point during or in between the recordings, but one monkey ('gra') was being stimulated through 1.0 Pt CK array implanted in the right somatosensory cortex. We could never appreciate any behavioral effect of stimulation on this monkey, but the data was large enough to get analyzed and is presented here. Biphasic, square-wave constant current pulses were used with the help of stimulus isolator (AM Systems, model 2200). We explored the possibility of such current injections on the recording pattern-changes as seen by changes in the waveforms resulting in different SNR or span or noise floor during or after stimulation period from pre-stimulation state of the same channel. We also compared the channels being stimulated with the channels not being stimulated. The pattern of current pulses we used and the comparison results are shown below.

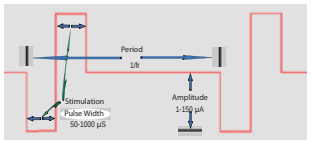


Fig 5: Typical microstimulation pulse used our the experiment

Rectangular, Biphasic
Period: 200 ms (5 Hz freqency)
Amplitude: 1 µA - 150 µA
Pulse Width: 200 µs - 500 µs
(amplitude and pulse width are identical in both cathodic and anodic limbs)
Interval: no interval

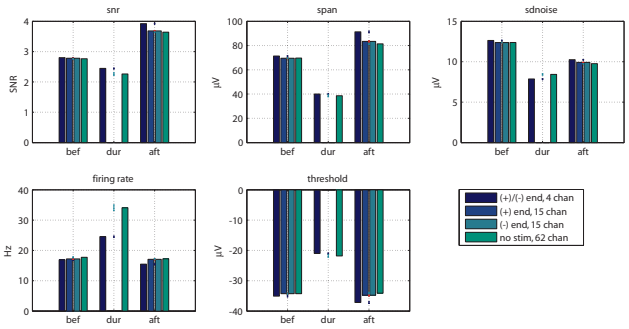


Fig 6: Comparison between channels of 1.0 Pt Utah array

4 channels were used for both cathodic (-) and anodic (+) stimulation
15 channels were used for anodic (+) and 15 as cathodic (-) stimulation
rest of the 62 channels never got stimulated, and are used as control.

'bef' - recordings before a channel ever got stimulated; ***'dur'*** - recordings from a channel between its first time stimulation and last time stimulation; ***'aft'*** - recordings from a channel after its last stimulation.

Note that the control channels were given these 'bef', 'dur', 'aft' stages by segmenting the data at the mean start and the end day for stimulation for other channels, just for comparison purposes. They never undergo any stimulation, but the segments help us demarcating any changes on the stimulation channels related to actual stimulation and not merely time varying nature of neural signal quality.

Future Directions

We are currently awaiting the histology results for 'gol' and in future we are planning to now compare the intrasession and intersession changes in the recording quality, specifically with the water controlled state of the animal and also comparing the microstimulation endurance of IrOx coated arrays versus traditional Pt arrays.

Please e-mail pratik.chhatbar@downstate.edu for poster copy requests or any other questions.
Thank you for stopping by!

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