403.3

CELL ACTIVITY IN MONKEY MOTOR CORTEX IS ALTERED BY CHANGES IN ARM POSTURE FOR MOVEMENTS WITH IDENTICAL HAND TRAJECTORIES.
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The debate continues as to whether neuronal activity in the monkey motor cortex during reaching movements is better related to the extrinsic (i.e. hand trajectory) or intrinsic (i.e. muscle activity, joint moments) attributes of the motor task. We have trained a monkey to move a pendulum-like handle to visual targets using two different arm postures, but with identical hand paths. In the first posture (control), the monkey was allowed to perform the task in its preferred arm orientation (largely in the sagittal plane). In the second posture (abducted), the monkey had to abduct its arm approximately 90 degrees in order to grasp and move the handle. This perturbed arm posture changed the mechanical properties of the muscles (length and moment arm about the joints) and changed the EMG activity patterns of muscles that span the shoulder and elbow joints. We recorded the activity of a large sample of cells in the contralateral motor cortex during the motor task. In the control posture, the activity of individual cells were broadly tuned to the task. The vectorial sum of population activity was oriented approximately with the movement direction. In the abducted posture, the activity of the cells during the motor task was usually not identical to that recorded for the control posture; tonic cell activity often increased or decreased and the preferred direction often changed. The population vectors in the abducted posture varied systematically from the direction of hand movement; these vectors were skewed towards one of two possible directions in which maximal shoulder movement was required to generate the motor task. The sensitivity of cell activity in motor cortex to arm posture is inconsistent with the notion that motor cortex cells signal only hand trajectory in space. (Funded by MRC Group Grant in Neurological Sciences to JFK and MRC Post-Doctoral Fellowship to SHS).

403.4

MULTI-ELECTRODE RECORDING OF NEURONAL ACTIVITY IN THE MOTOR CORTEX: EVIDENCE FOR CHANGES IN THE FUNCTIONAL CONNECTIVITY BETWEEN NEURONS DURING A REACTION-TIME TASK
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We have studied the changes in the functional connectivity between neurons, within a volume comparable in size to the modular organization of cortical structures, during the construction of a motor action. Two monkeys were trained in a reaction time (RT) task in which they performed a pointing movement with the arm, after a preparatory period (PP) of variable duration. A multi-electrode microdrive was used to transdurally insert into the cortex 7 independently driven microelectrodes, spaced 160 µm apart (Mountcastle et al., 1991). The activity of 780 neurons of the primary motor cortex was recorded during 255 sessions. In order to study the dynamic changes in interactions between sets of task-related neurons, joint peri-event time histograms (Aertsen et al., 1989) were then calculated on 265 pairs of simultaneously recorded neurons. The activity of 39 pairs of neurons (15%) was significantly synchronized during periods of time lasting 50 to 300 ms. Such periods of synchronization occurred just after the preparatory signal, at the end of the PP, during RT and/or during movement time. For 14 pairs, the neurons fired with a synchrony of less than 1 ms, whereas in the remaining 25 pairs, larger peaks of cross-correlograms were observed. Synchronized neurons were recorded with a mean horizontal distance of 377 µm (160 to 1980 µm) and a mean vertical distance of 464 µm (0 to 1810 µm). This study provides further evidence for dynamic changes in the functional connectivity within neuronal populations involved in the processing of sensorimotor information. Detailed analysis of cross-correlation data will be used in an attempt to decipher the functional organization of the basic processing unit of the cortical tissue and to investigate how cognitive functions are implemented in the microstructure of the cerebral cortex.

403.5

CHRONIC NEURAL RECORDING WITH MULTICONTACT SILICON MICROPROBES: EFFECTS OF ELECTRODE BIAS.
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Silicon microprobes with integral flexible cables (Neurosci. Abstr. 1993) have been implanted in monkey supplementary motor area for over seven months and continue to record multi-unit activity with spike amplitudes that permit unit isolation using conventional multi-unit spike sorting methods. The recording sites on our probes are sputtered iridium that have been activated to produce an oxide film that lowers the impedance of the electrodes by a factor of ten. However, this electrode impedance is voltage dependent. In this report we demonstrate that the application of a bias potential to the electrodes has a significant effect on the electrode impedance and on the recorded signal amplitude of the spikes. Signal to noise ratios are repeatedly increased by a factor of three or more by the brief application of an anodic bias to the electrode. In a typical recording session, this results in a substantial increase in the amplitude of the larger spikes and the emergence of several smaller spikes from the background hash. After several months of implantation without bias, neural activity is greatly diminished and impedances are increased. A small positive bias no longer shifts the electrode to the low impedance state. In order to return the electrode to a low impedance value, a larger bias must be applied such that currents of approximately 10 na flow. When this occurs, the electrode impedance drops and spike amplitudes are increased. Two phenomena that appear to affect long term recordings are the impedance state of the electrode and an encapsulating sheath around the electrode that may be disrupted by the passage of currents in the nanoamp range.

403.6

PRIMATE PREFRONTAL CORTEX PLAYS A SIGNIFICANT ROLE IN PERFORMING SEQUENTIAL BEHAVIOR WITH AN IMPOSED DELAY.
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To investigate the roles of the prefrontal cortex in generating sequential behavior, single neuron activity was examined in the periprincipal region while 2 monkeys performed a sequential hand-reaching task to two of three targets and a simple reaching task to one target as a control. In addition, to examine whether prefrontal neurons retain multiple target positions simultaneously, a 3-5 s delay period was imposed between the target presentation and the reaching behavior.

A total of 234 single neuron activities were analyzed. Among them, 138 exhibited task-related activity in at least one phase of either task; 85, 72, and 108 exhibited cue-, delay-, and response-related activity, respectively. A large proportion of these activities exhibited complex and context-dependent characteristics. For example, 36% of the delay-related activity was observed only when two specific targets were presented in a particular order during the cue period (pair- and sequence-dependent), and 18% of this activity was observed only when a specific target was presented in either the first or second position (position- and sequence-dependent). However, the remaining neurons exhibited task-related activity under simple conditions. For example, 8% of the delay-related activity was observed when the target was presented in a particular position, regardless of its order. A similar variety of response characteristics, from context-dependent to simple, was observed in response-related activity.

These results indicate that the prefrontal cortex plays an important role in executing sequential behavior. The prefrontal cortex may participate in complex sequential behavior by retaining target positions through a variety of activities, each of which can retain either simple information (e.g., a single position) or multiple and complex information (e.g., multiple positions and a particular order).

403.7

CROSS CORRELATIONS BETWEEN PAIRS OF IDENTIFIED CELLS IN MONKEY MOTOR CORTEX: IMPLICATIONS FOR THE ORIGIN OF POST SPIKE FACILITATION IN RECTIFIED EMG OF HAND MUSCLES.
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The technique of averaging rectified EMG with respect to pyramidal tract neurones (PTN's) recorded from primary motor cortex (spike triggered averaging, STA) has been claimed to allow demonstration of monosynaptic cortico-motoneuronal (CM) connections. Such connections are assumed when the average shows a short latency and duration post spike facilitation (PSF). Critics have suggested that synchrony between the firing of the recorded cell and CM cells could produce facilitation in STA without direct connections from the trigger cell to the motoneurones innervating the recorded muscle (eg Kirkwood, Behav Brain Sci 1992, 15:766-767).

Using two parallel microelectrodes separated by 2 mm, we have recorded from 16 pairs of identified PTN's in the motor cortex (7 pairs on the same electrode) of 4 *Macaca nemestrina* monkeys trained to do the precision grip task, whilst simultaneously recording EMG from up to 9 hand and forearm muscles. For 6 pairs (5 on the same electrode), both cells showed clear PSF in STA of at least one common muscle. In all 6 such pairs, there was a significant central peak in the cross correlograms between the two cells, mean width 15.0 ms, range 9.5-24.5 ms, mean strength as measured by fraction of total spikes synchronised 0.053 (range 0.016-0.1135), suggesting a common input to the two cells.

These data have been combined with other information in the literature to produce a realistic computational model of the effect of synchrony on the production of PSF. A previous study (Smith and Fetz, Neurosci Lett 1989, 96:76-81) addressed the same problem using a spike selection method and a convolution method. Our model takes account of non-linearities inherent in using rectified EMG, and is able to investigate the consequences of synchrony amongst different numbers of cells, allowing more comprehensive quantitative analysis of the contribution of synchrony to PSF.

Supported by the Wellcome Trust, Action Research and the MRC.

403.8

MOTOR CORTEX AND INTERCEPTION OF MOVING TARGETS: SINGLE CELL ANALYSIS.
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Two monkeys were trained to use a 2D articulated manipulandum to intercept moving targets on a computer screen. In random order, 9 targets either accelerated, decelerated or traveled at a constant velocity. For each motion condition targets traveled for one of three target movement times: 0.5, 1 and 1.5 s. Targets appeared randomly in either the right or left lower corner of the screen, then traveled along a 45° path until they crossed the vertical meridian. The monkeys were required to intercept the moving target as it crossed the vertical meridian, making an upward movement (12 cm) from an initial hold position. An interception was considered successful when the movement entered, within 130 ms of the target, a 1 cm radius positional window centered on the point at which the target crossed the vertical meridian. The spike activity of 411 cells were recorded in the arm area of the motor cortex in one monkey during task performance. We found that the activity of various populations of neurons was modulated during the interception task. In most cases the change in cell activity was similar to that observed during upward movements toward a stationary target, in another task, but in other cases changes in cell activity differed between the two tasks. Moreover, cell activity during the last 200 ms of the reaction time was frequently modulated in relation to the temporal characteristics of the ensuing movement; for example, activity in 31% of cells differed significantly ($P<0.05$, ANOVA) among trials with different target velocities, irrespective of the kind of target motion (accelerating, decelerating or constant speed), whereas in 6% of cells it differed according to the kind of motion above, irrespective of the speed itself, and in 11% of cells both speed and kind of target motion had a significant effect. These results indicate that the motor cortex is involved with processing of the temporal characteristics of the interception movement. (Supported by NIH grant PSMH48185).