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Discharge of red nucleus neurons during voluntary muscle contraction : Activity patterns and correlations with isometric force*.

C. GHEZ and D. VICARIO

The Rockefeller University, New York, NY 10021, U.S.A. **

SUMMARY :

Discharges of red nucleus neurons were analyzed in the cat during voluntary muscle contractions performed under isometric and anisometric conditions. The observations established : (1) that neurons of the red nucleus modulate their firing in advance of the motor output under both conditions; (2) that increased activity of these neurons is specific to the direction of the force exerted ; (3) that this increase is primarily related to the magnitude of the rate of force change generated by the animal.

Key-words : Red nucleus. Unitary activity. Motor performance.

INTRODUCTION

On the basis of converging anatomical and physiological evidence it is currently accepted that the red nucleus is intimately concerned with the control of motor function (MASSION, 1967). The present study was undertaken to determine : (1) whether neurons in the red nucleus modulate their activity in association with voluntary contraction of limb muscles ; (2) the timing and pattern of this modulation in relation to the motor output ; and (3) the parametric relationship which may exist between the firing frequency of these rubral units and the force exerted under isometric conditions. In addition, the change in activity produced by passive displacements of the limb was examined.

METHODS

Experiments were conducted in four cats trained to perform a tracking task which required rapid adjustments in the position of a lever or the force applied to it isometrically. Each animal was restrained snugly in a sleeve and its head and left humerus rigidly fixed to an external frame. The animal's forearm was strapped in a splint attached to the lever of a torque motor controlled manipulandum. During position adjustments, the cat flexed or extended its elbow to overcome simulated spring loads generated by the torque motor. During isometric force adjustments, the angular position of the lever was fixed. A compensatory display (GHEZ and KUBOTA, 1977) facing the animal indicated either a force or position error relative to a target level, according to whether isometric or anisometric contraction was studied. The display consisted of a retractable feeder and a pair of lamps which were moved from side to side by a second, servo-operated torque motor. The extent of display motion corresponding to a given error could be changed by altering the gain of the system. At random intervals, the target was stepped in one direction or another. When the animal realigned the display, a food reward was provided.

Once stable performance was achieved, the activity of neurons within the red nucleus contralateral to the limb performing the task was recorded. Units were sampled in the red nucleus in areas where microstimulation (300 Hz, 0.2 msec, 13 pulses) produced contraction of contralateral limb muscles with currents under 10 μA. Unit activity, electromyograms and transducer outputs were recorded on magnetic tape and analyzed off-line.

RESULTS

Target perturbations typically elicited rapid adjustments in limb position or in force applied to the lever with brief latencies. The interval between the target perturbation and the first increment in rate of force change dF/dt) showed daily means of 80 to 120 msec in all animals. Under isometric conditions the motor output was characterized by a linear relation between the peak force achieved and the peak dF/dt which preceded it. This relation was such that the time from onset to peak values of either of those parameters was essentially independent of the peak force (GHEZ and VICARIO, 1977). The patterns of muscle contraction were reciprocal only under isometric conditions. Increases in flexor force were associated with activity of forearm flexor muscles and decreased activity in extensor muscles. Extensor force was associated with activity in extensor

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