REFLECTION OF THE ARM ROTATION ANGLE IN TEMPORAL PARAMETERS OF KINESTHETIC EVOKED CORTICAL POTENTIALS IN *Macaca rhesus*

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Much experimental evidence has now been obtained on various aspects of the functional organization of systems conducting feedback signals and maintaining control of movement [2-7]. However, some problems concerning the central-peripheral organization of the kinesthetic system — the main channel of control and correction of the position of the body in space — remain unsolved. One of the most important problems is reflection of the kinematic characteristics of motor activity in the electrical responses of projection regions of the brain.

The aim of this investigation was to study the influence of the angle of arm extension at the elbow in the rhesus monkey (*Macaca rhesus*) on temporal characteristics of evoked kinesthetic potentials in the primary somatosensory area of the cortex.

EXPERIMENTAL METHOD

By using the method of natural stimulation of kinesthetic receptors, developed by the writers previously [1, 3], a near-linear relationship was discovered between the time of development of the positive wave of the kinesthetic potential and the amplitude (angle) of arm rotation. Experiments were carried out on five male rhesus monkeys (age 3-5 years, weight 4-7 kg). The animals were anesthetized with pentobarbital sodium (20-25 mg/kg, intravenously). Evoked potentials were recorded at the site of representation of the arm in the primary somatosensory cortex of the contralateral hemisphere by means of nichrome electrodes (diameter 0.4 mm), applied epidurally. Each monkey took part in the experiment two or three times. The method of natural stimulation of kinesthetic receptors [1] was as follows. The animal's head was fixed in a stereotaxic apparatus, and the hand and forearm were fixed to the horizontal platform of the kinesthetic stimulator. The arm was immobilized by a splint fixed to the stereotaxic apparatus. Kinesthetic stimulation was induced by passive extension of the limb at the elbow, at constant angular acceleration ($\alpha = 5 \times 10^4$ deg/sec^2), and at a fixed angle. The initial angle at the elbow was constant, namely 90°. The cycle of stimulation consisted of four phases: start, movement, stop, and return to the original position. Kinesthetic stimulation was applied in series (each of 20 stimuli) with a frequency of 0.2-0.5 Hz. The angle of stimulation was 2, 10, 30, and 40°. Kinesthetic evoked potentials (KEP) were recorded on a model 1266 Neuroaverager (from Biomedica, Italy). Evoked potentials were averaged for 10-20 realizations, the discretization step was 20-500 μsec, and the epoch of analysis 20-500 msec. The duration of the first positive wave (T_p), its amplitude, and the absolute and peak latent periods were measured. The integral power (P_i) of this wave was calculated by the equation:

$$P_i = \int_{t_1}^{t_2} f(t)\, dt,$$

where $\int(t)$ is a function approximating the positive wave of KEP, and t_1 and t_2 are the time limits of that wave. The significance of the results was analyzed by Student's t test and the chi-square test.

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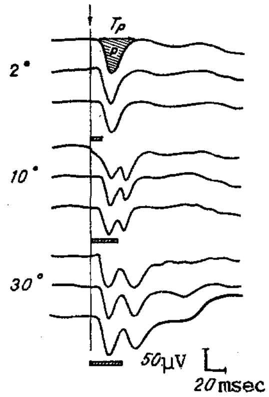

Fig. 1. Averaged KEP in response to extension of the arm at the elbow by 2, 10, and 30° (marker of time of movement shown below).

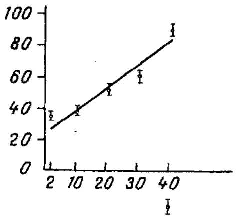

Fig. 2

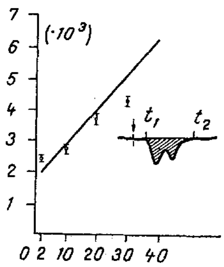

Fig. 3

Fig. 2. Graph showing dependence of duration of first positive wave of kinesthetic potential on angle of rotation. Abscissa, angle of stimulation (in deg.); ordinate, duration of first positive wave (in msec).

Fig. 3. Dependence of integral power of first positive wave of KEP on angle of rotation. Abscissa, angle of rotation (in deg.); ordinate, integral power (in μV·msec).

EXPERIMENTAL RESULTS

KEP recorded in response to rotation of the arm at the elbow, of different amplitude (angle), began with a surface-positive wave (Figs. 1-3). The absolute and peak latencies of KEP did not differ significantly at different angles (2-40°) of stimulation (Table 1). The amplitude of this wave of KEP likewise did not differ significantly in series with different angles of rotation of the limb at the elbow (Table 1). An increase in the amplitude of rotation of the joint from 2 to 10° or more led to an increase in duration of the surface-positive wave (T_p) in accordance with a near-linear relationship of the form:

$$T_p(\varphi) = 1.41 \cdot \varphi + 26.4 \ .$$

An increase in the amplitude of the angle of rotation of the arm to 10° or more was accompanied by splitting of the first positive wave and the formation of two additional components (N_2 and P_3). With an increase in the amplitude of stimulation peak latencies of N_2 and P_3 also increased (Figs. 1-3; Table 1). A change in the angle of rotation of the arm at the elbow between 2 and 40° changed the integral power (P_i) of the first positive wave of KEP. With an increase in the angle of deviation of the limb, (P_i) increased in accordance with a near-linear relationship:

$$P_i(\varphi) = 113 \cdot \varphi + 1710.$$

TABLE 1. Latent Periods, Duration, Amplitude, and Integral Power of First Positive Wave of KEP in Contralateral Somatosensory Cortex of Rhesus Monkeys Recorded in Response to Extension of the Arm at the Elbow, with Varied Amplitude (M ± m, n = 50)

Amplitude of rotation, deg	Time of movement, msec	Absolute latent period, msec	Peak latent period (P_1), msec	Duration, T_p, msec	Amplitude, Ap_1, μV	Integral power (P_1), μV·msec
2	8,9	8,3±0,35	17,0±0,56	35±1,3	70±1,2	2421±39
10	20,0	8,1±0,29	18,0±0,85	39±1,7	71±1,1	2737±13*
20	27,9	8,2±0,19	15,7±0,14	52±0,7*	73±5,5	3640±56*
30	34,4	8,3±0,25	18,4±0,40	61±1,5*	70±2,1	4225±35*
40	39,8	8,8±0,30	16,1±0,35	90±0,7*	73±1,2	6320±45*

Legend. *$p < 0.05$ compared with stimulation with an amplitude of 2°.

The results show that a change in the amplitude of rotation of the arm at the elbow is reflected mainly in the first surface-positive wave of KEP and, in particular, in its temporal parameters. A near-linear relationship exists between the time of development of that wave and the amplitude (angle) of rotation of the limb. The formation of the descending phase of the first positive wave is evidently linked with the action of positive angular acceleration during the triggering phase of movement, for its absolute and peak latency and amplitude were independent of the angle of rotation of the arm and the duration of action of stimulation. The descending phase of the third positive component of this wave is probably formed by the action of negative angular acceleration during the stopping phase, which precedes this component by 5-7 msec.

It can thus be postulated that with an amplitude of rotation of 10° or more, on- and off-responses are recorded to the starting and stopping of angular rotation of the limb at the elbow.

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