Post-Motion Positivity Potentials Accompanying Voluntary, Self-Paced Movements in Man

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Abstract In this study, we examined the scalp distribution of postmotion positivity potentials beginning at about 150 msec. and 320 msec. after a voluntary, self-paced movement as well as their functional significance with respect to motor control.

The present results showed that the P2 potentials were preponderant over the central area contralateral to the moving limb in both the right and left finger movement, with the midline-central area showing the maximal amplitude. Moreover, with the ankle movement, the P2 potentials were preponderant over the central area ipsilateral to the moving limb. In addition, the present experiments showed that the P3 potentials were larger over the midline-parietal area than over the central area. With the amplitudes of P2 and P3 potentials, the present results showed that the values of the P2 and P3 potentials were larger for plantar flexion of ankle than for finger movements. Therefore, it may be concluded that the P2, in part, reflects a central mechanism and the P3 potential reflects the afferent feedback which signals the information of limb position.


Key words : Post-motion positivity potential, movement-associated cerebral potentials, EMG, voluntary movement

Introduction

Kornhuber and Deecke (1965) first recorded four movement-associated cortical potentials from the human scalp, both preceding and accompanying

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a voluntary movement: (1) Readiness Potential (RP), (2) Pre-Motion Positivity Potential (PMP), (3) Motor Potential (MP), and (4) Complex positive-negative potentials following movement onset. The RP starts as early as 0.8-1.5 sec. prior to the onset of movement and has a bihemispherical distribution in all movements, even in unilateral ones. In the first half of the foreperiod the RP is bilaterally symmetrical. However, with finger movements, the precentral RP develops a contralateral preponderance of negativity halfway through its course. Therefore, RP is considered to be associated with the preparation and initiation of voluntary movements. It is reported\(^3\)\(^4\)\(^5\) that the PMP starting at about 80-90 msec. prior to the first EMG activity is usually seen over the fronto-central midline as well as in the parietal and ipsilateral precentral leads. However, the functional significance of motor control in PMP remains unclear. The MP starting at about 50-60 msec. prior to the first EMG activity is preponderant over the contralateral motor cortex and MP is considered to be associated with the initiation of voluntary movements. Thus, several cerebral potentials prior to voluntary movements have been extensively examined by many researchers.

However, many points remain unclear with respect to the complex positive-negative potentials following movement onset. In this study, we examined the scalp distribution of two post-motion positivity potentials starting at about 150 and 320 msec. following the onset of movement as well as their functional significance with respect to motor control.

Material and Methods

Subjects: The subjects were 5 young male students, ranging in age from 19-20 years old. They laid comfortably on a bed in a sound-damped, electrically shielded room with their eyes fixed upon a red lamp which was placed at a distance of 1.5 m.

Movement tasks: Each subject was instructed to perform unilateral self-paced movements at his own volition. Each session consisted of four movements, the sequence of which was balanced between experiments: (1) plantar flexion of the right ankle, (2) plantar flexion of the left ankle, (3) right finger movement, (4) left finger movement. The subjects were instructed to fix their sight on a designated point and avoid blinking or other contaminating movements during execution of the movement tasks. Intertrial intervals were not shorter than 10 sec.

Recording and analysis: The EEG was recorded monopolarly from the scalp using an EEG with a spiral electrode. The electrodes were placed at C3, CZ, C4 and PZ, according to the 10-20 electrode system, with reference to
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commonly linked ears. Electrodes above and below the left eye were used for recording vertical eye movements and blink potentials. The time constant used for measuring movement-associated cerebral potentials was 3 sec. The EEG signals were amplified by EEG-amplifiers (-3DB point at 30 Hz). The rectified EMG bursts which were bipolarity recorded from the triceps durae muscle of the right leg, from the flexor hallucis brevis muscle and the superficial flexor digitorum communis muscle using a silver-cup electrode with a time constant of 0.01 sec., served as the trigger. The EEG, EOG and rectified EMG bursts, which served as trigger pulse, were recorded on magnetic tape. After the experiment, the data stored on the tape were fed into the averaging computer and were averaged (ATAC 250 averaging computer) in reverse or normal time and recorded on the X-Y recorder. In this study, the onset times of post-motion positivity potentials were measured from the first EMG activity to each of the positive deflections. The amplitudes of the post-motion positivity potentials were obtained by measuring the differences in amplitude between each component and the component of opposite polarity which was immediately following. It is seen that the ratio of movement-associated cerebral potentials to background potential is improved by increasing the number of samples, but the contours of movement-associated cerebral potentials did not seem to differ substantially. Accordingly, we usually took 70 samples from each of the subjects for purposes of averaging in the case of the movement-associated cerebral potentials measurement. Analysis time for the movement-associated cerebral potentials on the averaging computer was 2.5 sec. All segments with artifacts were excluded from the data. Fig.1. shows a typical example of wave form for the movement-associated cerebral potentials and the measurement criterion.

Statistical analysis: A paired t test was used for statistical evaluation.

Results

The post-motion positivity potential (P2 potential) starting at about 150 msec. following the first EMG activity.

Fig.1.2 shows the scalp distribution of P2 potential following the first EMG activity. As shown in Fig.1., with the right finger movements, the P2 potentials were clearly larger over the midline-central area (CZ) and secondly over the left central area (C3) than over the right central area (C4) and midline-parietal area (PZ) (CZ>C3, not sig., CZ>C4, t(4)=11.24, p<0.01, CZ>PZ, t(4)=7.66, p<0.01, C3>C4, t(4)=8.93, p<0.01, C3>PZ, t(4)=9.71, p<0.01, C4>PZ, t(4)=2.78, P<0.05). Contrary to the finger movements, the P2 potentials of right ankle movement were larger over the right central area.
Fig. 1. A typical example in wave form of Movement-Associated Cerebral Potentials. The post-motion positivity potentials are measured from the first EMG activity to each of the positive deflections.

Fig. 2. The P2 potential after a right voluntary, self-paced movement.
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(C4) and midline-central area (CZ) than over the left central area (C3) and midline-parietal area (PZ) (C4＞CZ, not sig., C4＞C3, t(4)=2.83, P<0.05, C4＞PZ, t(4)=6.63, P<0.01, CZ＞C3, t(4)=2.80, P<0.05, CZ＞PZ, t(4)=6.62, P<0.01, C3＞PZ, t(4)=4.47, P<0.05). As for left finger movements shown in Fig.2, the P2 potentials were significantly larger over the right central area (C3) and midline-central area (CZ) than over the left central area (C3) and midline-parietal area (PZ) (C4＞C3, t(4)=10.43, P<0.01, C4＞CZ, not sig., C4＞PZ, t(4)=11.82, P<0.01, CZ＞PZ, t(4)=4.72, P<0.01).

Comparing the values of P2 potentials during various movement tasks, the P2 potentials were significantly larger for plantar flexion of the ankle than for finger movements (ankle movement＞finger movement, t(19)=6.06, P<0.01 for right movement, t(19)=3.79, P<0.01 for left movement, respectively).

The post-motion positivity potential (P3 potential) beginning at about 320 msec. following the first EMG activity.

Fig.3, 4 shows the scalp distribution of P3 potential after the first EMG activity. As shown in Fig. 3, the P3 potentials were larger over the midline-parietal area (PZ) than over the central areas in both the right finger and ankle movements (PZ＞C3, t(4)=3.46, P<0.05, PZ＞CZ, t(4)=3.18, P<0.05, PZ＞C4, t(4)=3.51, P<0.05 for finger movement, PZ＞C3, t(4)=4.55, P<0.05, PZ＞CZ, t(4)=4.17, P<0.05, PZ＞C4, t(4)=3.23, P<0.05 for ankle movement, respectively). As shown in Fig.4, the P3 potential were larger over the midline-parietal area than over the central areas in both the left finger and ankle movements (PZ＞

![Fig. 3. The P2 potential after a left voluntary, self-paced movement.](image-url)
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![Graphs showing amplitude vs lead placement for right movements.](image)

**Fig. 4.** The P3 potential after a right voluntary, self-paced movement.

![Graphs showing amplitude vs lead placement for left movements.](image)

**Fig. 5.** The P3 potential after a left voluntary, self-paced movement.

C3, t(4)=6.26, P<0.01, PZ>CZ, t(4)=6.34, P<0.01, PZ>CZ, t(4)=6.24, P<0.01 for finger movement, PZ>C3, t(4)=7.30, P<0.01, PZ>CZ, t(4)=6.67, P<0.01, PZ>C4, t(4)=5.92, P<0.01 for ankle movement, respectively). A significant dif-
ference was not found in the central areas for both the finger and ankle movements. Comparing the values of P3 potential during various movement tasks, the P3 potentials were larger for plantar flexion of the ankle than for finger movements (ankle movement > finger movements, t(9) = 3.63, P < 0.01, for the right movement, ankle movement > finger movement, t(9) = 7.06, P < 0.01 for the left movement).

Discussion

Many points remain unclear with respect to post-motion positivity potentials following a voluntary, self-paced movement. In this study, we examined the scalp distribution of post-motion positivity potential beginning at about 150 msec. and 320 msec. after a voluntary, self-paced movement onset as well as their functional significance with respect to motor control. The present experiments showed that the P2 potentials were preponderant over the central area contralateral to the moving limb in both the right and left finger movements, with the midline-central area showing the maximal amplitude. However, with respect to the ankle movements, the P2 potentials were preponderant over the central area ipsilateral to the moving limb. These results were consistent with those of the RP which begin at about 0.8 - 1.5 sec. prior to a voluntary movement. Boschert et al. (1983) reported that the P2 component is particularly pronounced at C3 and P3 during right finger movement and at C4 and P4 during left finger movement. However, from the present results we noted that the P2 potentials were more preponderant over the central area than over the midline-parietal area. Deecke et al. (1976) proposed that the post-motor potential course reflects reafferent input from kinesthetic receptors evoked by the movement itself, because the potential after movement onset shows the same sequence of positive and negative components. Contrastingly, the present results did not show preponderance over the midline-parietal area and were not consistent with those of Deecke et al. According to the studies in monkeys of Vaughan et al. (1970), it was reported that the positive component after a movement did not disappear following bilateral rhizotomy C2-C4. Arezzo et al. (1977) also reported that units which begin to discharge in approximate synchrony with the onset of movement located on both sides of the central sulcus as well as their activity are concurrent with the P2 component. Accordingly, from the scalp distribution of P2 component and the studies in monkeys of Vaughan et al. (1970) and Arezzo et al. (1977), it may be concluded that the P2 component, in part, reflects a central mechanism. As has already been described, with ankle movements, the P2 components were preponderant over the hemisphere ipsi-
lateral to the moving limb. These results were consistent with those in which RP begins at about 0.8-1.5 sec. prior to a voluntary movement. Therefore, the reason for these results may be that the distribution difference between the RP for foot and finger movements was not due to a control difference of cerebral hemisphere between foot and finger responses, but to the difference of the temporal ordering of the principal generators which might contribute to the RP, as previously reported. Furthermore, the present results showed that the P3 potentials were larger over the midline-parietal area than over the central area. Arezzo et al. (1977) also reported that the long latency MUA following the EMG is recorded exclusively in the post central gyrus and is associated with the P3 component. In addition, Boschert et al. (1983) also confirmed that the post-motor component is terminated by a pronounced late positive component. This late positive component shares the latency of P300 component of a sensory evoked potential. Other investigators have also reported that somesthetic stimulation evokes unit activity within area 5 at comparable latencies. Therefore, it may be concluded that the P3 component reflects afferent feedback signalling information on the limb position. Moreover, the present experiments showed that the values of the P2 and P3 potentials were significantly larger for plantar flexion of the ankle than for finger movements. A possible explanation for these results could be that it takes more cortical monitoring to perform plantar flexion for the ankle movement than for the finger movement, for man is more skilled with his fingers than with his feet.

References

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自発動作に伴う運動後陽性電位

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要 旨　著者らは脳電位、筋電位を用いて自発動作後約150 msecと320 msecに開始する運動後陽性電位の頭皮上分布とそれらの電位の運動制御上の意義を検討することに本研究の目的をおいた。その結果、運動後陽性電位の一つであるP2電位は、指の動作においては左右の動作とも動作肢と反対側の中心頸野で優位を示し、かつ導出部位CZの中心頸野において最大の振幅を示した。しかし、足関節屈屈動作におけるP2電位は同側の中心頸野上で優位を示した。さらに、運動後320 msecに開始するP3電位は導出部位PZ上で優位を示し、また指と足関節動作間を比べてみると、P2、P3電位とも足関節動作において大きな振幅を示した。それゆえ、P2電位の出現には中枢機構の一部が関与し、P3電位の出現には末梢からのフィードバック機構が関与していることが推察される。