

# Premovement Cerebral Potentials Preceding Voluntary, Self-Paced Foot, Toe and Finger Movements in Man.

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**Abstract** Whether the Readiness Potential (RP) prior to foot and toe movements shows a larger amplitude over the hemisphere ipsilateral to the movement was examined by the averaged EEG and EMG. Analysis showed that prior to foot and toe movements, the RP amplitudes were slightly larger over the ipsilateral hemisphere than over the contralateral hemisphere to the movement, but not consistently significant. The RP for finger movement, however, was clearly larger over the contralateral hemisphere to the movement.

It is considered that the project area of the lower limb is situated in the depth along the fissure longitudinalis and that of the hand area lies mainly buried within the central sulcus. The MEG (magnetoencephalographic) recordings of other studies did not show the paradoxical EEG side preponderance with respect to the RP prior to the foot movement. Therefore, from the recent studies and the present results, it is concluded that the distribution difference between the RP for foot and finger movement was not due to a control difference of the cerebral hemisphere between foot and finger responses, but to the difference of temporal ordering of the principal generators which might contribute to the RP constitution.

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**Key Words :** Premovement potential, CNV, Readiness potential, EMG, Voluntary movement

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## Introduction

It is widely known that movement-associated cortical potentials can be recorded from the human scalp both preceding and accompanying a voluntary, self-paced movement. Movement-associated cortical potentials were first recorded by Kornhuber<sup>15)</sup> and Deecke (1965). The successive components have been described as the Bereitschaftspotential (BP) or Readiness Potential (RP), the premovement positivity (PMP) and the motor potential (MP). In addition, it is known that the post-movement potentials is also consisted of some components. Shibasaki<sup>21), 22)</sup> et al. (1981) described 8 components, as did Gerbrandt<sup>12)</sup> (1973), 4 being pre-and 4 post-movement potentials.

It is considered that the premovement cerebral potentials are associated with preparation and initiation of voluntary movements, although the significance of motor control with respect to the PMP remains unclear. Several<sup>10), 12), 15), 16), 17), 18), 19), 20), 22)</sup> studies reported that prior to the finger and movements, the negative potential beginning about 800-1500 msec before the EMG burst was larger over the hemisphere contralateral to the movement. Recently, the findings mentioned above are supported by many researchers. Moreover, Grunewald et al. (1979) found that the late CNV was similar to the RP or BP described by Kornhuber and Deecke (1965) and only the late CNV was closely associated with motor preparation.

Brunia<sup>8)</sup> (1980), however, noted that prior to plantar flexion of the whole foot, the late CNV amplitude was larger over the hemisphere ipsilateral to the movement. Several<sup>4), 5), 6), 7)</sup> studies also reported that the RP or the late CNV did not show asymmetry prior to foot and toe movements. Therefore, why the RP or the late CNV asymmetry prior to the foot and toe movements has not occurred remains unclear. In this study, comparing the RP preceding the foot and toe movement with those prior to the finger movements, we also examined whether the RP prior to the foot and toe movements would show larger amplitude over the hemisphere ipsilateral to the movement.

## Material and Methods

Five right-handed males age 19–20 years took part in the experiment. They laid comfortably on a bed in a sound-damped, electrically shielded room with their eyes fixed upon a red lamp placed at a distance of 1.5 m. Each subject was instructed to perform unilateral self-paced movements at his own volition. Each session consisted of six runs, the sequence of which was balanced between experiments: (1) plantar flexion of the right foot, (2) plantar flexion of the left foot, (3) right-toe movement, (4) left-toe movement (5) right-

finger movement, and (6) left-finger movement. The subjects were instructed to fixate on a designated point and to avoid blinking or other contaminating movements during execution of the tasks. Intertrial intervals were not shorter than 10 sec.

The EEG was recorded monopolarly from the scalp using an EEG spiral electrode. The electrodes were placed at C3, Cz, C4, and Pz, according to the 10-20 electrode system, with reference to 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 premovement cerebral potentials was 3 sec. The EEG signals were amplified by EEG-amplifiers (-30B point at 30 Hz). The rectified EMG burst bipolarly recorded from the triceps dursae muscle in the right leg, from the flexor hallucis brevis muscle 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 burst served as the 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 time and recorded on the X-Y recorder.

In this study, the onset times of premovement cerebral potentials were measured from their first deflections to the onset of the rectified EMG burst. The amplitude of premovement cerebral potentials was measured on the basis of the baseline, computed using the first 500 msec of the interval. It is seen that the ratio of premovement cerebral potentials to background potential is improved by increasing the number of samples, but the contours of premovement cerebral potentials did not seem to differ substantially. Accordingly, we usually took 70 samples from each of the subjects for the averaging in the case of premovement cerebral potentials measurement.

Analysis time for premovement cerebral potentials on the averaging computer was 2.5 sec. All segments with artifacts were excluded from the data. Fig. 1. shows the experimental apparatus and data analysis process and Fig. 2. a typical example in wave form of RP (Readiness Potential) and the measurement criterion. A paired test was used for statistical evaluation.

## Results

Amplitudes of the RP preceding voluntary, self-paced movements.

As shown in Fig. 3., prior to the right toe movements, the RP amplitudes were slightly larger over the right central area (C4) and midline-central area (CZ) than over the left central area (C3) and midline-parietal area (PZ). But the RP amplitudes did not show statistical significance among various

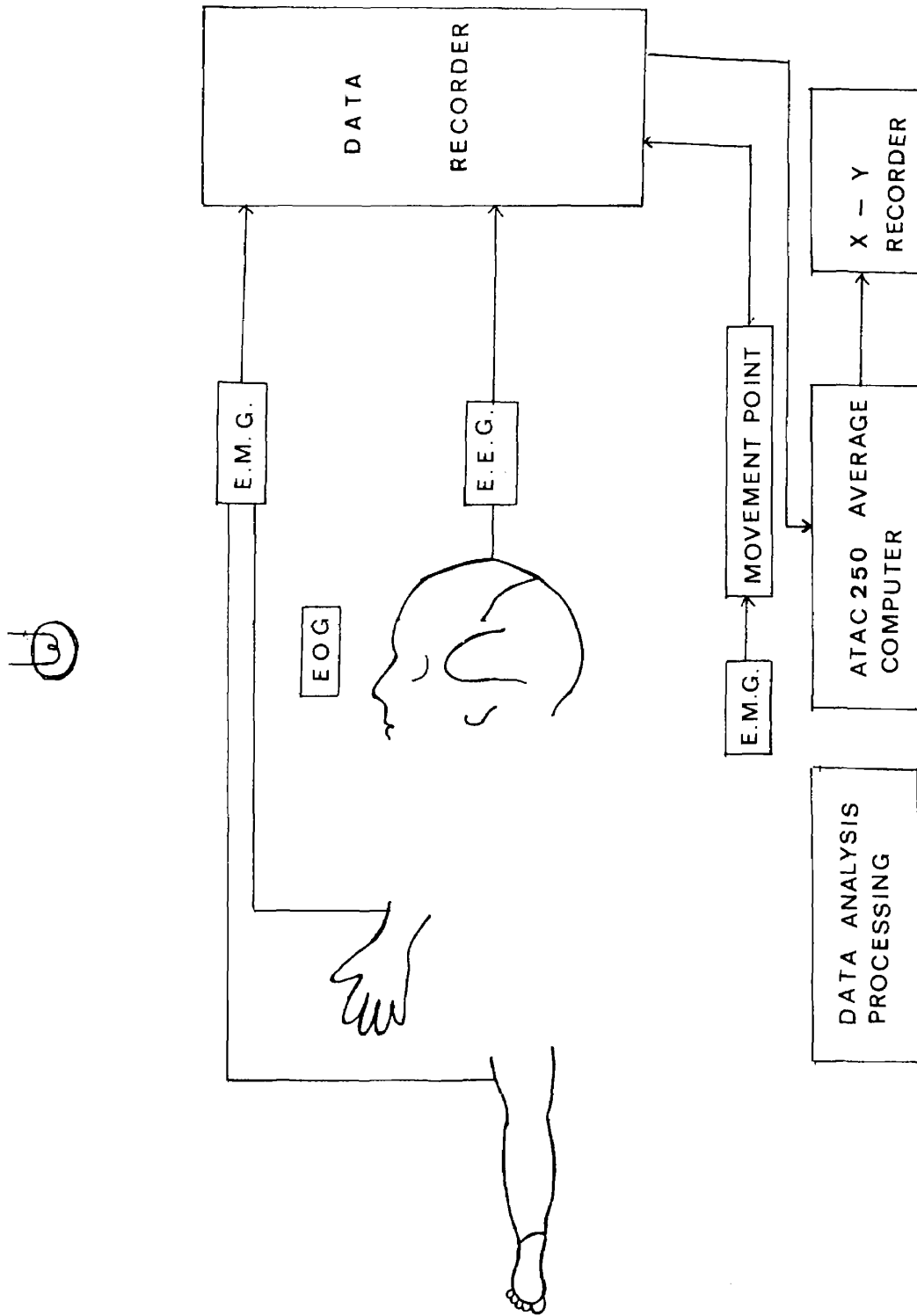
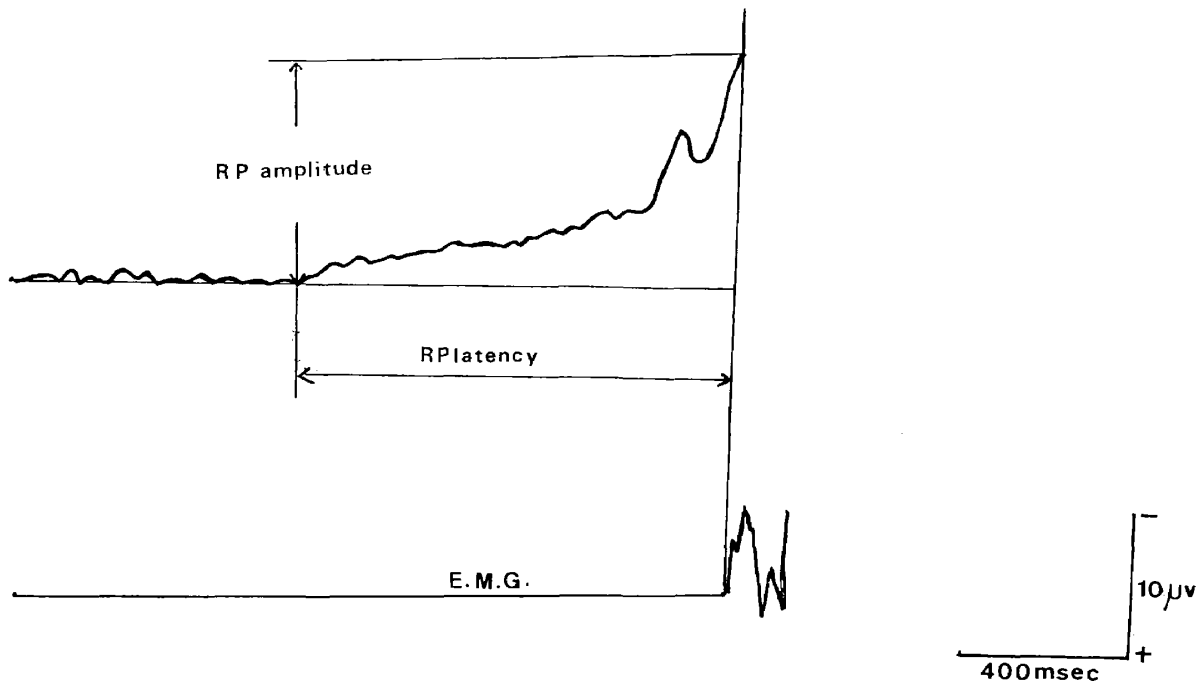


Fig. 1. The present experimental apparatus and analysis process. The EEG and EMG are recorded and stored on a cassette recorder. After the experiment, the data stored on the tape are fed into the averaging computer and are averaged (ATAC 250 averaging computer) in reverse time and recorded on the X - Y recorder.

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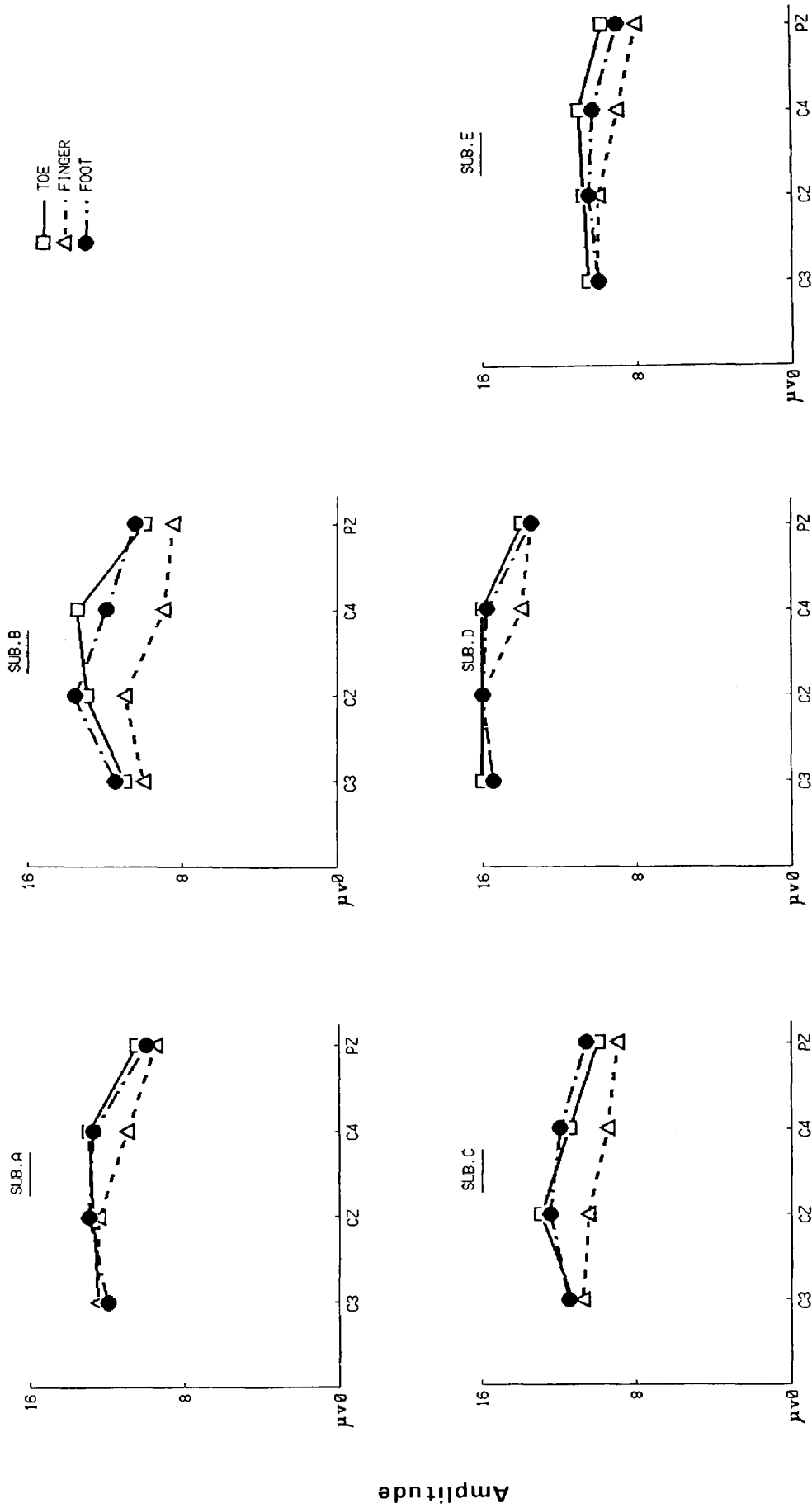


**Fig. 2.** A typical example in wave form of RP (Readiness Potential) and measurement criterion. The onset time of RP is measured from its first deflection to the onset of the rectified EMG burst. The RP amplitudes are measured on the basis of the baseline, computed using the first 500 msec of the interval.

electrodes except for the midline-parietal area (PZ) ( $PZ < C4$ ,  $t(4) = 5.05$ ,  $P < 0.01$ ,  $PZ < CZ$ ,  $t(4) = 6.00$ ,  $P < 0.01$ ,  $PZ < C3$ ,  $t(4) = 5.33$ ,  $P < 0.01$ ), although there was a trend for C4 and CZ to be larger than C3 and PZ.

With the right foot movements, the RP amplitudes were also larger over the right central area (C4) and midline-central area (CZ) than over the left central area (C3) and midline-parietal area (PZ). In this case, although the difference between C4 and CZ was not significant, the RP showed a significant difference between C4 and C3 ( $t(4) = 8.54$ ,  $P < 0.01$ ). In addition, comparing PZ with C4, CZ, and C3, the RP showed significant difference in all cases ( $C4 > PZ$ ,  $t(4) = 7.23$ ,  $P < 0.01$ ,  $CZ > PZ$ ,  $t(4) = 8.33$ ,  $P < 0.01$ ,  $C3 > PZ$ ,  $t(4) = 5.44$ ,  $P < 0.01$ ). Contrary to toe and foot movements, with respect to the right finger movements, the RP amplitudes were clearly larger over the left central area (C3) and midline-central area (CZ) than over the right central area (C4) and midline-parietal area (PZ) ( $C3 > C4$ ,  $t(4) = 11.22$ ,  $P < 0.01$ ,  $CZ > C4$ ,  $t(4) = 6.71$ ,  $P < 0.01$ ,  $CZ > C3$ , not sig.,  $C3 > PZ$ ,  $t(4) = 8.17$ ,  $P < 0.01$ ,  $C4 > PZ$ ,  $t(4) = 4.00$ ,  $P < 0.05$ ,  $CZ > PZ$ ,  $t(4) = 7.02$ ,  $P < 0.01$ ).

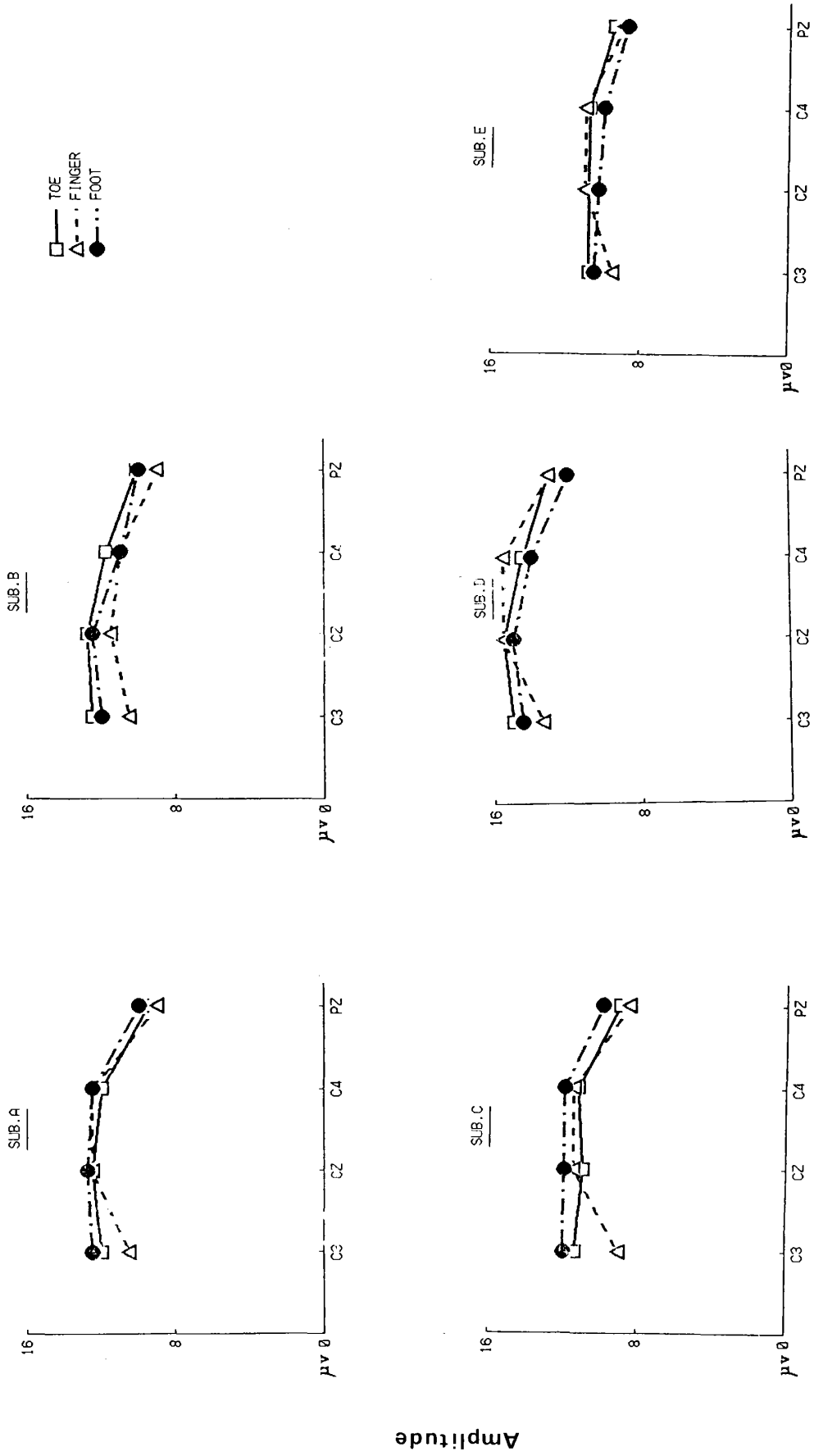
As shown in Fig. 4., prior to the left toe movements, the RP amplitudes were slightly larger over the left central area (C3) and midline-central area (CZ) than over other lead placements, but were not statistically significant among various lead placements except for PZ ( $PZ < C3$ ,  $t(4) = 9.69$ ,  $P < 0.01$ ,  $PZ < CZ$ ,  $t(4) = 7.50$ ,  $P < 0.01$ ,  $PZ < C4$ ,  $t(4) = 8.26$ ,  $P < 0.01$ ). With respect to



Lead Placement

Fig. 3. The RP amplitude preceding right foot, toe and finger movements

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Lead Placement

Fig. 4. The RP amplitude preceding left foot, toe and finger movements

the left foot movements, the results of RP amplitude distribution were also identical with those of the left toe movements ( $C3 > PZ$ ,  $t(4) = 13.64$ ,  $P < 0.01$ ,  $CZ > PZ$ ,  $t(4) = 8.64$ ,  $P < 0.01$ ,  $C4 > PZ$ ,  $t(4) = 6.25$ ,  $P < 0.01$ ). With the left finger movements, the RP amplitudes were significantly higher over the right central area (C4) and midline-central area (CZ) than over other lead placements ( $C4 > C3$ ,  $t(4) = 5.00$ ,  $P < 0.01$ ,  $CZ > C3$ ,  $t(4) = 7.01$ ,  $P < 0.01$ ,  $CZ > C4$ , not sig.,  $C4 > PZ$ ,  $t(4) = 9.04$ ,  $P < 0.01$ ,  $CZ > PZ$ ,  $t(4) = 10.73$ ,  $P < 0.01$ ,  $C3 > PZ$ ,  $t(4) = 3.28$ ,  $P < 0.05$ ).

Comparing the values of RP amplitude among various movement tasks, the RP amplitudes were significantly larger for toe and foot movements than for finger movements (toe > finger,  $t(19) = 5.12$ ,  $P < 0.01$ , foot > finger,  $t(19) = 5.43$ ,  $P < 0.01$ , for right movements, toe > finger,  $t(19) = 2.64$ ,  $P < 0.05$ , for left movements).

Latencies of the RP preceding voluntary, self-paced movements.

As shown in Table 1., 2., differences in the RP latencies were not found among other lead placements except for PZ in both the right and left limbs. But a significant difference was found among various movement tasks in both the right and left limbs. (toe > finger,  $t(19) = 13.98$ ,  $P < 0.01$ , foot > finger,  $t(19) = 14.01$ ,  $P < 0.01$  for right movements, toe > finger,  $t(19) = 21.12$ ,  $P < 0.01$ , foot > finger,  $t(19) = 19.40$ ,  $P < 0.01$  for left movements). That is to say, the RP latencies were longer for toe and foot than for finger movements in both the right and left limbs.

**Table 1**

Mean latencies (msec) of the RP in five subjects during various movement tasks (right)

Movement Tasks	Lead Placement			
	C 3	Cz	C 4	Pz
Toe Movement	856	857	854	832
Foot Movement	860	859	858	834
Finger Movement	760	761	761	736

**Table 2**

Mean latencies (msec) of the RP in five subjects during various movement tasks (left)

Movement Tasks	Lead Placement			
	C 3	Cz	C 4	Pz
Toe Movement	852	855	852	823
Foot Movement	853	855	854	824
Finger Movement	765	766	764	736



## Discussion

In this study, we examined whether the RP prior to foot and toe movements would show larger amplitude over the hemisphere ipsilateral to the movement. The present experiments showed that prior to foot and toe movements, the RP amplitudes were slightly larger over the ipsilateral hemisphere than over the contralateral hemisphere to the movement. Although the RP amplitude differences were slight, the present results nevertheless showed an ipsilateral preponderance of the RP quite consistently. The present results for foot and toe movements were consistent with those of Brunia<sup>8)</sup> (1980), Brunia<sup>7)</sup> and Vingerhoets (1980), Boschert<sup>6)</sup> et al. (1983) and Deecke<sup>11)</sup> et al. (1983). The RP amplitudes for finger movements were clearly larger over the contralateral hemisphere to the movement, as have been confirmed by<sup>3), 10), 12), 15), 16), 17), 21), 22)</sup> several studies. One might find surprising the RP distributed over the human scalp for foot and toe movements in the light of the general physiological conclusion that the cerebral motor cortex is preponderant over the hemisphere contralateral to a movement limb. In this study, we also confirmed that the laterality effect of the RP amplitudes was especially present over the precentral area.

It is considered that the project area of the lower limb is situated in the depth along the fissura longitudinalis and that of the hand area lies mainly buried within the central sulcus. Brunia<sup>5)</sup> and Vingerhoets (1981) reported that with the foot and toe movements, the dipole may be oriented in such a way that its activity is more easily recorded over the opposite hemisphere and that accordingly, the RP amplitudes over the right hemisphere would reflect activity in the left hemisphere. Deecke<sup>11)</sup> et al. (1983) also suggested that the RP for foot movement is situated under the midline close to the vertex, presumably in the depth of the interhemispherical fissure. Moreover, the MEG (Magenetoencephalographic) recordings by Deecke<sup>11)</sup> et al (1983) indicated a contralateral preponderance of the RP prior to foot movement. That is to say, the MEG recordings did not show the paradoxical EEG side preponderance with respect to the RP prior to foot movement. According to several<sup>6), 9), 11)</sup> studies, it is reported that there are two principal generators that are involved when we are preparing for a voluntary movement. One is probably the supplementary motor area (SMA) on the mesial of the surface of the hemispheres and the other is the rolandic motor cortex (MI) in accordance with the known somatotopic organization. In addition, it is presumed that these two generators may have contributed to the RP constitution. Recently, data<sup>6), 9), 11)</sup> from several experiments suggest that with finger movement, the SMA is active and both the SMA and the MI are active for foot and toe movements. Moreover, it is postu-

lated that the summation of the respective activities of the SMA and the MI is derived from the central area over the human scalp, as observed in animal<sup>1), 2), 14)</sup> experiments. Therefore, it may be concluded 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 temporal ordering of the principal generators which might contribute to the RP constitution. Moreover, we also confirmed that the RP amplitudes were significantly larger for foot and toe movements than for finger movements and the RP latencies were also longer for foot and toe movements than for finger movements, as has been reported by Boschert<sup>6)</sup> et al. (1983). Therefore, we also proposed that these findings may be attributed to the difference of temporal ordering of two principal generators which may have contributed to the RP constitution, because both the SMA and the MI are active prior to voluntary movement and the SMA activity precedes the activity of the MI, as also suggested by other<sup>6), 9), 11)</sup> studies.

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## 自発的な足，足趾，手指動作に先行する運動前脳電位

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**要 旨** 本論文において著者達は，随意的な手動作に先行して動作肢と反対側大脳半球上で優位を示す大脳準備電位（RP）が下肢や足指動作の場合も同じ分布を示すかということ，加算平均された EEG，EMG を用いて調べた。その結果，下肢や足指動作に先行して出現する大脳準備電位は動作肢と同側大脳半球上で優位を示す傾向にあったが，統計的には有意ではなかった。一般的に，下肢や足指の投射領域は大脳縦裂にそった深部にあり，手の領域は中心回の内部に埋もれていると考えられている。MEG（magnetoencephalographic）記録も下肢や足指動作に先行する大脳準備電位は動作肢と同側半球上で優位を示すことを確認している。それゆえ，本実験結果や今までの一連の研究から，手と下肢，足指動作間の大脳準備電位の頭皮上分布差は，大脳半球上での支配領域の差ではなく，大脳準備電位発生に関与していると推測されている二つの発生源の時間的な差によるものであると推察される。

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