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Evaluation of Upper Limb Motor Function by means of Tracking Motion on Reversal Element

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SUMMARY In order to evaluate motor function of upper limb in normal and pathological persons, we studied the manual tracking motion whose controlled object is reversal element. We suggest that proposing evaluation parameters reflect clinical symptoms of patients.

1. Introduction

As for manual control system, general control characteristics of normal subjects are widely studied with various methods(1). But there are a few reports about the clinical application.

Therefore, we studied manual tracking motion for the purpose of investigating motor function of upper limb in normal and pathological persons.

We performed experiments of manual tracking motion, and analyzed learning process with the following evaluation parameters, mean absolute error and proportion of patterns of motion which we proposed(2). Resulting from these experiments, learning process on reversal elements, which mean that output on the display is reversed by controlled objects(3), was more indicative for analysis in characteristics of the motion.

Then, we proposed the evaluation method by means of tracking motion on reversal element for the clinical application.

2. System and Experiment

The experimental system is composed of a 16 bit micro computer, a high resolution color display and a mouse which is a kind of a pointing device. The random reference input signal which varies smoothly is presented on the display as a circle, and the output of the actuator which is controlled by use of the mouse is shown as a cross. The moving speed of reference point is 64 dots/sec in the average. As for reversal elements, however, output on the display is reversed by controlled object. Horizontal reversal and vertical reversal mean that output is reversed in the horizontal direction and in the vertical direction, respectively.

The subject is instructed to pursue the reference point as accurately as possible by use of the mouse.

The experiment is performed on 10 trials on non-reversal, 10 trials on vertical reversal, 3 trials on non-reversal and 10 trials on horizontal reversal, namely 33 trials consecutively. The duration of each trial is 30 sec and the interval time between each trial is about 30 sec. We performed experiments on 10 normal subjects in their 20 s. And 7 patients with cerebellar ataxia were also examined.

As for the evaluation parameter, we have used the mean absolute error E_x, E_y and the proportion of patterns of the motion which are defined as follows:

$$E_x=\sum_{i=1}^{n}|r_x-c_y|/n\,(\text{dot})$$

$$E_y=\sum_{i=1}^{n}|r_x-c_y|/n\,(\text{dot})$$

As for D_x, D_y and R_x, R_y, at first, we calculated the velocities of reference input and controlled output, and divided them into three degree. '±' means that the absolute velocity is smaller than 40 dots/sec, '+' means that the velocity is larger than 40 dots/sec, and '−' means that the velocity is smaller than −40 dots/sec. Then, we compared two degrees of input and output on time base, and determined the proportion of delay motion D_x, D_y and the proportion of reversal motion R_x, R_y.

D_x, D_y(%) : Proportion of the motion where either degree is '±' and the other is '+' or '−'.

R_x, R_y(%) : Proportion of the motion where either degree is '+' and the other is '−'.

The proportion of patterns of the motion indicate not the largeness of the error immediately but the cause of it.

3. Results

Figure 1 shows transition of evaluation parameters of normal subjects. This figure indicates the following results:

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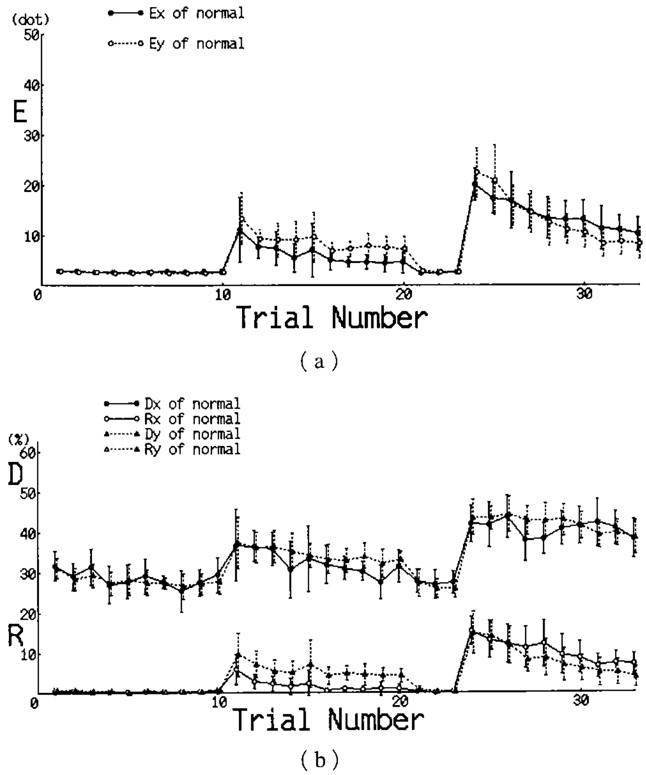

Fig. 1 Transition of parameters of normal subjects. (a) E_x, E_y, (b) D_x, D_y and R_x, R_y. Values indicate mean and standard deviation of 10 subjects.

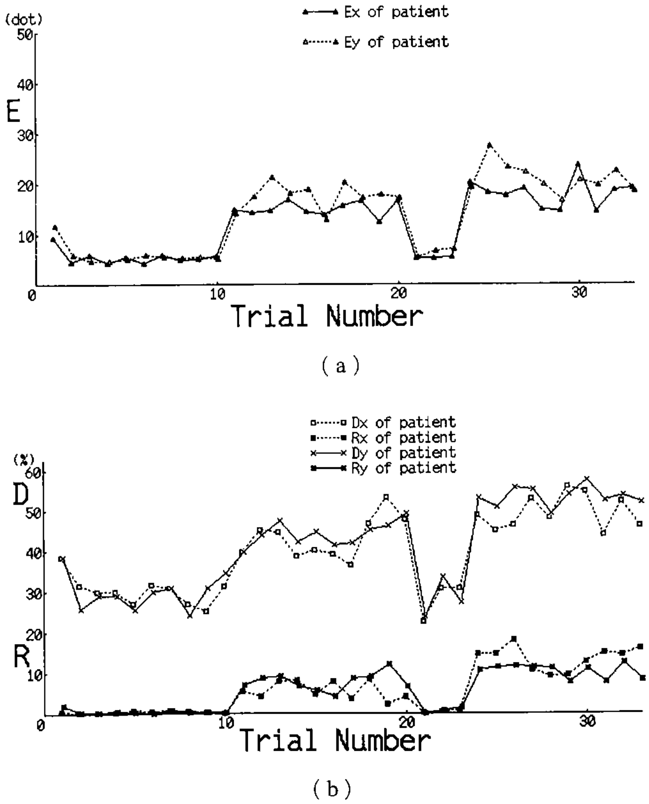

Fig. 2 Example of transition of parameters of mildly impaired group. (a) E_x, E_y, (b) D_x, D_y and R_x, R_y.

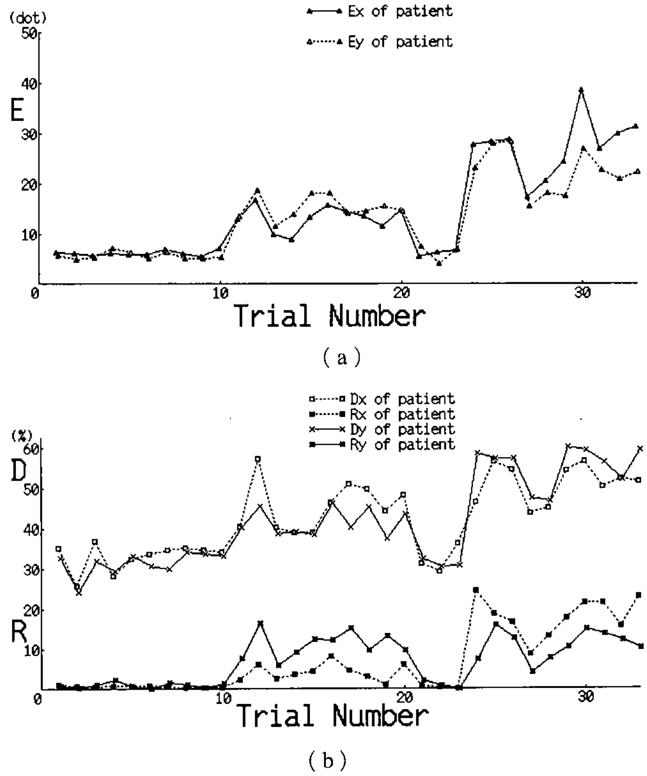

Fig. 3 Example of transition of parameters of moderately impaired group. (a) E_x, E_y, (b) D_x, D_y and R_x, R_y.

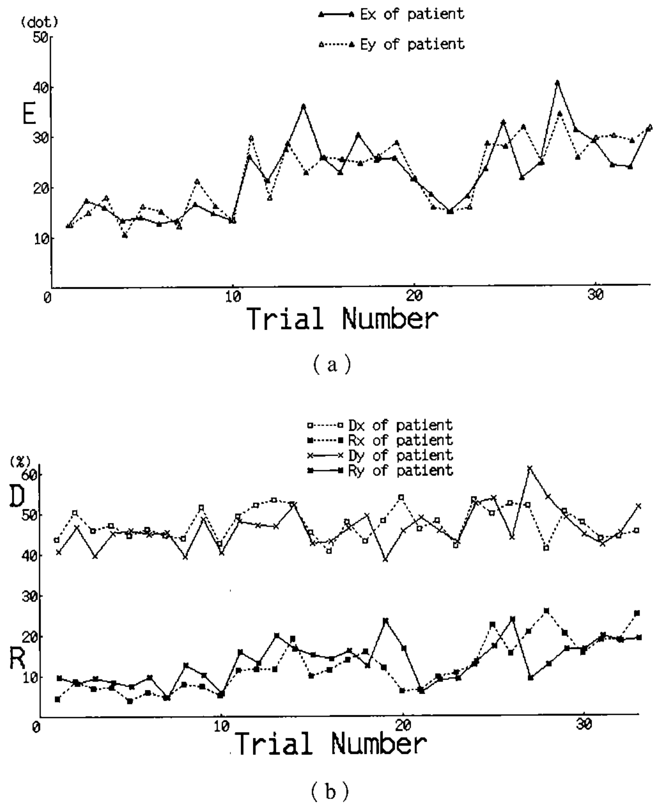

Fig. 4 Example of transition of parameters of severely impaired group. (a) E_x, E_y, (b) D_x, D_y and R_x, R_y.

(1) Difference between non-reversal and reversal elements was recognized definitely as for each parameter.
(2) Learning effect was observed on reversal elements.
(3) Values of each parameter on horizontal reversal were larger than those on vertical reversal.
(4) As for E and R of the first and the second trials on horizontal reversal, values of parameters in non-reversal direction were larger than those of reversal direction.

According to the results of patients with cerebellar ataxia, patients can be classified into three groups; mildly impaired, moderately impaired and severely impaired symptoms. Figures 2–4 show the examples of transition of parameters of each group.

Table 1 Mean and standard deviation of parameters on each 10 trials of normal subjects and patients A-G. (a) E_x, E_y, (b) D_x, D_y, and (c) R_x, R_y.

(a)

	Non-Reversal		Vertical Reversal		Horizontal Reversal	
	E_x	E_y	E_x	E_y	E_x	E_y
Normal	2.7±0.0	2.5±0.0	6.2±0.7	8.6±0.6	14.1±1.0	13.3±1.7
A	5.5±0.5	5.8±0.7	15.0±0.5	17.5±0.9	18.0±1.0	20.9±1.0
B	4.9±0.1	5.2±0.2	9.7±0.4	18.0±1.1	31.1±1.1	17.9±0.4
C	6.1±0.2	5.5±0.2	13.1±0.8	15.1±0.8	27.2±1.9	22.2±1.5
D	5.9±0.7	5.0±0.3	10.0±0.7	17.6±1.1	30.1±3.3	19.9±1.8
E	4.6±0.7	4.6±0.6	12.4±1.5	14.2±1.7	28.5±2.4	27.6±2.0
F	13.3±1.0	11.4±0.9	23.2±2.1	18.8±2.6	19.1±1.3	20.0±1.1
G	14.2±0.6	14.8±1.0	25.9±1.5	24.9±1.2	27.9±2.0	29.0±1.0

(b)

	Non-Reversal		Vertical Reversal		Horizontal Reversal	
	D_x	D_y	D_x	D_y	D_x	D_y
Normal	28.4±0.7	27.9±0.5	32.3±1.0	34.3±0.6	40.5±0.6	41.6±0.7
A	30.1±1.2	29.7±1.4	43.2±1.7	44.3±1.0	49.3±1.4	53.2±0.8
B	34.5±0.9	32.2±0.7	41.1±1.3	40.5±0.9	41.0±1.0	52.2±1.2
C	32.9±1.2	31.1±1.0	45.4±2.0	41.3±1.1	50.9±1.5	55.1±1.6
D	33.8±1.1	32.8±0.8	38.1±1.0	38.1±1.0	47.9±1.5	51.2±1.8
E	37.2±1.9	38.5±1.7	44.2±1.6	39.6±0.5	44.0±1.2	54.2±2.0
F	45.6±1.3	44.6±1.0	50.5±2.2	47.2±2.0	48.4±1.7	45.6±1.0
G	46.0±1.0	43.5±1.1	48.5±1.5	45.9±1.3	47.9±1.4	49.6±1.9

(c)

	Non-Reversal		Vertical Reversal		Horizontal Reversal	
	R_x	R_y	R_x	R_y	R_x	R_y
Normal	0.3±0.0	0.4±0.1	1.9±0.5	5.6±0.6	10.2±1.0	8.3±1.3
A	0.4±0.1	0.4±0.2	5.5±0.7	7.7±0.8	13.3±1.0	10.2±0.6
B	0.8±0.2	1.4±0.2	6.5±0.8	13.6±1.2	25.9±1.1	12.8±1.1
C	0.6±0.1	0.9±0.2	4.1±0.7	11.0±1.1	17.9±1.6	10.7±1.2
D	1.3±0.5	1.0±0.4	3.4±0.5	7.3±1.3	17.2±1.2	13.2±1.4
E	1.9±0.5	3.8±0.9	3.8±0.9	14.6±1.6	21.3±1.5	9.2±1.7
F	5.6±0.9	4.5±0.5	9.3±1.1	12.5±0.8	12.6±1.9	14.8±1.2
G	6.1±0.5	8.4±0.8	12.1±1.2	16.2±1.1	19.3±1.4	16.4±1.4

These figures indicate the following results:

The mildly impaired group;
(1) Difference between non-reversal and reversal elements was recognized definitely as for each parameter.
(2) Difference between values of each parameter in non-reversal direction and reversal direction was recognized.

The moderately impaired group;
(3) Learning effect was hardly observed.
(4) Reversal motion on non-reversal element was sometimes recognized.

The severely impaired group;
(5) Difference between non-reversal and reversal elements was hardly recognized as for each parameter.
(6) Difference between values of each parameter in non-reversal direction and reversal direction was hardly recognized.

As it was difficult to evaluate the motion quantitatively by only the graphic presentation, we calculated mean and standard deviation of evaluation parameters of 10 normal subjects and 7 patients. They are shown in Table 1. Patient A and B are in mildly impaired group, C, D and E in moderately impaired group, F and G in severely impaired group.

4. Discussion

According to these results, the following are supposed:
(1) As for normal subjects, values of each parameter on horizontal reversal were larger than those on vertical reversal, which implies the affection by learning from the former performance on reversal element.
(2) Characteristics of mildly impaired group is like that of normal subjects except for learning effect.
(3) The result that learning effect was hardly recognized in moderately impaired group may be explained by the fact that the cerebellum is concerned with learning of motor control.
(4) Severely impaired group may hardly control even on non-reversal element.

As the discussion mentioned above can be proved by proportion of delay motion and reversal motion, we conclude that supposing parameters are effective for evaluation of the motion.

5. Conclusion

We performed experiments of the tracking motion on reversal elements in order to investigate motor function of upper limb in normal and pathological persons, and analyzed characteristics of the motion with the evaluation parameters, mean absolute error and proportion of patterns of the motion.

These results obtained from patients with cerebellar ataxia manifest the clinical symptoms and we can explain the difference of the symptoms by transition of evaluation parameters.

We suppose that this evaluation method can be useful for other neurologically disordered cases. Then, we can point out the high probability for the clinical application.

However, because patients loose their interests easily, we should examine practical method with 15 trials or so for clinical use. And we will investigate more cases of cerebellar ataxia and other disorders in order to indicate the difference between them, with reference to the aging problem.

Acknowledgement

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References

(1) Iguchi M.: "Ningen-kikai kei", pp. 1-13, Kyouritsu-shuppan (1970).
(2) Kobori S.: "Learning Process of the Tracking Motion on Reversal Element", The Japanese Journal of Ergonomics, 26, Supplement, pp. 122-123 (1990).
(3) Yoshizawa M., Nisaka H., Takeda H., Ohtomo H., Kounosu T., Sato G. and Osaka K.: "Anisotropy of the Human Operator's Control Characteristics and the Brain Bilaterality", Japanese Journal of Medical Electronics and Biological Engineering, **26**, 4, pp. 187-195 (1988).