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SPECIFICITY OF BILATERAL TRANSFER EFFECT IN MIRROR DRAWING

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The effect of the combination differences among limbs upon bilateral transfer in mirror drawing task was investigated for 70 undergraduate students divided into 14 groups, consisting of 10 experimental and 4 control groups, each of which contains 5 subjects. Analysis of interlimb transfer showed that the most significant effect was found in the group of the experimental design from foot to foot. In addition, there were the bilateral transfer effects also in other hand-foot combinations. Then, these effects were generally seen in the designs from hand to foot, whereas there was little effect in the reverse ones: the different combinations among limbs produced different effects of transfer.

From the results of the tracing time analysis per each side of star-shaped figure, it was inferred that the magnitude of transfer effect would be related to the shortening of time on the sides showing a tendency to a relatively marked decrease in the course of trial blocks. On the other hand, the transfer effect to another foot, though the effect of training in one performing foot was lower than that in hand, was largest in all experimental combinations among limbs. Therefore, it was suggested that the magnitude of the transfer effect would not only depend upon the acquisition of specific responses, but also upon the learning of general principles independent of the muscles concerned.

The bilateral transfer known as the phenomenon that the training with one-sided effector of the body affects the performance with the other had long attracted psychologists' attention as supporting the formal discipline before. In the middle of the 19th century, the presence of transfer effect was already noticed in the study of a tactile discrimination. That is, in an investigation on the two-point limen, Volkmann found that (a) sensitivity increased after repeated exercise on the same cutaneous surface; (b) there was a comparable increase in sensitivity on the corresponding surface area of the other arm; (c) this transfer was temporary and very localized

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(Oléron, 1970). Further, the bilateral transfer has also been studied by observing the changes through training of peripheral muscle activities. A positive transfer effect from one hand to the other was usually found out. Bray (1928) noticed that the transfer might occur also from hand to foot, and pointed out that in the experiment of mirror aiming in which experimenter had subject hit at a target with a pencil held in the hand or strapped to the foot, there was substantial transfer effect from hand to foot, especially the right hand to the right foot, in addition to the effect from hand to hand. In Cook's extensive study on bilateral transfer effects among hands and feet (1933a, 1933b), it was suggested that transfer from one performing member to another was greatest to the symmetrical muscle group on the opposite side of the body, next to the muscle group on the same side, and least in the case of the diagonal members.

In the early stage of the 20th century, the presence of bilateral transfer has been substantiated in such a manner. However, further analytical investigations were needed to elucidate more thoroughly the mechanism of bilateral transfer. Although the researches concerning transfer effect between hand and foot have also stimulated a great interest in connection with neural organization of the brain, they do not appear to have obtained sufficient informations about the neural mechanisms of bilateral transfer. Recently the neurological data from split-brain preparations showed the important role of the corpus callosum in interhemispheric visual-motor integration (Gazzaniga, 1970).

In the stage where functional differentiations have fully developed between the right and left sides of the body, it is supposed that performance characteristics between hand and foot would be different in a large degree from each other. And so it is difficult to expect simply that significant transfer effect will positively occur in all of limbs. Sato (1956) indicated that in the mirror drawing with hand, a nondominant hand little used in everyday life showed often higher performance scores than a dominant one because the nondominant hand was not relatively influenced by interference like associative inhibition, and suggested that the differences among performance characteristics of limbs related to handedness would play an important role in the transfer of mirror drawing.

The purpose of the present study was to investigate how the differences of combinations among limbs had various effects on bilateral transfer. At the same time, we tried out to obtain further informations about the effect of bilateral transfer, especially that between hand and foot.

Method

Subjects: The subjects were 70 undergraduate students including 21 females who had become used to writing letters with the right hand. Almost all of them were inexperienced in the experiment of this kind. As indicated in Table 1, they were divided into 14 groups, consisting of 10 experimental and 4 control groups, each of which

Table 1 Design of mirror drawing experiment

Experimental group	Control group
A. RH-RF-RH[1]	K. RH-RH
B. LH-RF-LH	L. LH-LH
C. RH-LF-RH	M. RF-RF
D. LH-LF-LH	N. LF-LF
E. RF-RH-RF	
F. LF-RH-LF	[1] RH: Right Hand
G. RF-LH-RF	LH: Left Hand
H. LF-LH-LF	RF: Right Foot
I. LF-RF-LF	LF: Left Foot
J. RF-LF-RF	

contained 5 subjects.

Task figures and Apparatus: The figures used as the mirror drawing task were a six-pointed star in shape, with 12 sides and angles symmetric with respect to right and left, up and down. These were composed of 60 small circles 4, 8 mm in diameter and 25, 50 mm in length on a side for tracing by hand and foot respectively. These star figures that had often been used so far, were this time utilized for convenience of comparison of the data obtained.

A mirror drawing device and two sandals enabling subjects to trace with either foot were made as a trial in addition to a drawing apparatus for hand. The former, assembled with angle irons, was a platform-type device 40 cm wide, 56 cm long, 8 cm high, with a mirror 40 cm by 70 cm and an adjustable screen for concealing the task figure from the subject. To lucite sandals 5 mm thick cut out roughly according to the shape of the right and left foot, were fastened three casters with bolts on their soles. The sandals are held securely to the feet by strap and adjustable aluminum cleats are fastened on both sides and to the rear of each sandal, with a cylindrical metal fittings fixing a ball pen used in tracing with the foot, attached in the front.

Procedure: The starting point for tracing was the same as the finishing one and nearest from the subject; i.e. farthest from mirror. The subject was instructed to trace the star figure clockwise as fast as possible. At the beginning of each trial, the subject's hand or foot was guided to the starting point. One trial was to go round the course from the starting to the finishing point. The tracing time and error scores were calculated per each side and trial. In order to obtain these scores, the experimenter recorded a mark on magnetic tape every time the pen moved by the subject passed through the transition point from one side to the adjacent. On reproducing, the tracing time of each side was measured by means of TKK Digitimers.

Intertrial interval was about 30 sec. The subject was given two tracings of pre-test and 3 min rest, and then followed by 10 practice tracings. After the termination of these tracings and another 3 min. rest, the subject was required to do two more tracings of post-test. The procedure of the control groups was also the same as the experimental groups except that the practice tracings and two 3 min. rests before and after them were replaced by 15 min. rest.

Data Reduction: Two sorts of scores were calculated from the tracing time and number of errors. Both scores, though different in the way of counting errors, can be obtained from the same formula as follows:

$$\text{Score} = \frac{\text{60–number of errors}}{\text{time in sec.}} \times 60.$$

These scores are shown as A type and B type score: A type takes error for the small circle without tracing and B type for the case of getting away from the course. Thus A type score expresses the number of the small circles traced for a minute. B type score, on the other hand, represents "tracing accuracy" for a minute, if we consider that the small circles making up the star diagram construct 60 blocks; and this score has the possibility indicative of negative value.

Results

Effect of bilateral transfer: In the present study, the transfer effect was calculated from the mean difference scores between pre-test and post-test, since two groups, as Tsuji and Ide (1974) pointed out, were not completely matched in the prestage. The transfer effect, as indicated in Table 2, was greatest between right and left foot, next in three groups, G, E, F of combinations from hand to foot except H group, and least in the groups from foot to hand except A group in B type scoring. Both scorings of A and B type produced substantially the same results in regard to transfer effect.

Further, the transfer percentage was calculated from the following formula presented by Tsuji and Ide (1974), by taking both scores in the pre- and post-test into consideration,

$$T = \left(\frac{E_0 - Er}{C_0 - Cr} - 1\right) \times 100,$$

Table 2. Order of magnitude of transfer effect based on P values as for two types of scoring, A and B

Order	A score						Order	B Score					
		Exp. G.	$t(t')$	df	P	% Trans.			Exp. G.	$t(t')$	df	P	% Trans.
1	I	LF-RF-LF	3.876	18	.01	150.24	1	I	LF-RF-LF	3.990	18	.001	205.79
2	J	RF-LF-RF	3.700	18	.02	342.63	2	G	RF-LH-RF	3.843	18	.01	177.95
3	G	RF-LH-RF	2.842	9	.02	149.89	3	F	LF-RH-LF	3.036	18	.01	165.65
4	E	RF-RH-RF	2.296	9	.05	126.81	4	J	RF-LF-RF	3.213	9	.02	313.27
5	F	LF-RH-LF	2.211	18	.05	59.06	5	A	RH-RF-RH	2.282	18	.05	65.31
6	A	RH-RF-RH	1.719	18	n.s.	48.25	6	E	RF-RH-RF	2.190	18	.05	93.78
7	D	LH-LF-LH	1.386	18	n.s.	42.43	7	D	LH-LF-LH	1.536	18	n.s.	41.05
8	H	LF-LH-LF	.954	18	n.s.	30.31	8	H	LF-LH-LF	1.507	18	n.s.	61.78
9	C	RH-LF-RH	.454	18	n.s.	10.68	9	B	LH-RF-LH	.944	18	n.s.	32.48
10	B	LH-RF-LH	.326	18	n.s.	11.98	10	C	RH-LF-RH	.857	18	n.s.	13.08

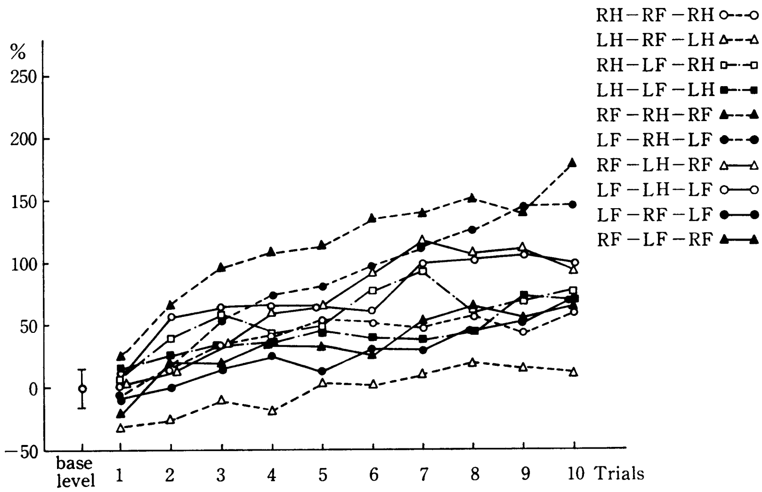

Fig. 1a. Percentage changes of A score, plotted from the mean scores of the first practic trials as base level

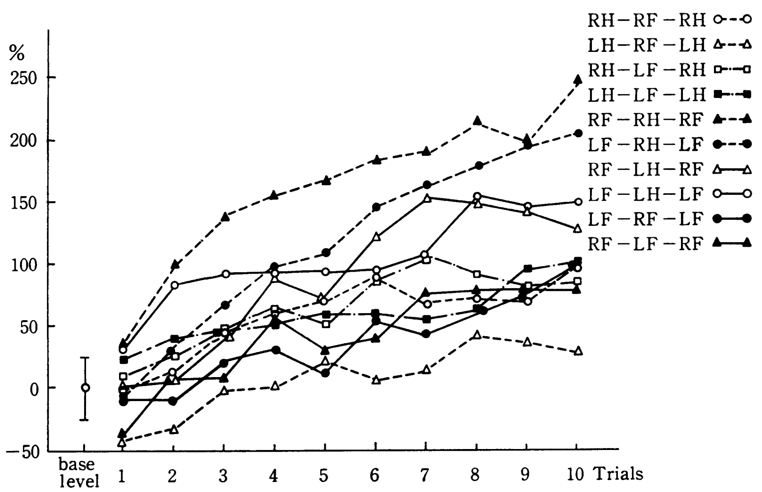

Fig. 1b. Percentage changes of B score, plotted from the mean scores of the first practice trials as base level

where Er, Eo are the mean scores in the pre- and post-test, respectively for the experimental group, and Cr, Co for the control group. The order of decreasing the transfer percentage was much the same as that of P values calculated by t and t' tests; i.e. two groups with the experimental design from foot to foot, as seen in Table 2, showed greater percentages of transfer than any other group. The results of t tests were not always identical to those of transfer percentages; though t value of I group, for example, was greater than that of J group, the results of transfer percentages was inverse.

Percentage changes of two types of scoring in practice trials: Figs. 1a and 1b show the percent changes plotted from the mean scores of the first practice trials as base levels. It seems that the percentage scores can be divided into three groups, since these scores after fourth trial were highest in right hand, next in left hand, and the scores on either foot were lower in any experimental combination than those of hand in both Figs. 1a and 1b. The scores in B type tended to become higher at the second half of practice trials than A type, corresponding to the larger decrease of errors in many subjects in B type. However, this is true only for the scores of hands. The scores on feet gave rise to much the same results in both scorings of A and B type. It may be said, in this respect, that the foot performance differs to some degree from the hand one.

The above-mentioned results showed that in the case of the hand with the higher scores or percentages in practice, the transfer effects to foot were rather smaller than those in the case of practice trials by foot, and that the scores of practice exercises by foot, while lower than by hand, produced the more facilitating effect on bilateral transfer.

Further, though the positive transfer effect was gained from hand to foot, the effect from foot to hand was not always positive, but rather negative. These results appear to suggest, therefore, that the performance characteristics of hands and feet are different to some degree from each other. In order to elucidate this point, we attempted mainly to investigate the performance curves in practice trials.

Changes of performance curves in practice exercises: Although it has already been made clear that tracing time and errors would decrease gradually with continued trials, little information has so far been provided about their changes per each side. We tried out to investigate the characteristics of limb performance qualitatively, grasping finer changes in time measure per each side. Figs. 2a to 2d show the mean changes of time in sec per each side as a function of 5 trial blocks, each block of which consists of two trials. Fig. 2a shows the case of left hand in practice, and Figs. 2b to 2d show the cases of right hand, left foot, and right foot respectively. The time required on each side varied with the sides of star diagram. There was the trend of gradual decreases in mean time with relative clarity when higher scores were recognized till the second block at the first half of practice. In addition, it was noticed that the pattern of the curves in right hand was similar to that in right foot, and the pattern in left hand to that in left foot; i.e. the performances by hand and foot on the same side had a resemblance to each other. The pre-post differences were relatively small on the sides vertical to mirror such as sides 3, 4 and 9, 10, and the differences in mean scores among the sides of star diagram at the post stage too were small as compared with those of the pre-stage.

Similarity between performance curves in pre- and post-stage: The pre-post similarity of performance curves was examined using the Spearman rank correlation coefficients (r_s). This coefficient was used because of relatively large standard deviation values of scores. In Table 3, higher r_s values were found out in the groups, H, C, D. These were, as indicated in Table 2, groups not indicative of significant transfer

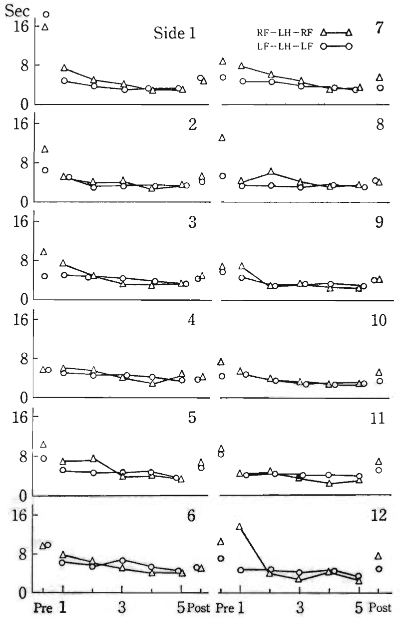

Fig. 2a

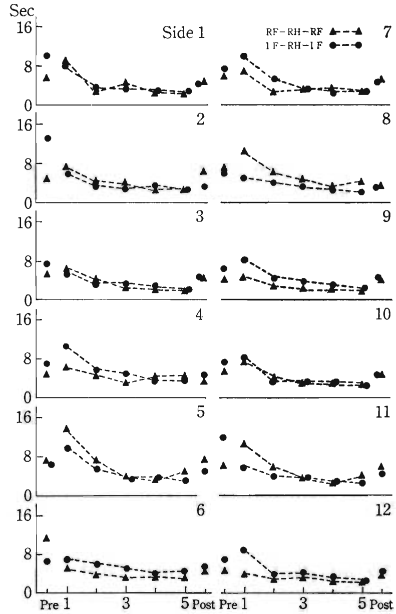

Fig. 2b

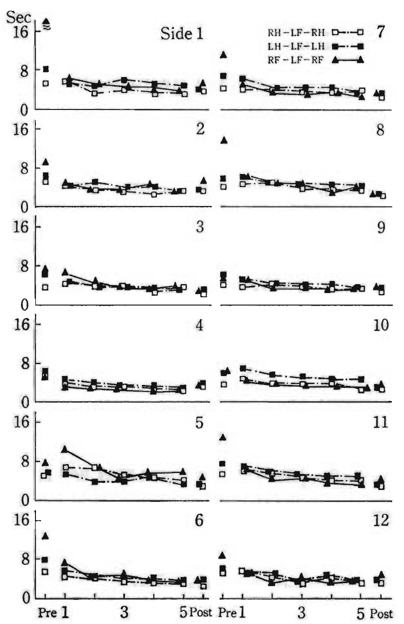

Fig. 2c

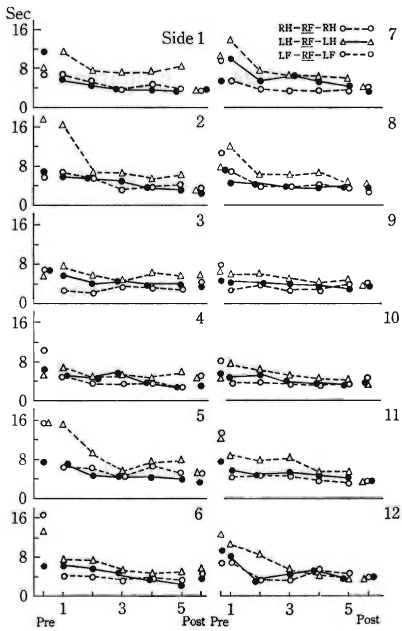

Fig. 2d

Fig. 2. Mean changes of tracing time in each of 12 sides of star diagram. Fig. 2a to 2d are the cases of left hand, right hand, left foot and right foot in practice respectively.

Table 3 Rank correlation between pre-post performance curves

Order	Exp. G		r_s
1	H	LF-LH-LF	.775
2	C	RH-LF-RH	.573
3	D	LH-LF-LH	.552
4	A	RH-RF-RH	.451
5	E	RF-RH-RF	.384
6	G	RF-LH-RF	.293
7	F	LF-RH-LF	−.265
8	J	RF-LF-RF	.167
9	I	LF-RF-LF	.098
10	B	LH-RF-LH	.083

effects. Therefore, these results suggest that the groups with the higher pre-post correlation coefficients might show non-significant transfer effects, with the exception of the B group with the lowest r_s value and transfer effect.

Similarity among practice performance curves in time and error score: In the experiment of this kind, it seems that measure should be used with combined measure of time and error because their values are well known to decrease as a function of trials. However, it is questionable whether both measures are equivalent to each other on any side. Thus, as a means for discussing the issue about such measures, we tried to examine the relationship among the performance curves described by the mean scores in time and error during practice exercises. Now, Spearman rank correlation coefficients were obtained since it was considered that this aspect of data processing could also help to make the performance characteristics on hand and foot clearer.

Table 4 shows rank correlation coefficients between practice performance curves in mean time scores. It is found from this table that the correlations between performance curves by foot, as indicated in the highest correlation between 1 and 2,

Table 4 Rank correlation coefficients (r_s) practice performance curves in time

		A	B	C	D	E	F	G	H	I	J
A	RH-RF-RH		.832**	.640*	.266	.511	0	.448	.175	.469	.622*
B	LH-RF-LH			.504	.287	.518	−.203	.322	.105	.511	.581
C	RH-LF-RH				.685*	.420	−.056	.224	.119	.203	.720*
D	LH-LF-LH					.287	−.196	−.189	−.350	0	.385
E	RF-RH-RF						−.070	−.021	.147	.154	.385
F	LF-RH-LF							.546	.560	.322	−.217
G	RF-LH-RF								.748*	.476	.252
H	LF-LH-LF									.315	.287
I	LF-RF-LF										−.118
J	RF-LF-RF										

*$p<.05$, ** $p<.01$

Table 5 Rank correlation coefficients (r_s) practice performance curves in error

		A	B	C	D	E	F	G	H	I	J
A	RH-RF-RH		.182	.329	.336	.738*	−.259	.280	.385	.322	.175
B	LH-RF-LH			.077	.371	.332	−.371	−.077	.434	.357	.657*
C	RH-LF-RH				.196	.486	.308	.518	.762*	.671*	.532
D	LH-LF-LH					.738*	−.280	.119	.262	.664*	.301
E	RF-RH-RF						−.011	.395	.633*	.717*	.500
F	LF-RH-LF							−.154	.287	.168	.280
G	RF-LH-RF								.329	.189	.161
H	LF-LH-LF									.259	.797**
I	LF-RF-LF										.525
J	RF-LF-RF										

* $p<.05$, ** $p<.01$.

that is, two RF curves, are high as compared with those by hand. The correlations between right hands were markedly low. This appears to demonstrate that the responses peculiar to the particular side are rarely made in hand-writing performance. Table 5 is the correlation coefficients in case of counting errors in B type scoring. Hereupon, a similarity to the result of Table 4 was also shown in that the rank correlations were relatively high between performance curves by foot. However, the correlation was not so high between both measures of time and error (r_s=.39). These results appear to indicate that it would be better to use combined measure of time and error in the study of this kind since these measures often utilized as learning ones are not highly correlated.

Discussion

In this experiment, we attempted to investigate the drawing performance accuracy qualitatively, calculating the score based on the tracing time and error in the task figure divided into 60 small circles. The significant transfer effects were shown in some hand-foot combinations. Among them, the most significant effect was found in the group of the experimental design from foot exercise in practice to foot in post-test. Although there were bilateral transfer effects in some hand-foot combinations, some degree of directivity was recognized: the transfer effects were generally seen in the designs from hand to foot, whereas there were little effects in the reverse designs. Cook (1933a, 1933b) indicated that the percentage of transfer was higher between the muscle groups on the same side than between diagonal members. Yet, the agreement of our result with Cook's was only in the case of the diagonal combination from foot to hand, while that from hand to foot showed a superiority over the ipsilateral combinations. Further, from the data concerning the similarity between pre-post curves, it was proved that significant bilateral transfer effects were seen in the lower groups in correlation value. This means probably that the performance pattern shown in pre-session was reproduced also in post-session, and so this may be considered to be one proof indicative of the absence of transfer effect.

Then, these transfer effects, on the characteristics of experimental design, may have a close relationship with practice exercises. A detailed analysis had rarely been attempted per each side of star-shaped figure before. It was revealed, from a qualitative analysis of the practice curves, that on any side the tracing time generally tended to decreases gradually with continued trials, but that the side conspicuous in gradual decrement was relatively specific. This fact demonstrates that the magnitude of transfer effect will be related to the shortening of time in the side mentioned above, and its effect is not produced equally on any side. In mirror drawing, the mirror reverses its forward and backward direction while leaving its right and left unchanged. A right-left line calls for the usual eye-limb coordination. Although a front-back line must be reversed in the drawing, the tracing of such line was fairly easy in the present experiment. In an oblique line, a spacial orientation between mirror and tracer will become more difficult than that in such simple forward-backward and right-left directions. The tendency of gradual decrease in time with continued trials was particularly marked on the oblique sides. It may be inferred, therefore, that the magnitude of the transfer effect is related to the learning of some responses on such sides with relative specificity. However, in some aspects we can not generalize that the transfer effect will depend only upon the learning of some specific responses. Although the effect of training in practice was increasing in the order of right hand, left hand and feet, the transfer effect was not always larger in the condition of hand in practice than in that of foot. The transfer effect to another foot, though the effect of training in one performing foot was lower than that in hand, was largest in all combinations of limbs. This suggests that the magnitude of the transfer effect will not only depend upon the acquisition of specific responses, but also upon the learning of general principles or the learning to learn, independent of the muscles concerned. Mitani's assertion (1971) that the essence of the bilateral transfer is expected to lie between two views of centralism and peripheralism, agrees with our findings.

How the transfer of learning to learn takes part in the mechanism of bilateral transfer is not so clear. Therefore, further study is needed to specify this respect. It has often been said so far that it is probably important in transfer to get used to the setting of the experiment (for instance, Bray (1928)). It does not seem, however, that habituation to the experimental situation is a primary factor in transfer, considering the fact that the different combinations of limbs produce the different effects of transfer. As was pointed out by Woodworth & Schlosberg (1954), factors of a more physiological sort will demand earnest consideration as to why transfer is greatest in one combination of limbs and least in another. It will be reasonable to infer that the operating mechanism in bilateral transfer is found in part among the different cerebral loci of function, from the fact that the right side of the body is connected with the left hemisphere, and the left with the right. Milner (1965) revealed that the acquisition of some motor skills such as mirror drawing would be independent of the hippocampal system. Further, Glickstein & Sperry (1960) and Gazzaniga (1970) suggest that in the studies of interhemispheric eye-hand combination the weak ipsilateral route may be used under particular task situation. These researches have not arrived at their completion capable of identifying the loci participating in bilateral transfer. It seems there is some combination difference among limbs in the strength of functional connections of hand and foot within sensory-motor control system. Thus, still more information about such behavioral difference will serve to clarify neural mechanism of transfer.

As regards the measures in mirror drawing, Kawai (1969) pointed out that the tracing time and error would express the different sorts of psychological aspects. In our study too, it was suggested that both measures did not always show a high correlation. These measures often have so far been used separately, but it seems to be more adequate for this kind of experiment to utilize a score with both measures combined.

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