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ORIENTATION OF CONTROLS IN BILATERAL TRANSFER OF TRAINING

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ABSTRACT

This study was conducted to determine the relative effectiveness of a mirror arrangement of controls versus a place arrangement of controls in a task involving bilateral transfer of training. Comparisons between the two arrangements were made on the basis of response latency, errors, subject-expectancy, and subject-preference.

Results indicate performance is more efficient with the mirror arrangement, that subjects expect a mirror arrangement over a place arrangement by approximately a two to one ratio. It was further found that sex differences do not significantly influence these results.

PUBLICATION REVIEW

The report has been reviewed and is approved.

FOR THE COMMANDER:

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INTRODUCTION

In the operation of a great many modern machines the operator is required to perform functionally similar tasks, either separately or simultaneously, with each of his hands. Examples can be found in the home,in industry, in commerce, and in combat equipment of the military services. In most such examples, where the tasks for either hand are complex enough to require more than one control, a problem exists as to the proper spatial orientation of these controls. Perhaps the most illustrrative example of such a situation can be found in the ordinary kitchen stove which has burners on the left and burners on the right with corresponding left and right controls for these burners. Characteristically the controls are aligned horizontally across the upper portion of the front vertical surface of the stove. Now suppose the back burner on the left is operated by the leftmost (outside) control on the left. Which, then, of the righthand controls, the leftmost or the outside (rightmost), should be made to operate the back burner of the right. It is predicted that opinion would be about equally divided between favoring the two leftmost controls in one case and favoring the two outside controls in the other case. Indeed, stove manufacturers have adopted no consistent solution to this problem and have continued to produce models differing in their control-burner relationships on quite an arbitrary basis.

The control-burner problem of the kitchen stove can be solved without adopting either of the two opposing relationships by having the controls on each side oriented one above the other with the upper controls operating the back burners and with the lower controls operating the front burners. In this solution the spatial orientation of the "functions" to be controlled conveniently suggest a corresponding and natural orientation of the controls. In many engineering situations, however, no such solution is possible, and the equipment designer is forced to adopt one of the two opposing control-function relationships previously discussed. To illustrate this situation, the example of a multi-engine aircraft cockpit arrangement can be used. The controls are customarily arranged so that the pilot in the left seat operates the aileron and elevator control (wheel) with his left hand and operates several engine controls with his right hand, while the pilot in the right seat operates the wheel with his right hand and the engine controls with his left hand. In a few models the left-seat pilot operates the wheel with his right hand and the engine controls with his left hand while the right-seat pilot has the reverse arrangement. In both these arrangements the problem is the same: what is the proper spatial orientation of the respective sets of engine controls assuming that a given pilot flies in the left seat one time and in the right seat another time? Each time he changes seats he also exchanges the functions to be controlled by either hand. Thus, in one seat he operates the several engine controls with the right hand. If in the left seat he becomes accustomed to locating a given engine control on the left side of the pedestal and nearest to his body, where then will he expect to find the duplicate control when he has changed seats, and, as a consequence, must operate engine controls with the opposite hand? Will he expect to find it on the left side of the pedestal (it was on the left side of the pedestal before) or on the right side of the pedestal next to his body (it was also next to his body before)? In other words, which is the predominant cue for locating that control - its place with respect to the pedestal or its place with respect to the pilot? If the control is not where he expects it to be, he will, in most cases, recognize the fact and locate it elsewhere with loss of nothing but a few seconds of time. If, however, he unknowingly operates the wrong control, the possible outcome, in terms of safety of the aircraft and its occupants, can be extremely hazardous.

That such control errors do occur is shown in a report by Fitts and Jones (4). Out of a total of 460 errors made by pilots in operating cockpit controls, 229 (one short of 50%) were "errors of substitution" in which an incorrect control was operated in place of a desired control. Of these substitution errors, 87 (more than one-third) were made in the operation of engine controls located on the control pedestal. These errors were reported by pilots "who lived to tell about it" and covered a wide range in the seriousness of their consequences. That more serious consequences have resulted from such errors is highly probable, though the exact frequency can only be a matter of speculation.

If the questions posed in the foregoing discussion regarding bilaterally symmetrical versus bilaterally asymmetrical control orientation were answered by pertinent research, the logical finding would be a population stereotype favoring one or the other of the two possible orientations. This knowledge could then be utilized in the design of aircraft cockpits wherein control orientation is compatible with the established population stereotype. A significant reduction in the number of "substitution" errors made, and a corresponding increase in the safety of operation, should follow such a program. This is a generalization applying not only to aircraft engineering, but equally well, though perhaps with less practical significance, to the design of other machines or equipment which require bilateral control of duplicate functions.

Past research related to this problem is scanty and no answers are to be found to the specific questions posed in the preceding discussion. That significant positive transfer effects result when a task that has been learned with one hand is practiced with the opposite hand is generally recognized. Woodworth (7), McGeoch (5) and others cite evidence supporting this generalization.[1] However, none of the experiments reported by these authors was designed to gather evidence on the relative efficiency of transfer to a symmetrically oriented (mirror image) task versus transfer to a task in which the essential control elements retain their original left-right relationships. These two possible bilateral orientations are illustrated schematically as follows:

(1) 1234 --------4321 (2) 1234 --------1234

Diagram No. 1 shows a mirror orientation which shall henceforth be referred to as the "mirror arrangement." Diagram No. 2 shows the alternative orientation which shall henceforth be referred to as the "place arrangement."

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[1] A review of the related research prior to 1928 is presented in an article by Bray (1).

PURPOSE

This investigation was designed to provide data on the relative efficiency of bilateral transfer of training under two experimental conditions:

1. A perceptual motor task involving operation of several controls oriented bilaterally according to a mirror arrangement is learned with one hand, then practiced with the opposite hand.
2. Same as condition No. 1 except that the controls are oriented bilaterally according to a place arrangement.

Answers were sought to a number of questions as follows:

1. Which arrangement is optimal as measured by speed of response in the final task?
2. Which arrangement is optimal as determined by the number of errors in the final task?
3. Which arrangement is optimal as determined by preferences of subjects?
4. What is the relationship between subjects' preferences and the condition under which they performed?
5. What arrangement expectancies do subjects have immediately prior to practicing the final task?
6. Does the changing of hands result in a significant decrement in performance with either arrangement?
7. Are there significant sex differences operating with respect to any of the preceding determinations?

SUBJECTS

The subjects used in this experiment were 64 (32 male and 32 female) undergraduate college students all of whom at the time were taking a course in introductory psychology. A requirement of the course was that students serve a minimum number of hours as subjects in psychological experiments. Since the data of this experiment were collected during the first third of the academic quarter it may be concluded that all subjects were alike with respect to their eagerness to "volunteer."

The subjects were assigned to four groups at random except for the following restrictions:

1. 8 males and 8 females were in each group.
2. Left-handed subjects were, to the extent possible, equally divided among the four groups.

The latter restriction on randomness was imposed because Ewert (3) showed that transfer (in a mirror drawing task) is greater from the preferred to the non-preferred hand than in the opposite direction.

The four groupings were in accordance with the four ways in which subjects were to accomplish the task set for them. Group 1 subjects trained with the left hand and then practiced with the right hand on the mirror arrangement. Group 2 subjects trained with the left hand and then practiced with the right hand on the place arrangement. Groups 3 and 4 were different from groups 1 and 2 respectively only to the extent that the subjects trained with the right hand and practiced with the left. The breakdown of subjects in each of these groups was as follows:

	1	2	3	4
Right-handed Males	6	6	6	5
Right-handed Females	8	7	7	7
Left-handed Males	2	2	2	3
Left-handed Females	0	1	1	1
Total	16	16	16	16

APPARATUS

Four colored lights (red, green, blue and yellow) were arranged so that each could be projected with equal intensity upon a common white target which was visible through a single aperture in a vertical panel. The panel was four feet high and five feet wide with the aperture centered on it laterally and at eye-level vertically. Two banks of switches were mounted in front of the vertical panel so that they occupied bilaterally symmetrical positions. On each bank were four spring-loaded toggle switches in lateral alignment and separated from each other by three inches. These switches were used to turn off the four colored lights as they were presented in the aperture. Each bank of switches was connected to the lights so that either of two switch-light relationships, as selected by the experimenter, would be correct. These relationships were as follows:

	Relationship One				Relationship Two			
Switch:	1	2	3	4	1	2	3	4
Light:	Red	Green	Yellow	Blue	Blue	Yellow	Green	Red

Midway between and slightly in front of the two banks of switches was a flat metal disk which served as a starting point for the responding hand of the subject. (See Figure I.)

A rotary switch mounted on the experimenter's side of the apparatus was used to control the order of presentation of the colored lights. Using this control the experimenter selected the appropriate position for a desired light. The light was then turned on by operating another switch which energized a holding relay. This relay remained closed until the subject operated the correct switch for de-energizing the circuit. Thus, once the light was turned off it could not be turned on again by the subject's release of the toggle switch. Response time, the interval from stimulus onset to operation of the correct switch, was measured to the nearest one-thousandth of a minute.

Every response of the subject was monitored by means of a panel of four numbered lights each of which came on when its corresponding switch on either of the switch banks was operated by the subject. A switch was provided to enable the experimenter to select one or the other set of subject's switches for operation at a given practice session. (See Figure 2.)

The apparatus was isolated in a semi-soundproof, ventilated room. Overhead illumination, of average intensity, was used so that all components of the apparatus except the front surface of the vertical panel were in direct light. This enabled subject and experimenter to see their respective controls adequately, yet provided maximum contrast between the lighted aperture and its surround.

PROCEDURE

Each subject, upon reporting, was designated for one of the four groups (described in section on Subjects) on the basis of sex and handedness. The subject was then taken into the experimental room and seated at the apparatus. The instructions, pertinent to the task for that subject, were read. Explanation, as requested by the subject, was given in a manner consistent with the requirement for standardization of subject set. As part[2] of the instructional procedure a check was made on the ability of the subject to discriminate and name quickly the four colors of light.[3]

The training task consisted of learning to operate, with the hand appropriate for the subject's group, switch 1 when the red light was presented, switch 2 when the green light was presented, switch 3 when the yellow light was presented, and switch 4 when the blue light was presented. Each subject trained through a total of 48 trials in six blocks of eight trials each. Within each block each color was presented twice, the order of the eight presentations being otherwise random. Each stimulus presentation followed completion of the preceding trial by approximately three seconds. The experimenter recorded by number the responses, including the incorrect responses which necessarily preceded the correct response for a given trial, as they were made. The time interval between successive blocks of trials was approximately ten seconds. During this interval the experimenter noted and recorded the time which had accumulated during the preceding block of eight trials and reset the timer.

2. See Appendix I for complete set of instructions.
3. Only students with normal color vision were asked to volunteer for this experiment.

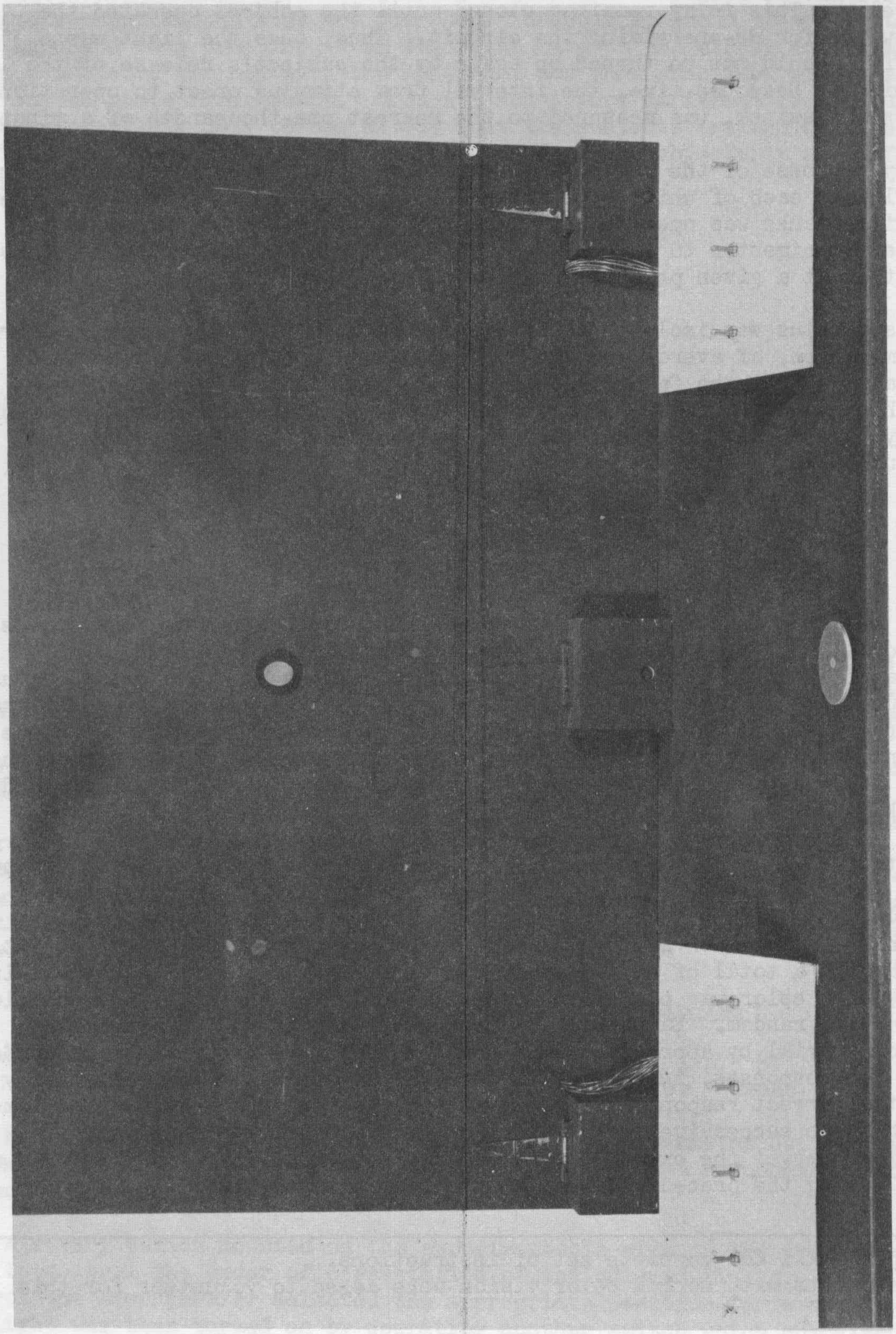

Figure 1: Subjects' View of Apparatus

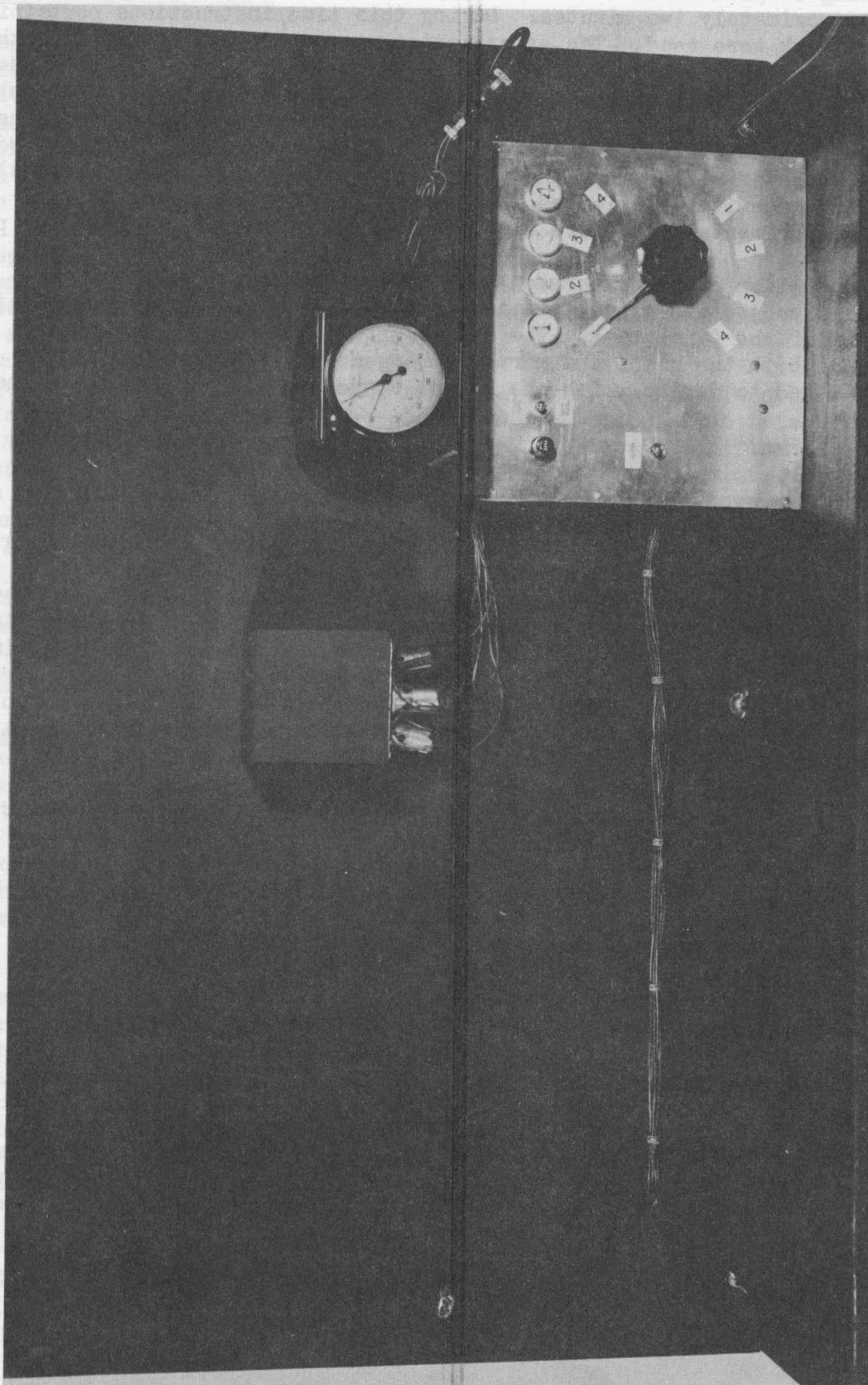

Figure 2: Experimenter's Side of Apparatus

Following completion of the training phase the subject was allowed to relax for approximately two minutes. During this time, instructions pertaining to the final task were read. The experimenter was careful in instructing the subject only that he was to continue practicing the task as learned with the opposite hand. The final task consisted of thirty-two trials[4] in four blocks of eight trials each. All subjects completed this phase using the hand other than the one with which they had trained. One half of the subjects operated with the switches oriented according to the place arrangement; the other half operated with the switches oriented according to the mirror arrangement. The general experimental procedure was identical with that of the training phase.

Upon completion of the experimental session the subject was asked to state what his subjective expectations of switch-light relationships were at the beginning of the final task. The experimenter then made a comparative explanation of both the place and mirror arrangements, following which the subject was asked to decide which one he would prefer in a performance situation.

RESULTS

For purposes of detailed description of the complete experimental treatment of subjects, it has been convenient in the preceding sections of this report to differentiate between four subject groups. This differentiation was on the basis of whether the subject used his left or right hand in the training phase as well as on the basis of mirror versus place arrangement for the final task. Since the "right versus left" differentiation was made only to insure that hand-dominance effects operated equally for the mirror and place groups, it will not be treated in the results. The results are differentiated on the basis of two major groups, each of which is sub-divided according to sex. To facilitate reference to these groups they have been coded as follows:

Group	Identification
MM	Mirror Arrangement - Males
MF	Mirror Arrangement - Females
MT	Mirror Arrangement - Total (both sexes)
PM	Place Arrangement - Male
PF	Place Arrangement - Female
PT	Place Arrangement - Total (both sexes)

4. Forty-eight trials were given in the training phase since preliminary investigation had shown that subjects would reach an asymptote at between 40 and 48 trials on the average. The choice of 32 trials after the change of hands was an arbitrary one. Only the first few trials after the change were expected to show differences since relearning would be rapid.

Performance on Training Task

Table I presents the mean time required by each group for completion of each successive block of eight trials in the training phase of this experiment. These data are graphically portrayed in Figure 3. Also shown in Table I are the standard deviations about the group means for the 9-16, 25-32 and 41-48 blocks of trials. Standard deviations were computed for only these blocks in order to reduce the computational load and yet provide an adequate sampling on which to base inter-group comparisons.

Inspection of the data of Table I and the curves of Figure 3 reveals that the groups are alike to an acceptable degree in their training performance. It can be seen that the group means and standard deviations follow a common pattern as stage of learning progresses, i.e., the mean values and inter-group differences between means become smaller while the standard deviations show within-group dispersion following the same pattern. The only important deviation from this rule is represented by the performance of Group MF on trials 25-32 wherein mean response time is seen to increase. Tests of significance of differences between groups show that the MF group does not deviate significantly (less than .10 value) from any other groups at this stage however. All the other "t" values for inter-group comparisons are lower yet; not one approaches the .10 level of significance.

It is apparent that the groups performed in an acceptably homogeneous fashion on the training task of this experiment.

Performance on Final Task

Latency: Table II presents the mean time required by each group for completion of successive blocks of trials in the final task. The standard deviations about these means and "t" values of tests of differences are also shown. The relationships between means are portrayed graphically in Figure 4.

It can be seen that the mirror-arrangement groups begin the final task with much lower time scores and with less intra-group variability than do the place-arrangement groups. The differences between means are significant only when the total mirror group is compared with the total place group however.

After the first eight trials the initial differences in performance are no longer present and those that are evident, with the possible exception of the group MF deviation[5] on trials 17-24, are apparently only random. Thus it seems that changing to a mirror-arrangement results in initially superior performance as compared with changing to a place-arrangement but this superiority is short-lived and only random differences are found after a few trials.

It can be seen that there is extremely close correspondence between the

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5. The MF group does not differ significantly from the other groups on trials 17-24.

TABLE I

Mean time (in thousandths of a minute) for completion of successive blocks of training-task trials with standard deviations and "t" values shown for selected comparisons.

Group	N	Trials 1-8	9-16	17-24	25-32	33-40	41-48
MM	16						
Mean		261	190	153	143	137	140
S.D.			73.6		19.3		21.5
MF	16						
Mean		243	180	151	154	141	143
S.D.			43.5		36.5		20.1
MT	32						
Mean		252	185	152	148	139	141
S.D.			41.5		20.5		14.4
PM	16						
Mean		249	174	151	145	142	141
S.D.			39.1		32.9		22.4
PF	16						
Mean		216	169	141	142	140	138
S.D.			41.0		29.0		20.7
PT	32						
Mean		232	172	146	144	141	139
S.D.			27.7		21.4		15.2

"t" values

MM vs PM	0.77	0.21	0.13
MF vs PF	0.73	1.03	0.69
MT vs PT	1.06	0.53	0.38

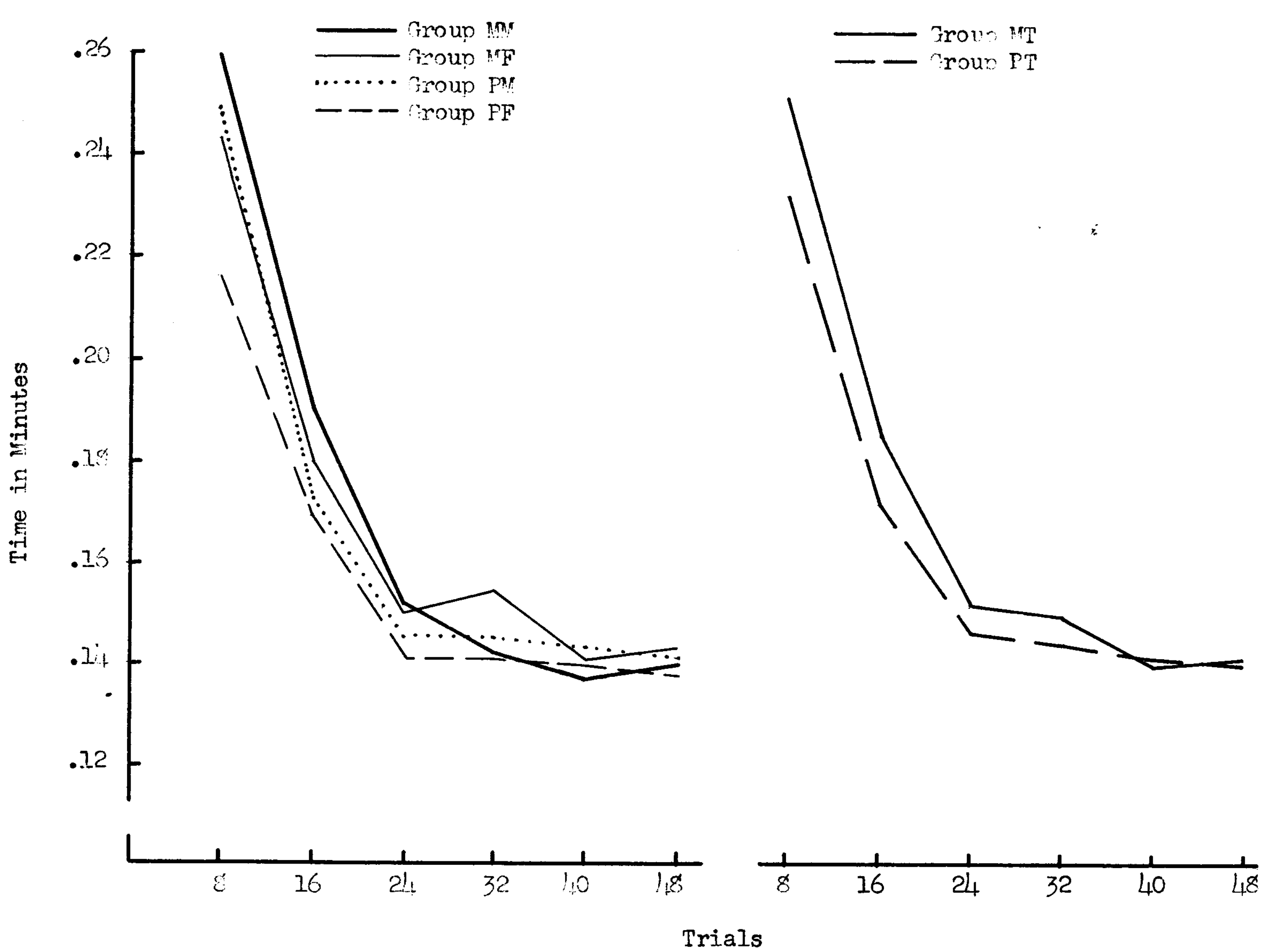

Figure 3: Mean Time to Complete Successive Blocks of Eight Trials in the Training Task.

TABLE II

Mean time (in thousandths of a minute) for completion of successive blocks of final-task trials with standard deviations and "t" values for inter-group comparison.

			Trials			
	Group	N	1-8	9-16	17-24	25-32
MM	MM	16				
	Mean		157	139	137	133
	S.D.		26.4	14.2	18.9	14.7
	MF	16				
	Mean		153	149	154	137
	S.D.		29.2	19.3	31.8	18.5
	MT	32				
	Mean		155	144	145	135
	S.D.		27.5	12.2	19.0	11.7
	PM	16				
	Mean		173	144	140	136
	S.D.		30.7	19.9	22.4	23.7
	PF	16				
	Mean		176	148	139	138
	S.D.		54.8	29.1	22.5	22.9
	PT	32				
	Mean		174	146	140	137
	S.D.		43.7	17.3	15.5	16.1
	"t" values					
	MM vs PM		1.56	0.82	0.41	0.43
	MF vs PF		1.51	0.11	1.41	0.14
	MT vs PT		2.14*	0.37	0.81	0.39

* Significant beyond 5% level

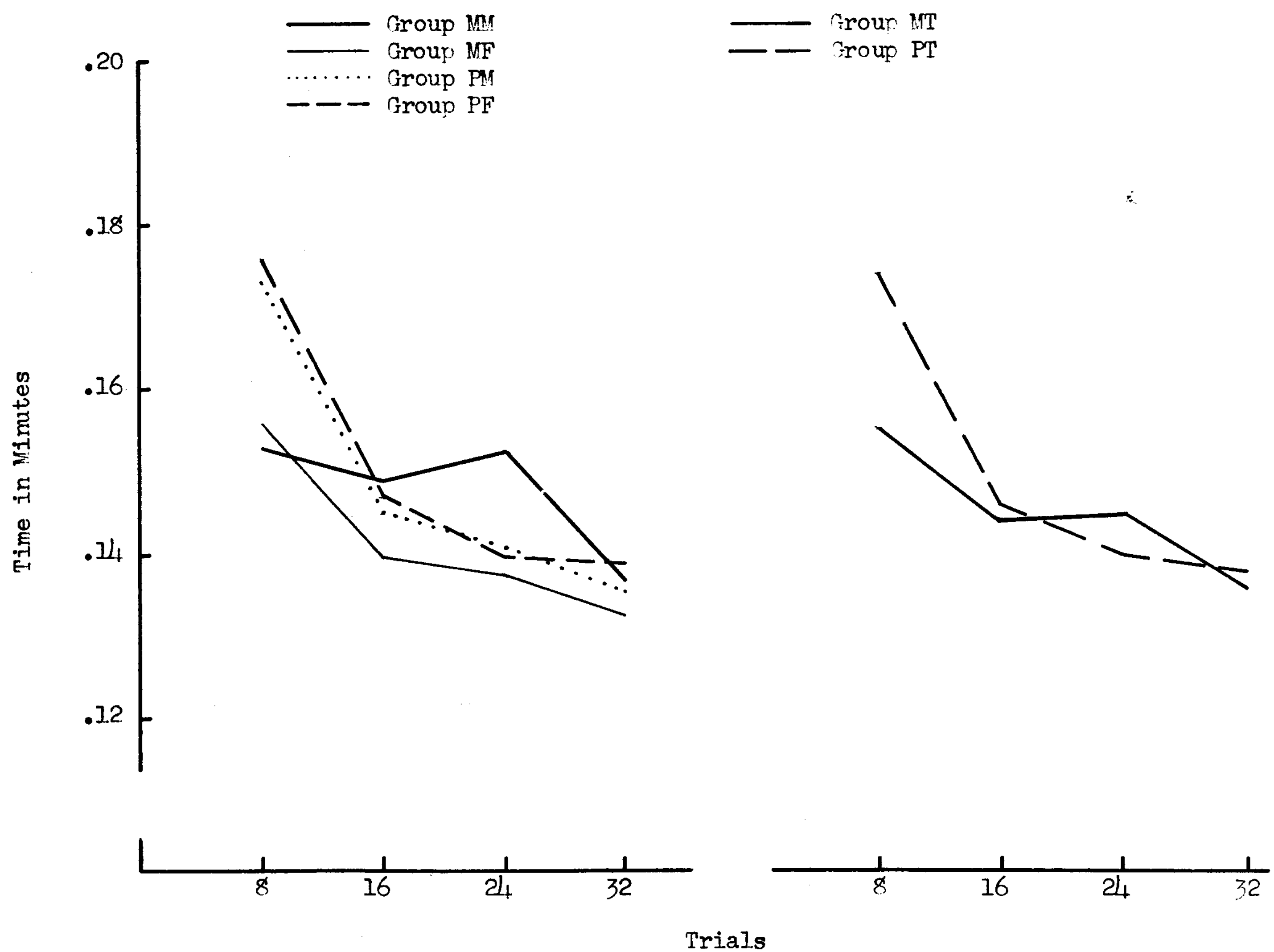

Figure 4: Mean Time to Complete Successive Blocks of Eight Trials in the Final Task.

performances of the male and female groups having the place arrangement. The mirror arrangement groups are similar in initial and final performance, deviating, though not significantly so, during the intermediate stages. Apparently, then, response-time differences due to arrangement are general and cannot be differentiated according to sex.

Errors: Table III shows the total number of errors made by each group during the final task. These errors are differentiated on the basis of those made on trial one versus those made on other trials. An error was recorded each time an incorrect switch was operated by a subject. It can be seen that the total number of errors made by any group during the final task was small, averaging slightly over two errors per subject in the total place-arrangement group (PT) and less than one error per subject in the total mirror-arrangement group (MT). One-half or more of the errors made by each of these major groups were made on the first trial, indicating that relearning the appropriate switch-light orientation was rapid for those subjects who made errors initially. In this connection, Table III also shows the percent of subjects in each group making one or more errors on trial one, one or more errors on other trials, and one or more errors for the entire task. It is noted that only slightly more than one-fourth of all the mirror-arrangement subjects made errors on the first trial, and further, that less than one-half of these subjects made errors at all. In contrast with this, 69 percent of the place-arrangement subjects made errors on the first trial and 78 percent made errors at some stage of the task.

TABLE III

Results of Tabulation of Error Data from Final Task

	Group					
	MM	MF	MT	PM	PF	PT
Errors on Trial 1	12	1	13	21	17	38
Errors on Other Trials	6	7	13	20	9	29
Total Errors	18	8	26	41	26	67
% Ss making errors on Trial 1	50%	6%	28%	75%	63%	69%
% Ss making errors on other trials	31%	19%	25%	44%	25%	34%
% Ss making errors on one or more trials	69%	19%	44%	81%	75%	78%

No statistical analysis of the data of Table III was undertaken because of the fewness of the errors and the non-normality of the distributions of errors made by each group. In general, however, it can be seen that the data strongly favor the mirror-arrangement groups. In every comparison between a mirror-arrangement group and its corresponding place-arrangement group, whether in terms of errors made or in terms of percent of subjects making errors, the mirror-arrangement group is superior.

Expectation of Subjects

It was expected that the first response of each subject on trial number one of the final task would serve to indicate the nature of his expectation as to switch-light orientation. If he expected the arrangement that was assigned to his group he would begin the final task without error. If his expectation was not in accord with the experimental condition for his group he would make initial errors and the pattern of these errors would provide a basis for inference about his expectation. Such inferences were possible in nearly every case and the results of determination of subject expectation on this basis are presented in Table IV along with the results of subjectively reported expectancies.

Since all subjects performed under identical conditions during the training phase the differentiation in Table IV is by sex rather than according to experimental groupings. It can be seen that close agreement exists between expectancies as determined by performance and as determined by verbal[6] report. In either case the total number of subjects expecting a mirror arrangement is more than double the number of subjects expecting a place arrangement and analysis by "chi-square" shows that these proportions differ from chance at beyond the one percent level of significance. This predominance of mirror-expectancy is more pronounced for female subjects than for male subjects, not reaching the five percent level of significance for the latter. The difference between male and female subjects is not significant, however.

TABLE IV

Arrangement expectancies at beginning of final task as determined by subjects' performance and verbal report.

	Performance		Verbal	
	Male	Female	Male	Female
Subjects Expecting Mirror Arrangement	19	24	18	24
Subjects Expecting Place Arrangement	12	7	12	5
Subjects with Undetermined Expectancy	1	1	2	3
	32	32	32	32

6. Verbally reported expectancies were verified by performance expectancies in every case but one.

Subject Preference and Relation to Experimental Conditions

Preferences of subjects for one or the other of the two bilateral arrangements are shown in Table V. It will be noted that on an overall basis the mirror arrangement is preferred by a highly significant ratio of about 3 to 1. This ratio is approximated by the split in both the total mirror-arrangement group (MT) and the total place-arrangement group (PT) although there is a slight but not significant tendency for subjects to prefer the arrangement which was assigned to them for experimental purposes. Among the sub-groups the only significant deviation from the overall ratio is found in the MF group which split 14 to 1 in favor of the mirror arrangement, with one subject neutral. Since the PF group was less favorable to the mirror arrangement than any other group there is some basis for concluding that female subjects are more prone than males to prefer their assigned arrangement. Considering all female subjects as a group, however, their 24 to 7 split (one neutral) in favor of the mirror arrangement closely approximates the overall preference ratio. The male subjects split 23 to 9 in favor of the mirror arrangement.

TABLE V

Arrangement Preferences expressed by subjects.

	Preferred Arrangement		
Group	Mirror	Place	No Preference
MM	11	5	-
MF	14	1	1
MT	25	6	1
PM	12	4	-
PF	10	6	-
PT	22	10	-
Combined MT and PT	47	16	1

In general then it appears that the mirror arrangement is preferred by a ratio of approximately 3 to 1 by both male and female subjects. Among the latter, however, deviations from this ratio occur in a manner more favorable to one or the other arrangement depending upon which was assigned in the experiment.

Effects of Changing Hands

It will be noted from inspection of Figure 3 that all groups reach a practical asymptote of response time during training trials 33-40 and that little if any improvement occurs during the next (and final) block of training trials. For this reason, and in order to obtain a more stable index of each group's performance at the close of training, each subject's mean performance over the last sixteen trials was determined and included in a new distribution based on these means. Such a procedure brought the various group means and standard deviations even closer together and made them more representative of the level of performance in effect at close of training. When these values are compared with the means and standard deviations of the same groups for trials 1-8 on the final task the results are shown in Table VI.

It can be seen that the immediate effect of changing hands in a bilateral task is to increase response time regardless of whether it is to a mirror arrangement or a place arrangement. The increase is significant for every group except MF.

TABLE VI

Comparison of mean group performance (response time) prior to change with performance after changing hands.

Group	N	Prior	After	"t" values
MM	16			
Mean		139	157	2.14*
S.D.		21.6	26.4	
MF	16			
Mean		142	153	1.16
S.D.		22.7	29.2	
MT	32			
Mean		140	155	2.35*
S.D.		21.8	27.5	
PM	16			
Mean		141	173	3.45**
S.D.		20.0	30.7	
PF	16			
Mean		139	176	2.54*
S.D.		18.6	54.8	
PT	32			
Mean		140	174	4.10**
S.D.		19.0	43.7	

*Significant beyond 5% level
**Significant beyond 1% level

These data should not be interpreted to mean that the original training results in negative transfer effects. Even the place arrangement groups, which suffer the greatest increases in response time after changing hands, still show positive transfer effects by any one of several possible measures. A comparison of Figures 3 and 4 shows, for example, that initial performance on the final task is superior to initial performance on the training task for every group.

DISCUSSION

As was suggested in the introduction to this report, the logical or expected outcome of research on equipment design is, in many cases, the establishment of evidence of a population stereotype favoring one or the other of two or more alternative designs. That a population stereotype seldom reflects unanimously the disposition of the total population is, while regrettable in many critical instances, not unexpected. The reactional disposition with which each subject must cope in performing or learning a new task is a composite of all the innate and past-learned responses that are closely related to the response requirements of the new task. Considering the diversity of response-histories among a group of performers, it is surprising to find that more than a simple majority of them prefer or perform better with a given task orientation. Where such stereotyped dispositions are known or found, it is only good sense to design equipment to accommodate them. Thus for purposes of efficiency of training and subsequent operation, as well as in the interest of safety, a task should be oriented so that the required responses are those that are natural for most of the people who perform that task.

The results described in the preceding section show that among the population tested there exists a stereotyped disposition favoring controls oriented bilaterally according to a mirror arrangement rather than according to a place arrangement. This was demonstrated by greater speed of response, fewer errors, greater subject expectancy and greater subject preference. It is obvious that these are not independent measures for it can be shown that response time depends in part upon the presence or absence of errors and that errors in turn depend upon the rightness or wrongness of the subjects' expectations. It is not so easy to place subject-preference as the genesis item in this series of successively dependent measures, but certainly expectancy tends to follow preference, there being a positive correlation between the two. This is not to rule out the importance or necessity of any one of the measures used in this study, but rather to emphasize the complementariness of all when taken together. Thus when each of several related but different measures agrees with all the others in establishing a principle, generalizations based on that principle are more apt to lead to optimal equipment design.

The underlying rationale for the superior efficiency of performance on the mirror oriented task is apparently quite complex. In many bilateral tasks such a finding could be adequatedly explained on the basis of neuromuscular organization. In circumscribing circles with both hands for example, it is easily demonstrated that contra-rotation is accomplished with greater facility than is simultaneous rotation in the same direction. This phenomenon suggests some mechanism for bilateral innervation of symmetrical muscle groups. It has been pointed out by Woodworth (7), however, that most of the tasks employed in bilateral transfer studies involve a relatively "higher level of cerebral function" than is necessary in the duplication of a simple movement by the opposite hand. The task in this experiment called for discrimination of color and choice of switch and was, therefore, at a similarly higher level of function. It has been suggested by Miller (6) that reactions in a "critical choice" situation depend primarily upon a dominant perceptual cue and that this cue varies among individuals depending upon their experiences in preceding situations. In the present study it is quite possible that the dominant cue for locating a given switch was, in a majority of the cases, the position of that switch relative to the subject. For a minority of the subjects, on the other hand, the dominant cue was the position of the switch relative to the switch bank. Thus while there is little doubt that other cues were influencing the responses of the subjects, it is suggested that their final-task efficiency was largely dependent upon the correctness of the positional cue which they had utilized in the original learning with the opposite hand. If a majority of the subjects utilized the cue of "position relative to the subject" in the training task, then it is to be expected that the mirror arrangement would lead to relatively better performance in the final task than would the place arrangement.

SUMMARY AND CONCLUSIONS

This study was conducted to determine the relative effectiveness of a mirror arrangement of controls versus a place arrangement of controls in a task involving bilateral transfer of training. Sixty-four subjects were divided into two groups in a manner designed to counterbalance sex and hand dominance effects. The subjects in one group performed a perceptual-motor task oriented bilaterally according to a mirror arrangement while the subjects in the other group performed the same task oriented bilaterally according to a place arrangement. Comparisons between the two arrangements were made on the basis of response latency, errors, subject-expectancy and subject-preference.

It is concluded that:

1. Performance, as measured by response latency and errors, is more efficient when bilaterally operated controls are oriented according to a mirror arrangement.

2. Subjects who have learned a task with one hand and them must perform a functionally similar task with the opposite hand expect to find the controls oriented according to a mirror arrangement by a ratio of approximately two for every one expecting a place arrangement.

3. Subjects prefer a mirror arrangement over a place arrangement by approximately a three to one ratio.

4. With either arrangement a decrement in performance results from the initial change of hands.

5. No significant sex differences operate with respect to any of these conclusions.

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APPENDIX

DIRECTIONS

Training Task

This is a learning experiment. Your task is to discover the relationship between these toggle switches (point) and the four colors you will see in the aperture in front of you. (demonstrate)

You are to begin with your ___*___ hand. You place it on the metal disk in front of you. When one of the colored lights appears in the aperture you are to turn it off by moving your hand to the switches and operating them one at a time until the correct switch is found. When you have turned the light off return your hand to the metal disk. Soon after you have completed this operation another color will appear in the aperture and you are to proceed immediately to turn it off with the appropriate switch and return your hand to the disk. We will continue in this manner until you have thoroughly learned the correct switch for any given light and then I will ask you to change hands and continue practicing. You are to turn off the light as soon as possible after its appearance - try to be accurate in selecting a switch, but don't worry about making errors if you are not sure.

You are to keep going on this problem until I say STOP even though you think you have solved it.

Do you have any questions?

O.K. Place your ___*___ hand on the disk, look at the aperture, and when you see the first light, begin.
(complete initial training)

Final Task

You are now to continue this task using the other set of switches. You will have to use your ___*___ hand. The relationship between switches and lights remains the same.

Place your ___*___ hand on the disk and when you see the first light, begin.

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* "Left" or "right" as appropriate for subject's group and task.