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Transfer of Training Between Tracking Tasks Employing Quickened and Unquickened Displays

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TRANSFER OF TRAINING BETWEEN TRACKING TASKS EMPLOYING QUICKENED AND UNQUICKENED DISPLAYS

by

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TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION AND REVIEW OF THE LITERATURE	1
	Definitive comments	1
	Characteristics of various levels of control	1
	Quickening	4
	Statement of the Problem and its Importance	8
	Statement of the problem	8
	Importance of the problem	9
	History of the Problem	9
	Organization of the Remainder of the Thesis . .	11
II.	METHOD	13
	Subjects	13
	Apparatus.	13
	Control	15
	Display	16
	Related apparatus and equipment	16
	Procedure	19
	Design of the experiment.	19
	Instructions to the subjects.	20
III.	RESULTS	22
	Transfer from Quickened to Unquickened Tracking	26
	Transfer from Unquickened to Quickened Tracking	32

CHAPTER PAGE

IV. DISCUSSION 33

V. SUMMARY 35

BIBLIOGRAPHY 37

APPENDIX A. 39

APPENDIX B. 41

LIST OF TABLES

TABLE		PAGE
I.	Analysis of Variance of Learning Curves for Quickened and Unquickened Tracking	25
II.	Analysis of Variance of the Quickened Learning Curve	27
III.	Analysis of Variance for the First Five Trials of the Unquickened Group and the Unquickened Transfer Trials.	28
IV.	Analysis of Variance for the Last Five Trials of the Unquickened Group and the Unquickened Transfer Trials.	29
V.	Analysis of Variance for the First Five Trials of the Quickened Group and the Quickened Transfer Trials.	30
VI.	Analysis of Variance for the Last Five Trials of the Quickened Group and the Quickened Transfer Trials.	31

LIST OF FIGURES

FIGURE		PAGE
1.	An Unstable System	5
2.	Direct Quickening of the Output.	6
3.	Quickening of the Output	7
4.	Holland and Henson Tracking Apparatus Figure . .	12
5.	Tracking Apparatus	14
6.	Learning Curves for Quickened and Unquickened Tracking	23

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CHAPTER I

INTRODUCTION AND REVIEW OF THE LITERATURE

Man's propensity for solving complex non-linear operations during continuous tracking is high. If the situation demands it he can readily learn to differentiate a displayed signal after the mechanism he is controlling has integrated it. If the tracking is made more and more complicated, however, accuracy falls off rapidly and learning time increases. For any specific task, it is usually possible to design a machine to assume the human operator's functions, but it is not always desirable to replace a man with another machine in a complex tracking task. Non-linear automatic systems are difficult and expensive to build. Most important, however, they are usually restricted to one application and do not share man's flexibility. For practicality and economy, then, it is desirable to try to simplify the operator's task in situations that call for more accuracy than a man ordinarily gives.

I. DEFINITIVE COMMENTS

<u>Characteristics of various levels of control</u>. The simplest "level" of control is <u>position</u> control, or, in the engineer's jargon, "zero-order" control. Here the position of the control is directly proportional to the position of

the display. A good example of position control is volume adjustment on a radio. Turning the knob (control) directly controls the volume (position of the auditory display) of the radio. If the signal strength of the radio station varies, then in maintaining a constant volume (assuming a lack of automatic gain control) the operator is faced with a continuous compensatory tracking task. The target is the desired volume level.

Position control generally offers very few problems for human operators. With this level of control a man can track with adequate speed and precision within a wide range of display-control parameters. Unfortunately, the immutable facts of inertia, gravity and other physical properties <u>integrate</u> through time the applied control quantities of many systems.

With a single integration of the control quantity the operator no longer controls the position of the system as a direct function of the position of his control. Instead, he controls the <u>rate</u> of change of the position of the system. This is variously called rate, velocity, or first-order control. With any one setting of the control the system changes at a constant rate. A good example of rate control is the child's electric train. The position of the transformer handle determines the rate at which the train travels (ignoring the acceleration or deceleration during a change of rate).

If the control quantity is integrated twice the operator controls the acceleration or deceleration of the system (the rate of change of the rate of change). This is called acceleration or second-order control. This marks an important break in the hierarchy of control orders. From two integrations upward the operator no longer receives immediate knowledge of results concerning the consequences of his control movement. If, after a corrective movement, the control is returned to the "zero" position, the cursor does not stop immediately but slows down gradually (decelerates). The length of time that it takes to stop is dependent on the particular characteristics of the system in question. However, if the time constants of the integrators are long this pseudo-lag may make control difficult for the operator.

One type of problem that arises from high orders of tracking is "oscillation". Oscillation refers to overshooting the desired target one or more times (it is also called "hunting" or "searching"). A system that is prone to develop oscillation is said to be unstable, and this is highly undesirable. In real situations it may lead to serious consequences if not damped quickly by the operator.

Adjustment of the control-display sensitivity to an optimum level, and training the operator, add considerably to system stability. But if more integrations are added, or the time constants of the integrators are lengthened, the system will become unstable and the operator is in difficulty. Such a system is represented in Figure 1, page 5.[1]

Quickening. With long time constants the integrators of Figure 1 will provide delayed knowledge of results to the operator. In addition to information delay, the amount of control movement becomes more and more critical since the integrators have a cumulative effect on the display. Although human operators are extremely versatile and can adapt themselves readily to highly complex tracking tasks, their performance gets poorer the more complicated the task. Thus it is profitable to try to simplify the operator's task. "Quickening" is one method of providing this simplification. It is called quickening because it gets "quick" information to the operator, i.e., display information is speeded up. No longer does the operator need to wait for or predict the effects of a particular control movement.

Two methods of quickening the system shown in Figure 1 are available. The first (Figure 2, page 6) is direct quickening of the output of the system. Feedforward loops are taken from the components of position, rate, acceleration and the first derivative of acceleration, algebraically

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[1] Figures 1, 2, and 3 and the discussion of quickening which follow are taken from H. P. Birmingham and F. V. Taylor, A design philosophy for man-machine control systems, Proc. Inst. Radio Engrs., 1954, 42:1755. The writer has made slight modifications of the figures for the sake of clarity.

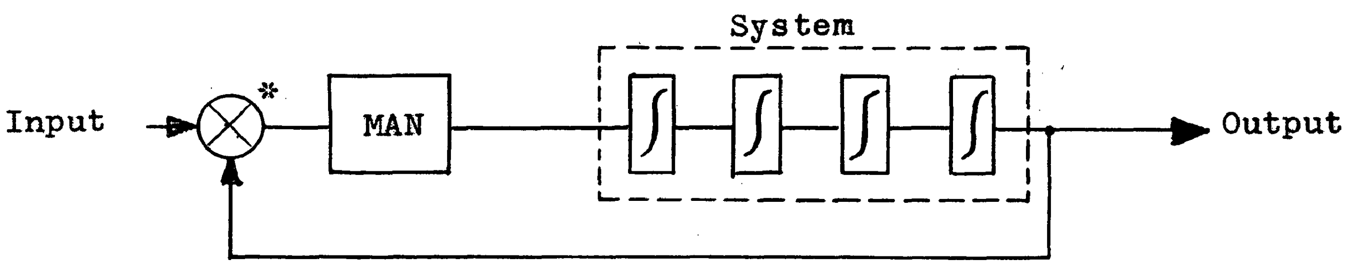

FIGURE 1

AN UNSTABLE SYSTEM

* ⊗ Denotes an algebraic summing.

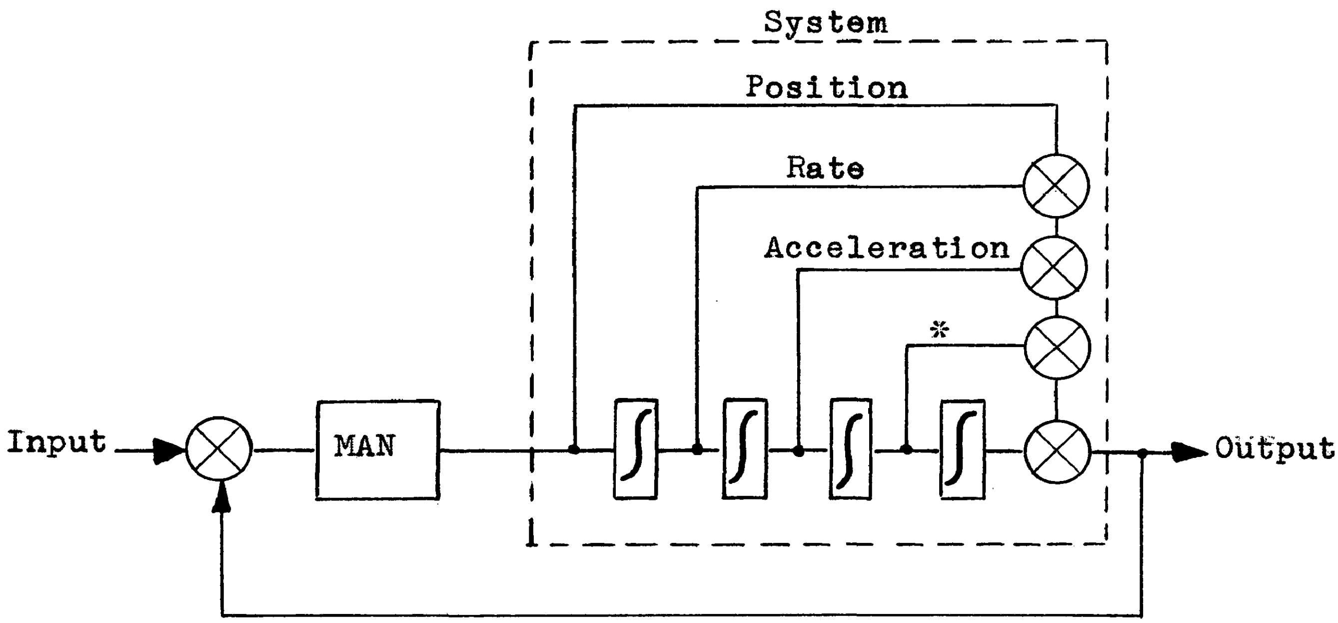

FIGURE 2

DIRECT QUICKENING OF THE OUTPUT

*The first derivative of acceleration.

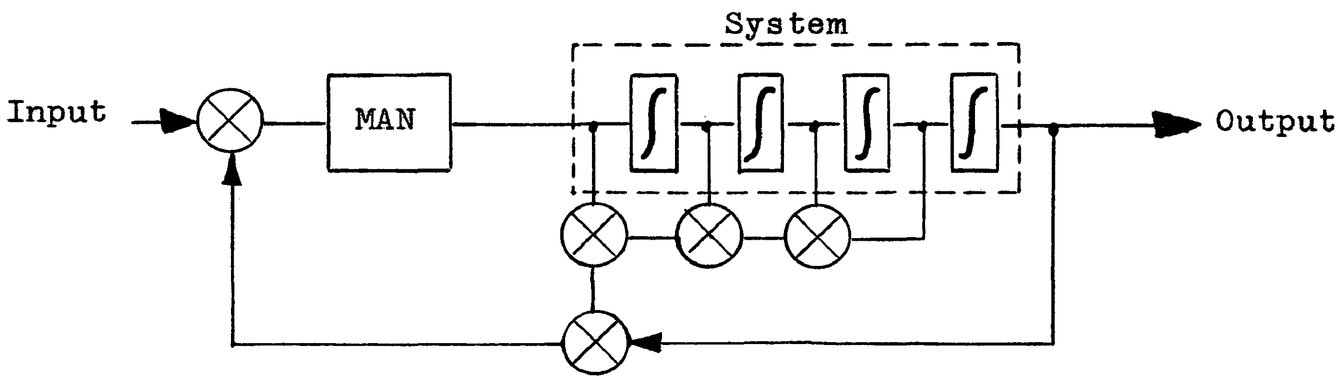

FIGURE 3

QUICKENING OF THE DISPLAY

added, and fed to the output. With this additional circuitry the system (and display) receives immediate knowledge of results of the control movement. Improvement of overall system performance results from this addition.

This is the most direct and desirable method of quickening. Unfortunately in most real situations it can not be used because of circumstances which make the direct alteration of the output of the system impossible. In submarine depth control, for example, the output of the system is directly dependent on the facts of hydrodynamics. The usual place where direct quickening of the output of a multi-integrated system is feasible is in systems where mass and inertia are negligible. Electronics systems are about the only example available.

If the output of the system does not lend itself to direct quickening, an alternative is available; the display may be quickened. Figure 3, page 7, shows this arrangement. Note that the output of the system has not been changed in any way. The operator, however, receives immediate knowledge of results of the effects of his control movement from the quickened display circuit. The overall stability of the system is enhanced, but the performance does not improve as it does with the direct quickening of the output.

II. STATEMENT OF THE PROBLEM AND ITS IMPORTANCE

Statement of the problem. This thesis will deal with the transfer of training between quickened and unquickened tracking. To what degree is there transfer of training between quickened and unquickened tracking systems; are the transfer effects positive or negative?

Importance of the problem. Before quickened tracking can be adopted in a real situation it is important to know (1) how operators trained on the unquickened system transfer to the quickened system once it is installed, and (2) what happens to the operators trained on the quickened system if for some reason they must switch to the unquickened system. It is quite possible, for example, that due to emergency or wartime conditions the computer necessary in the quickened system would be made inoperative.

III. HISTORY OF THE PROBLEM

A direct attempt to solve the problem described above was made by Holland and Henson in 1956.[2] Using a one-dimensional tracking task they set up four groups of six subjects each to determine the amount of transfer between quickened and unquickened tracking:

> "Two groups were trained on the unquickened system -- one of these received 140 40 sec. learning trials, and the other received 260 40 sec. learning trials. The remaining two groups were trained on the quickened system -- one received 140

[2] Holland, J. G., and Henson, J. B. Transfer of training between quickened and unquickened tracking systems, J. Appl. Psychol. 1956, 40:362-66.

trials and the other received 260 trials."[3]

After the learning trials were completed the subjects switched to the opposite type of tracking in order to determine the amount and direction of the transfer. Since the transfer scores differed significantly from the initial trial of the opposite group Holland and Henson concluded that the transfer effects were greater than zero in both cases. They went on to compute the per cent transfer according to a formula. This formula may be symbolically shown as

$$\frac{X_i - X_t}{X_i - X_a} \times 100$$

where X_i= scores for inexperienced subjects

X_t= scores for transferred subjects

X_a= scores at asymptote to learning[4]

The application of this formula resulted in the following table:

TABLE I[5]

Degree of Training	Transfer Scores (Per Cent)	
	Quickened to Unquickened	Unquickened to Quickened
Low	58	64
High	51	46

---

[3] *Ibid.*, p. 363.

[4] *Ibid.*, p. 364.

[5] *Ibid.*, p. 364.

In block form, Holland and Henson discussed their quickened and unquickened tracking tasks, as shown on page 12.

Note the position of the "error integrator." With the switch in the "Q" (quickened) position the system was being rated in terms of a quickened output. This is a very important point.

Any application of these data must be made with this in mind. For systems whose output does not lend itself to quickening and whose display is quickened the data are invalid.

In order to rate the system in terms of an unquickened display the score should be taken from the output of the second integrator. This would leave the display quickened while the recording device is scoring in terms of a system whose output is not quickened. It has already been pointed out that this latter type of arrangement is the most practical. It corresponds to the arrangement shown in Figure 3 on page 7.

IV. ORGANIZATION OF THE REMAINDER OF THE THESIS

In order to provide the data to answer the questions posed by the problem an experiment was performed. The details of that experiment are discussed in Chapter II. Chapter III presents the results of the experiment, and Chapter IV discusses those results. Chapter V is a short summary with suggestions for further research. Following Chapter V are the Bibliography and Appendix.

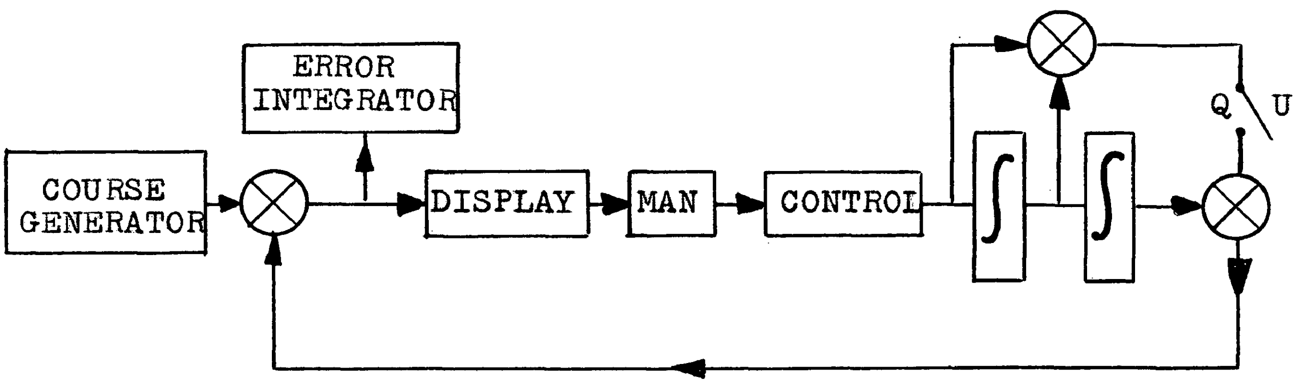

Fig. 1. Simplified block diagram of tracking apparatus. Switch position Q provided the quickened system and switch position U provided the unquickened system.*

FIGURE 4

HOLLAND AND HENSON TRACKING APPARATUS FIGURE

*Holland and Henson, op. cit., p. 363.

CHAPTER II

METHOD

This chapter deals with the method employed to answer the questions posed in Chapter I. Except for the difference in the method of rating the quickened task this experiment was designed to conform as much as possible to the experiment of Holland and Henson.[1] This should allow the results to be more comparable. Major deviations will be pointed out as the experiment is described.

I. SUBJECTS

Twelve male volunteers participated in the experiment. All subjects were students at the University of Omaha during the summer session of 1962. Ages ranged from eighteen to twenty-seven, with a median of 23 years. None of the subjects had physical defects apparent to the experimenter which could have hindered their performance. Likewise, none were experienced with similar apparatus.

II. APPARATUS

The photograph on page 14 may help to clarify some of

[1]Holland and Henson, op. cit., p. 363.

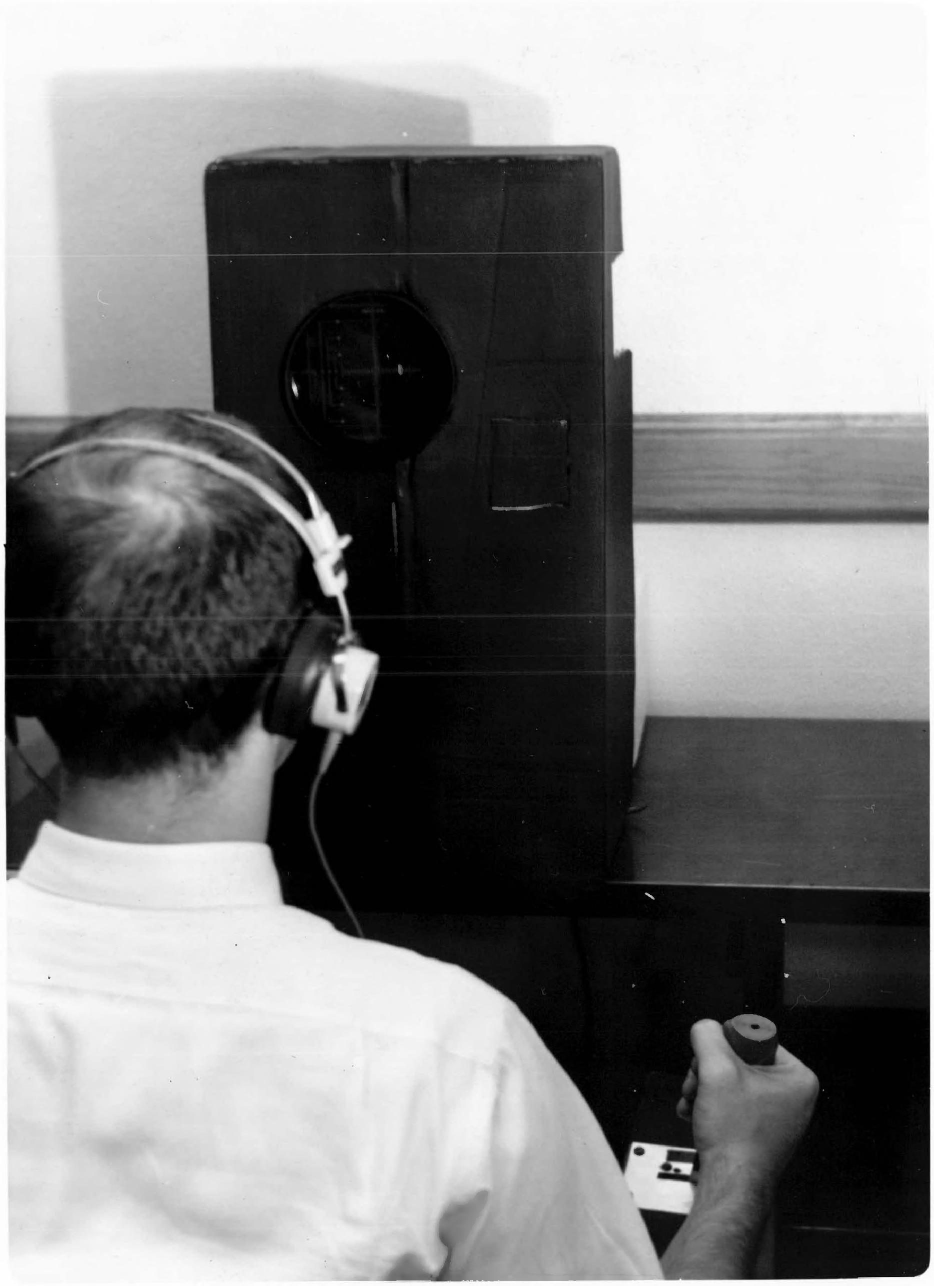

FIGURE 5

TRACKING APPARATUS

the points in the following discussion of the apparatus. Taken over the right shoulder of the subject it provides a good view of the display and shows placement of the control handle.

<u>Control</u>. A spring restrained joystick which was free to move laterally served as the control. A maximum movement of 2½ inches on each side of center was permitted. This distance was measured from the center of the grip.

The joystick was mounted on an armrest which was fastened to the right side of a standard classroom chair after the conventional armrest had been removed. The handle was covered with a red bicycle grip and the armrest was painted flat black.

The handle was fastened to the shaft of a linear potentiometer. Thus, when the handle was moved it turned the shaft which changed the voltage that was considered the control quantity. The shaft fit into the handle in such a way that when the handle was in the center of its movement (at rest) the potentiometer was also at exactly half of its rotation. Since an equal amount of voltage was applied to each end terminal of the potentiometer, and since the voltages were opposite in polarity, the resulting voltage (on the center tap) when the handle was at rest was zero. When the handle was moved, one polarity dominated to an extent proportional to the amount of movement.

The subject received information concerning the position of the handle from the tension on the spring. If the handle was released it returned to the center position.

Display. The position of the simulated system was displayed on the face of a five inch diameter cathode ray tube at eye level to the seated subjects. The cursor was a spot of light (about one sixteenth inch wide and one fourth inch high) which was free to move back and forth on the vertical center of the tube. A green grid screen defined the horizontal and vertical centers for the subjects.

Population sterotypes concerning the control-display relationships were followed. Thus, when the control was moved to the right the spot moved to the right and when the control moved left the spot moved left.

Since the cathode-ray tube was a component of an oscilloscope it was necessary to mask out the front panel of the instrument to avoid distracting stimuli. This was accomplished with a cardboard panel painted flat black with a hole cut in it to allow viewing of the tube only.

Related apparatus and equipment. The voltage coming from the control was sent to an analog computer for alteration and interpretation. A complete computer diagram is presented in the appendix.

Unquickened tracking. For the unquickened task the control voltage was integrated twice in the computer. Therefore, the subjects controlled the acceleration of the spot on the scope. A displacement of one inch of the control resulted in an acceleration of sixteen inches per second squared of the spot. This conformed with the apparatus of the Holland and Henson experiment.[2]

Quickened tracking. The quickened tracking employed the feed-forward loops discussed in Chapter I. Birmingham and Taylor[3] are careful to point out that the relative effects of the loops should be carefully adjusted in order to get the most benefit from the quickening. Following the lead of Holland and Henson[4] who cite research on this problem, the effects of these loops were adjusted as follows: one inch of control movement resulted in a displayed (1) displacement of two inches, (2) rate of four inches per second and (3) acceleration of sixteen inches per second squared.

Error. The spot was moved back and forth across the screen in a sine wave of three cycles per minute. This sine

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[2]Holland, Henson, op. cit., p. 363.

[3]Birmingham and Taylor, op. cit., p. 1755.

[4]This research was only available as a secondary reference. Holland and Henson cite this reference as: Searle, L. V. Psychological studies of tracking behavior. VI. The intermittency hypothesis as a basis for predicting optimum aided-tracking time constants. U.S. Naval Lab. Rep., 1951, No. 3872.

wave was produced by the action of a cam acting on a potentiometer through a follower arm. The spot moved two inches in each direction from the center of the display (80% of the range). At the beginning of a trial the spot was at one of its extreme movements to the right or left of center. The side was determined randomly for each trial.

Scoring. "Time on target" served as the score. (This deviated from the Holland and Henson experiment which used absolute integrated error.) The time was measured to the nearest hundredth of a second on an electronic timer (Lafayette No. 20225) when the spot was within three-fourths of an inch on either side of the target. This made the target thirty per cent of the total range of movement.

Since, in both tasks, the scoring voltage was taken from the output of the second integrator the quickened task was being rated in terms of a quickened display and an unquickened output. This is the major deviation from the Holland and Henson experiment. It should allow the experimental question posed in Chapter I to be answered.

Auditory masking. In order to prevent subjects from getting uncontrolled auditory feedback from the scoring relays it was necessary to mask the equipment sounds with another auditory stimulus. They were required to wear headphones which carried white noise. The white noise sufficiently masked this information channel and tended to eliminate distraction as well.

III. PROCEDURE

Design of the equipment. The twelve subjects were divided non-systematically into two groups of six subjects each. One received one hundred one-minute learning trials on unquickened tracking and then were tested on quickened tracking for five trials. The other group received one hundred one-minute learning trials on the quickened tracking and then were tested on the unquickened tracking for five trials. The transfer effects are evaluated by comparing test trials of each group with the first and last[5] learning trials of the opposite group.

The one hundred trials were carried out over a four day period (consecutive days) for each subject. Twenty-five trials were given each day with the exception of the last day when an additional five trials on the opposite condition were given. The subjects were scheduled for a particular hour and were required to report at the same time (plus or minus one hour) each day. Thus, the sessions for each subject were one day apart.

The one-minute trials were all separated by a break of thirty seconds except between trials 12 and 13 they received a rest pause of three to five minutes. A similar

[5]This is assuming that the last trial represents the asymptote of the learning curve.

rest pause was given after the last learning trial and before the five test trials on the last day.

It was necessary to provide two practice trials both initially and before the five test trials. The subjects had to have some level of proficiency so that they would not lose the spot off the side of the cathode ray tube. If the spot went beyond the range of the display, tracking became impossible because of severe oscillation. During the practice trials it was pulled on the tube by the experimenter if it slipped off. None of the subjects lost the spot after the practice trials.

Instruction to subjects. Because of the large amount of time the subjects were investing in the experiment, it was necessary to inform them of the general nature and schedules of the experiment before they actually reported. That is, they were told the number of trials each day and that they would be "tracking", or moving a spot of light with a control. If they were curious concerning the reason that there would be an extra five trials on the last day they were merely told that that would be explained "when we get to it." This was to prevent any "set" from developing which could have affected their performance.

When the subjects reported for their first session this information concerning the scheduling was reviewed informally to prevent any misunderstandings about their responsibilities. After this review the following instructions were read to them:

> When the trial is about to begin you will have several cues. First of all, the earphones that you are wearing will have some noise in them. This noise is merely to help you concentrate on the tracking and so you won't pay any attention to me. About five or ten seconds after the noise starts I will tap you on the shoulder like this... [demonstrate]. This means "Get ready! You have about two seconds." Then on this screen a small spot will appear [demonstrate]. It may either be on this side or on the other -- you can never tell.
>
> When the spot comes on it is your cue to begin tracking. That is, <u>you move this control and keep the spot as near the center as you can.</u> When the one minute of tracking is over the spot will disappear and the noise will stop. Then I will tell you your score in seconds and hundredths of a second. For example, if your score is 29.87 seconds this means that you were in the acceptable zone for 29.87 seconds out of the sixty second trial. I can't tell you the exact limits of the zone, but you keep it as near as you can to the center at all times.
>
> Any questions?
>
> Fine. Now remember these first two trials are just for practice.

At the end of the last learning trial there was a three to five minute rest break. Then the subjects were told:

> In these last five trials the control of the spot is going to be slightly different. The task is just the same, however -- move the control and center the spot. We will have two practice trials, and I will help you if you lose the spot off the side of the screen.

When the last test trial was completed the subjects were thanked for their cooperation and the experiment was explained to them.

CHAPTER III

RESULTS

The data relating trials to performance are summarized in Figure 6, page 23. Each point on the graph represents the mean of five trials for six subjects. Numerical values for these points can be found in the appendix. The last points on the right of the graph represent the transfer trials at the end of the fourth day of practice when the subjects were tested on the opposite condition. The unquickened group is shown in black and the quickened group is shown in red.

An analysis of variance of these two curves (excluding the transfer trials) was made as a check on various aspects of the data. First of all, as interesting auxilliary information, the analysis would reveal if there were any statistically significant difference between the overall performance level of the two groups. Secondly, it was important to show improvement during the one hundred trials. If no learning is demonstrated from the first trial to the last, then this is an undesirable artifact of the task and equipment. For obvious reasons no evaluation of the transfer effects could be made without a learning situation.

The results of this analysis are shown in Table I, page

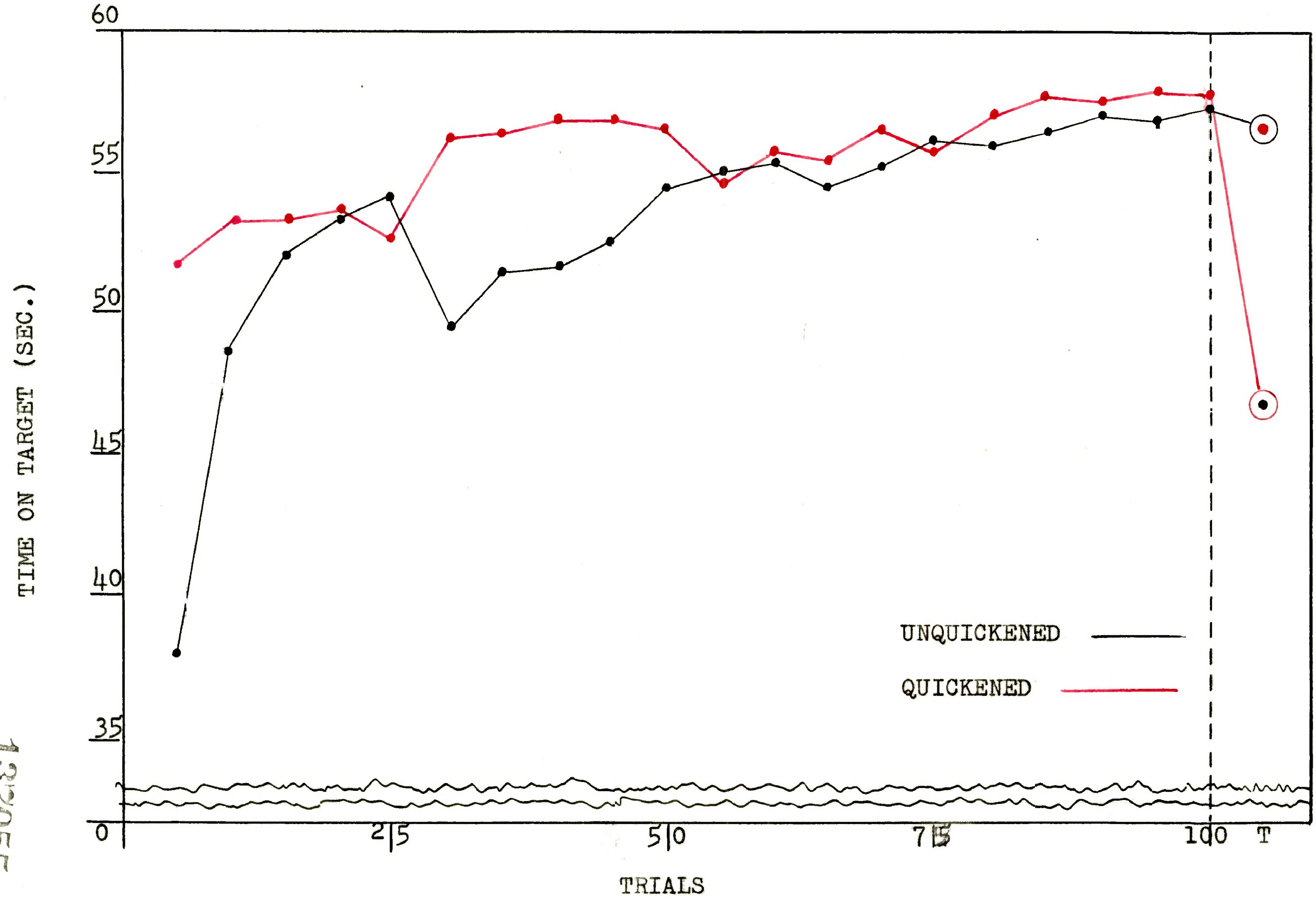

FIGURE 6

LEARNING CURVES FOR QUICKENED AND UNQUICKENED GROUPS

25. For computational purposes this analysis was made over the means of each five trial series for each subject. Thus, the analysis is based upon 240 means (12 subjects X 20 means for each) instead of the 1200 raw observations (12 subjects X 100 observations for each).

Several conclusions can be drawn from this analysis: (1) there is no statistical difference between the methods; (2) the two groups showed highly significant improvement over the twenty trials, and (3) the interaction of trials by methods is also highly significant.

Although this analysis answers most of the questions posed concerning the nature of the curves themselves it presents yet one more. The significance of the interaction of trials by methods might mean that the significance between trials could be accounted for by only one of the curves. That is, taken together the curves might show improvement through trials while only one of the curves contributes to this improvement. Inspection of the graph (Figure 6, page 23) is sufficient to show that only the quickened group could be under suspicion. If this group shows an upward trend through the trials then it may be assumed that the unquickened group would show the same thing when subjected to the same test.

To test the quickened group separately another analysis of variance was made. The results of this second

TABLE I

ANALYSIS OF VARIANCE OF LEARNING CURVES FOR QUICKENED AND UNQUICKENED TRACKING

Source of Variation	Sum of Squares	Sum of Squares Total	df	df Total	Mean Square	F
Between methods	350.28		1		350.28	2.55
Between subjects in same group	1371.85		10		137.18	
Total between subjects		1722.13		11		
Between trials 1-20	1902.91		19		100.15	7.44*
Interaction: Trials X methods	668.57		19		35.19	2.61*
Interaction: Pooled subjects X trials	2557.84		190		13.46	
Total within subjects		5129.32		228		
Total		6851.45		239		

*p is beyond .005 level of significance.

analysis are shown in Table II; only now we may safely conclude that the two curves represent improvement through trials, and proceed to the evaluation of the transfer effects.

If we are to conclude that there are any positive transfer effects then the transfer trials must differ significantly from the initial trials of the opposite group. Likewise, if we are to conclude that the transfer is not complete then the transfer trials must differ significantly from the final trials of the opposite group. In order to test these conditions raw data from the transfer trials were compared with the raw data of the first five and last five trials of the group which had been trained on the transfer condition from the outset. These four comparisons were made with analyses of variance. The results of these analyses are found on the following four pages, in Tables III through VI. Also reported on these pages are the variances of the groups, and a statement of the results of Bartlett's test for the homogeneity of variance.

I. <u>TRANSFER FROM QUICKENED TO UNQUICKENED TRACKING</u>

Looking at Table III we see that no positive transfer can be assumed on the basis of an insignificant <u>F</u> value between methods. Table IV confirms this with a significant value of <u>F</u> between the transfer trial and the final trial, but the variances in this second table are drastically different,

TABLE II

ANALYSIS OF VARIANCE OF THE QUICKENED LEARNING CURVE

Source	Sum of Squares	df	Mean Square	F
Trials	423.08	19	22.27	1.95*
Subjects	956.66	5	191.33	
Subjects X trials	1084.81	95	11.42	
Total	2464.55	119		

*p is beyond the .05 level of significance.

TABLE III

ANALYSIS OF VARIANCE FOR THE FIRST FIVE TRIALS OF THE UNQUICKENED GROUP AND THE UNQUICKENED TRANSFER TRIALS[a]

Source of Variation	Sum of Squares	Sum of Squares Total	df	df Total	Mean Square	F
Between methods	1182.19		1		1182.19	1.98
Between subjects in same group	5980.34		10		598.03	
Total between subjects		7162.53		11		
Between trials 1-5	296.35		4		74.09	1.01
Interaction: Trials X methods	68.56		4		17.14	0.23
Interaction: Pooled subjects X trials	2945.32		40		73.63	
Total within subjects		3310.23		48		
Total		10472.76		59		

[a]Variance for the first five trials = 177.06; variance for the transfer trials = 143.31. Bartlett's test for the homogeneity of variance is not significant at the .05 level of significance.

TABLE IV

ANALYSIS OF VARIANCE FOR THE LAST FIVE TRIALS OF THE UNQUICKENED GROUP AND THE UNQUICKENED TRANSFER TRIALS*

Source of Variation	Sum of Squares	Sum of Squares Total	df	df Total	Mean Square	F
Between methods	1630.73		1		1630.73	6.76**
Between subjects in same group	2411.94		10		241.19	
Total between subjects		4042.67		11		
Between trials 1-5	35.58		4		8.89	0.21
Interaction: Trials X methods	58.79		4		14.70	0.35
Interaction: Pooled subjects X trials	1668.38		40		41.71	
Total within subjects		1762.75		48		
Total		5805.42		59		

*Variance for the last five trials = 0.65; variance for the transfer trials = 143.31. Bartlett's test for the homogeneity of variance is significant at beyond the .01 level of significance.

**p is beyond the .05 level of significance.

TABLE V

ANALYSIS OF VARIANCE FOR THE FIRST FIVE TRIALS OF THE QUICKENED GROUP AND THE QUICKENED TRANSFER TRIALS[a]

Source of Variation	Sum of Squares	Total	df	Total	Mean Square	F
Between methods	354.34		1		354.34	3.78
Between subjects in same group	936.56		10		93.66	
Total between subjects		1290.90		11		
Between trials 1-5	181.91		4		45.48	4.15
Interaction: Trials X methods	35.60		4		8.90	0.81
Interaction: Pooled subjects X trials	438.73		40		10.97	
Total within subjects		656.24		48		
Total		1947.14		59		

Variance for the first five trials = 47.72; variance for the transfer trials = 7.21. Bartlett's test for the homogeneity of variance is significant at beyond the .01 level of significance.

TABLE VI

ANALYSIS OF VARIANCE FOR THE LAST FIVE TRIALS OF THE QUICKENED GROUP AND THE QUICKENED TRANSFER TRIALS*

Source of Variation	Sum of Squares	Sum of Squares Total	df	df Total	Mean Square	F
Between methods	22.76		1		22.76	3.17
Between subjects in same group	71.86		10		7.19	
Total between subjects		94.62		11		
Between trials 1-5	22.45		4		5.61	2.19
Interaction: Trials X methods	20.65		4		4.16	1.63
Interaction: Pooled subjects X trials	102.33		40		2.56	
Total within subjects		145.43		48		
Total		240.05		59		

*Variance for the last five trials = 0.29; variance for the transfer trials = 7.21. Bartlett's test for the homogeniety of variance is significant at beyond the .01 level of significance.

which makes this *F* value questionable.

What appears to have transferred in this situation is the high variability of scores which is seen in the initial trials of the unquickened group. Practice on quickened tracking did not produce significantly less variability than would be expected if the subject had no previous training at all.

II. TRANSFER FROM UNQUICKENED TO QUICKENED TRACKING

The analyses of the quickened groups reveal that none of the between methods *F* values are significant. This puts the interpretation in a somewhat paradoxical situation. The transfer trial does not differ from either the initial or final trials, but the initial and final trials differ from each other. As previously stated, the variances are not homogeneous in either test, and this throws doubt on the interpretation of the *F* values.

Looking at the variances for these groups it can be seen that practice on the unquickened task reduced the variance in the transfer trial from what would be expected from that of the initial trial of the quickened group. Therefore, it is probably of some benefit to practice on the unquickened task even though the *F* tests are insensitive to this benefit.

CHAPTER IV

DISCUSSION

From the data of this experiment it cannot be concluded that there was any transfer of training, except where the practice on the unquickened task reduced variability when the subjects switched to the quickened task. If there was any transfer in mean performance the measures used to detect it were not sufficiently sensitive to show it.

Comparing these results with the results of Holland and Henson is especially difficult because different performance criteria were used. The Holland and Henson experiment used absolute integrated error.[1] That is, the voltage corresponding to the subjects' error was continuously averaged (without regard to sign) and integrated throughout the trial. In contrast, this experiment used a time on target score with the target being thirty per cent of the range. Research on these two scores shows that the time on target score (with a thirty per cent target) is less sensitive to performance changes than integrated error, and that there is no linear relationship between the two scores.[2]

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[1]Holland and Henson, op. cit., p. 363.

[2]Bahrick, H. P., Fitts, P. M., and Briggs, G. E. Learning curves - facts of artifacts? Psychol. Bull., 1957, 54, pp. 256-268.

Since Holland and Henson do not report variability there is no way of knowing if similar differences were found. Thus, it is difficult to make comparisons in the amount of transfer found in the two studies. Only the occurrence of transfer effects, and the direction these effects took, may be compared.

Future researchers may be interested in the differences between transfer effects when the output and display are quickened, or when just the display is quickened, but it seems of minor importance now since quickening of the output has so few applications. More important would be research dealing with a quickened display in a real situation. Although quickening a display does not seem to increase the accuracy of even moderately skilled subjects, it may prevent loss of control or severe oscillation in early trials for real situations.

CHAPTER V

SUMMARY

This study was patterned after a study by Holland and Henson[1] which sought to determine the direction and amount of transfer of training between quickened and unquickened tracking. The critical difference between the two studies was that this one used only a quickened display so the scoring was always in terms of an unquickened system. This arrangement is probably the most practical since most systems do not lend themselves to a quickened output.

Twelve subjects were divided into two groups of six subjects each. One group received one hundred one-minute learning trials on the quickened display, and the other received one hundred one-minute learning trials on the unquickened display. After completion of the learning trials the subjects were tested for five trials on the task in which they had no training. The transfer effects were evaluated by comparing the five test trials with the first and last five trials of the opposite group.

The results of this study suggested that operators trained on a tracking system whose display is either quickened

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[1]Holland, J. G., and Henson, J. B. Transfer of training between quickened and unquickened tracking systems, J. Appl. Psychol. 1956, 40, 362-66.

or unquickened will experience limited positive transfer effects when switching from one to the other, and no negative effects. Practice on unquickened tracking reduces the variability of scores when the subject is switched to the quickened task, but the reverse is not true.

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APPENDIX

APPENDIX A

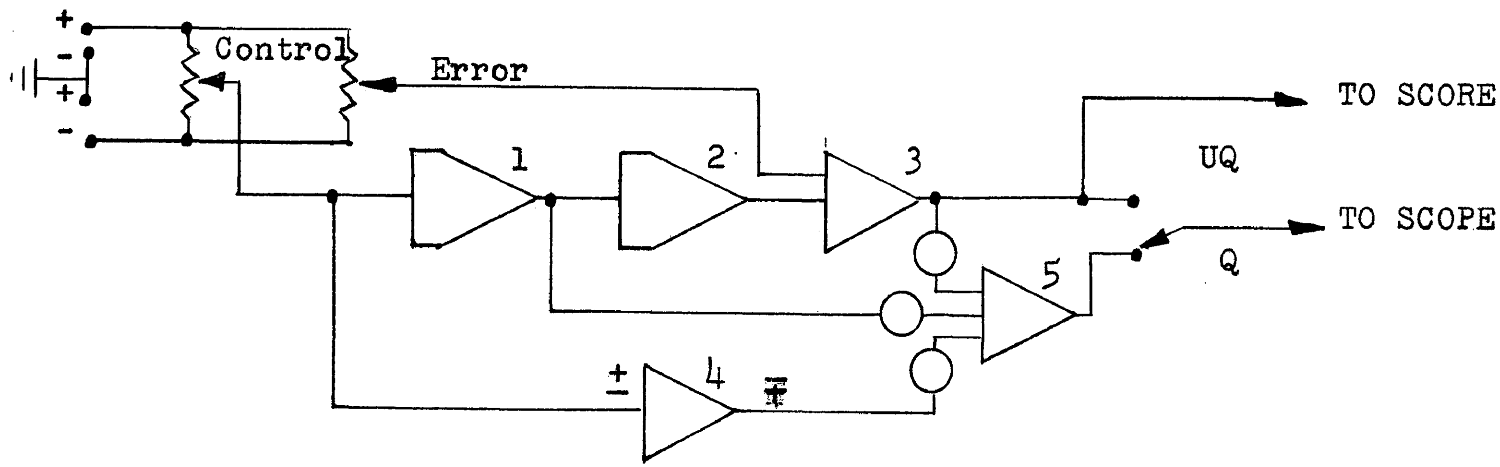
COMPUTER CIRCUIT

In general, the computer diagram (Figure 1 page 40) is read from the upper left hand side where the initial condition voltage is applied to the right hand side where the outputs to the scoring device and display are obtained.

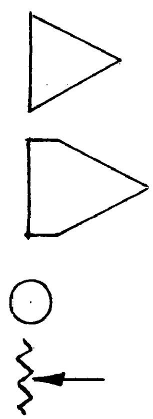
Two independent power supplies feed constant voltages of opposite polarity to the "control" and "error" potentiometers. Since the power supplies have voltage regulator tubes in their own circuits the potentiometers are also independent. That is, changing the setting of one will not affect the output of the other.

The voltage coming from the control potentiometer is integrated twice in amplifiers 1 and 2. Amplifier 3 algegraically sums the integrated control voltage with the error voltage. The error is added at this point to avoid integrating it. This makes the problem more analogous to a real situation where the error forces do not act through the control, but affect the system externally. For example, the wind which pushes an airplane off course does not push the control handles, but pushes the entire system.

For the unquickened task the output of the third amplifier was fed directly to the oscilloscope for display. The quickened task came from the output of amplifier 5. This fifth amplifier served to sum the three feedforward (quickening)



Explanation of symbols:



Amplifier acting as a summer of sign inverter.

Amplifier acting as an integrator.

Coefficient potentiometer.

Potentiometer.

FIGURE 1

COMPUTER DIAGRAM

loops which were adjusted to the proper relative effects by coefficient potentiometers. Amplifier 4 was used merely to change the sign of the voltage of the position component which came directly from the control potentiometer. It was necessary to have all the voltages of the loops of the same polarity since the control voltage has only one polarity, and the loops must all have the same directional effect on the display.

When the switch (Q - UQ) is in the quickened (Q) position the score is entirely independent of the output of the fourth amplifier and the quickened task. The voltage to be scored was fed to a circuit which operated an electronic timer when the voltage was within a specified range around zero volts. This unconventional scoring circuit is discussed by Simoneau[1] as an improvement over conventional methods of obtaining time on target scores.

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[1] Simoneau, George. "An improved circuit for time on target and integrated error-scores in continuous tracking," _Am. J. Psychol._, 1961, 74, pp. 471-472.

APPENDIX B

FIVE-TRIAL MEANS

The following table presents the means for each five-trial series for the quickened and unquickened groups.

TABLE I

Unquickened Trials	Unquickened Mean	Quickened Trials	Quickened Mean
1-5	38.14	1-5	51.94
6-10	48.96	6-10	53.33
11-15	52.13	11-15	53.53
16-20	53.58	16-20	53.68
21-25	54.28	21-25	52.93
26-30	49.60	26-30	56.27
31-35	51.73	31-35	56.49
36-40	51.85	36-40	57.01
41-45	52.70	41-45	57.00
46-50	54.55	46-50	56.84
51-55	55.26	51-55	54.73
56-60	55.68	56-60	55.86
61-65	54.74	61-65	55.86
66-70	55.51	66-70	56.85
71-75	56.45	71-75	56.18
76-80	56.10	76-80	57.18
81-85	56.53	81-85	57.98
86-90	57.03	86-90	57.97
91-95	57.10	91-95	58.09
96-100	57.45	96-100	58.04
Transfer	56.80	Transfer	47.02