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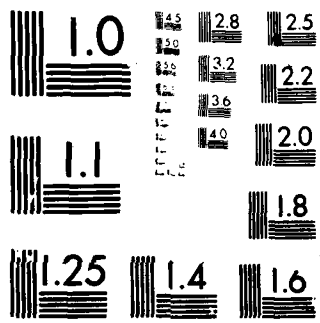

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Staff Paper

THE EFFECT OF VARIOUS LEVELS OF AUDITORY FEEDBACK ON PURSUIT ROTOR PERFORMANCE

by

Richard W. Sheldon
Elmo E. Miller
John F. Bjorklund

May 1970

DAHC19-70-C-0012

BASIC RESEARCH 9, "Learning of Skills"

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This paper describes an experiment on the effects of various levels of auditory feedback on target tracking in a pursuit rotor task. The hypothesis that an intermediate level of supplementary auditory feedback produces the best psychomotor performance is tested. Tables present analyses of mean gain scores for each level of feedback.

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PREFATORY NOTE

This paper is the summary of an investigation of the effects of supplementary auditory feedback on performance of a pursuit rotor task. It was part of a Human Resources Research Organization project, Basic Research 9, "Learning of Skills," the objective of which was to produce and sustain high performance levels, in both individual and group tasks, by specifying standards of performance and reinforcing increasing approximations of these standards. The research was conducted at HumRRO Division No. 2, Fort Knox, Kentucky.

ABSTRACT

To compare the effects of different levels of auditory feedback on performance of a pursuit rotor task, each of five groups (20 subjects per group) was given five sessions of practice (seven trials per session). Feedback during Sessions 2 - 4 for four of the groups consisted of momentary clicks for some minimum interval of continuous contact during a session. Clicks were provided by a counter, located behind the pursuit rotor so that the subject could see how many signals he had received during the session. The fifth group (control) received no feedback at any time. The results show that auditory feedback facilitated tracking performance, the greatest facilitation occurring with intermediate levels of feedback, though not all differences between groups were statistically dependable. Differences between the feedback groups and the control group decreased when feedback was withdrawn (in Session 5).

SUMMARY AND CONCLUSIONS

Problem

Studies in which an auditory reinforcing stimulus was introduced, to produce and sustain a high level of skill on a psychomotor task, have yielded ambiguous results. The present authors take the position that (a) the contradictory findings could be attributed to differences in average motivation among the populations being studied, and (b) auditory feedback facilitates psychomotor performance to the extent that it motivates the subject in an otherwise extremely monotonous task situation.

Purpose

An experiment was designed to study the effects of various levels of auditory feedback on target tracking accuracy, and to test the hypothesis that performance would be best with an intermediate level of supplementary auditory feedback.

Method

Five groups, 20 men per group, were given 35 trials on the pursuit rotor. The subjects were assigned to groups on the basis of time on target scores for the first seven trials (Session 1), when they performed without feedback. During Sessions 2, 3, and 4, consisting of seven trials each, a brief click was presented automatically whenever the stylus was kept continuously on target for specified durations. The intervals of contact required for a click during Sessions 2, 3, and 4 were 0.067 sec. for Group A; 0.20, 0.30 and 0.50 sec. respectively for Group B; 0.50 sec. for Group C; and 0.50, 0.75, and 1.00 sec. respectively for Group D. The control subjects in Group 0 received no auditory feedback throughout the sessions. The click was provided by a counter, which was situated behind the pursuit rotor so that the subject could see how many signals he had received during a session. All subjects performed without feedback during Session 5 (the last seven trials).

Results

The principal results of the study are:

1. Auditory feedback facilitated performance of a pursuit rotor task.

2. Performance was facilitated most with intermediate levels of feedback.

3. The differences in performance between the feedback groups and the control group decreased when the auditory feedback was removed.

Conclusions

It was concluded that the results support the view that feedback facilitates pursuit rotor performance to the extent that it motivates the subject in an otherwise extremely monotonous situation. It was also concluded that further work is necessary, to determine the relationship between motivation and the difficulty of meeting criteria to obtain auditory feedback, and between performance and motivation.

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THE EFFECT OF VARIOUS LEVELS OF AUDITORY FEEDBACK
ON PURSUIT ROTOR PERFORMANCE

BACKGROUND

The question of the effect of auditory feedback on psychomotor performance has produced considerable debate, especially in the area of pursuit rotor tracking. The contradictory findings, however, appear to be explainable in terms of differences in the populations used in the studies, as hypothesized by Archer and Namikas (1). It was found that the introduction of auditory signals as feedback facilitated the performance of military personnel (2, 3, 4, 5), but had little or no effect on the performance of university or high school students (1, 6).

Reynolds and Adams (5) found that the performance of an experimental group receiving a momentary click after every 0.5 sec. of continuous tracking was superior to that of a group receiving no feedback. The experimental group also performed better than groups who received a click for every 0.1, 0.2, 1.0, or 2.0 sec. of continuous contact, but none of these differences were statistically dependable. Though the authors (5) concluded that the results admit of a motivational interpretation, they viewed the established differences in performance as primarily attributable to differences in habit strength.

A program of research was instituted by HumRRO to investigate the employment of feedback in producing and sustaining a high degree of skill on a continuous motor task. The first two studies (2, 3) involved the application of Skinner's (7) technique of shaping to a pursuit rotor task by administering an auditory click for progressively longer contacts of the stylus on the target. Marked gains in performance as soon as the clicks were introduced (2), and negligible differences in performance among groups in both studies when feedback was withdrawn, suggest that shaping procedures did not condition habit strengths differentially.

In order to determine whether or not information theory might account for the role of feedback on this task, Miller et al (4) varied the percentage of contacts to be reinforced by an auditory signal. It was predicted that (a) subjects who are reinforced for 50% of their contacts should perform best, because this reinforcement schedule would provide the maximum discrimination between the "good, longer" hits and the "bad, shorter" ones; (b) subjects who receive a signal for 0% or 100% of their contacts should perform worst, as there would be no distinctive cue for differentiating between the longer and shorter hits; and (c) those subjects who are reinforced for 11% or 89% of their contacts should track at a level midway between these extremes. The feedback was provided by a buzzer, which was activated after a predetermined minimum interval of continuous contact and remained activated until contact was broken. Though the results indicate an inverted-U relationship between performance and percentage of hits receiving feedback, the curve was negatively skewed, and there were no dependable differences found among the data for the 50%, 89%, and 100% groups. It was concluded that information theory alone could not account for the results, and that an explanation involving secondary reinforcement was tenable.

The results of the six studies above (1, 2, 3, 4, 5, 6) are consistent with the position that feedback facilitates pursuit rotor performance to the extent that it raises the subject's level of motivation in this situation. But the relationship between feedback, motivation, and performance is not simple. Reynolds and Adams (5) and Miller et al (4) found indications that an intermediate level of feedback facilitated performance more than other levels did, although few of these performance differences were statistically dependable.

A possible explanation is that subjects operating under the most frequent feedback schedules are less than optimally motivated because they are less able to discriminate differences in performance on successive trials than subjects operating under an intermediate schedule. For example, in the Reynolds and Adams study (5), the 0.1-sec. and 0.2-sec. clicks are too frequent to count, whereas subjects can count the 0.5-sec. clicks quite easily. Similarly, in the Miller et al study (4), subjects in the 89% group could probably differentiate the differences in the minimum interval of contact needed to activate the buzzer on successive trials, and thus they could distinguish between relatively "good" and "bad" trials more easily than the subjects in the other groups. It might be found that the greatest facilitation occurs under the most frequent feedback schedules, if the subject could refer to a counter to find out how many clicks he had received or look at a clock to determine how long the buzzer had been activated.

PURPOSE

The purpose of the present experiment was to investigate the effects of several levels of auditory feedback on performance of a pursuit rotor task. Feedback consisted of momentary clicks produced by a counter and presented at different rates during the time the subject was on target. The counter was located behind the pursuit rotor in such a manner that the subject could see the number of clicks accumulated during the trials of a session. This score was introduced to provide a control for the possibility that subjects operating under the maximum feedback schedule had greater difficulty in discriminating differences in performance on successive trials than did subjects operating under an intermediate schedule.

METHOD

Apparatus[1]

The pursuit rotor task consisted of tracking with a stylus a 3/4-in. target, mounted 3-1/4 inches from the center of a turntable, which rotated clockwise at 60 rpm. The experimenter and recording devices were located in a separate room in order to eliminate any extraneous cues from these

[1]The experimental use of any device whose trade name appears in this report does not constitute an endorsement of the device.

sources A one-way mirror enabled the experimenter to monitor the subject's performance

Each 30-sec. work interval (trial) was preceded by a 5-sec. warning period and followed by a 25-sec. rest. Timing was controlled by microswitches activated by a motor-cam arrangement. Subjects started tracking as soon as the white warning light went out and the turntable began to rotate, and they stopped performing when rapid deceleration of the turntable marked the end of a trial. Time on target was totaled on a Standard Electric Clock with a 0.2-sec. scale.

The auditory feedback consisted of clicks from an advancing counter, which was situated behind the pursuit rotor and which the subject could observe. Automatic presentation of clicks for the longer intervals of contact was controlled by a Grason-Stadler Electronic Timer, E5350A. A recycle control on the timer made it possible to deliver more than one click during a single long contact. Thus, if the interval setting was 0.2 sec., the subject would hear a click every 0.2 sec. after the stylus first touched the target and for as long as he maintained the contact. Automatic presentation of clicks for extremely short intervals of contact was controlled by a Grason-Stadler Pulse Former. When this device was activated by contact between the stylus and target, the counter advanced at the rate of 15.0 points per sec. The initial click in a series required a minimum contact of 33 msec.

Subjects

A total of 110 enlisted men, drawn from the population at Fort Knox, Kentucky, participated in the study. In order to control statistically for extreme individual differences in initial tracking skill, a subject was assigned to one of the five conditions of the study after seven trials on the basis of his time on target during those trials. After the desired 20 subjects per study were run, it was decided that the groups would be more uniformly matched if one group included a subject with a score of less than 6% time on target and another group included a subject with a score of more than 35% time on target during these seven trials. An additional 10 subjects participated in the study before this objective was attained. The distributions of time on target scores (in per cent) for the 20 subjects selected for each condition are given in Table A-1 (Appendix), and are roughly equivalent. The 10 subjects whose data were not included in the analyses averaged 17.9% time on target during the seven trials and the standard deviation was 8.4%,--slightly lower than the overall mean of 19.6% and standard deviation of 10.6% for the 100 selected subjects, but there is no indication of sampling bias.

Procedure

Two subjects at a time reported to the laboratory for one morning or one afternoon period and performed successively on the same pursuit rotor for five sessions. A session consisted of seven 30-sec. trials interspersed with 25-sec. rests and 5-sec. warning periods. There was a 10-

min. break on the average between sessions. All subjects were told at the start that there would be a brief discussion of the study after both men had completed testing and that they would be able to see how well they had performed.

After the seven trials of Session 1, during which all subjects performed without auditory feedback, the subjects in Group 0 (control group) continued to perform without feedback for the remaining four sessions. The alphabetical designation of the four experimental groups corresponds to decreasing probabilities of receiving clicks during Sessions 2 to 4. During Sessions 2, 3, and 4 respectively, the subjects in Group A received a click for every 0.067, 0.067, and 0.067 sec. of continuous tracking, those in Group B for every 0.20, 0.30, and 0.50 sec., those in Group C for every 0.50, 0.50, and 0.50 sec., and those in Group D for every 0.50, 0.75, and 1.00 sec. The men in the experimental groups were always informed at the beginning of Sessions 2 to 4 that the counter was connected and that they could accumulate points depending on how well they performed, but they were never told what aspect of their performance was being reinforced. The counter was not operating during Session 5 for the experimental groups in order to determine whether subjects tend to sustain performance when feedback is withdrawn, and they were told at the beginning of Session 5 that there would be no feedback.

RESULTS AND DISCUSSION

The mean percentages of time on target for each session are plotted as a function of groups in Figure 1. The inverted U shape of the curves suggests that facilitation of performance is greatest at some intermediate level of feedback, but optimum performance was found to occur under a more frequent feedback condition than that found by Reynolds and Adams (5). In both studies, the administration of clicks for 0.5-sec. contacts had no apparent effect on tracking skill during the first 14 trials. But during trials 21 to 28, the indicated facilitation of performance under this 0.5-sec. condition (Group C) was approximately twice as great as that found by Reynolds and Adams. These results might be attributable, at least in part, to the longer rests between trials and the introduction of breaks between sessions in the present study. The smaller differences in performance between the experimental groups and the control group during Session 5 as compared to Session 4 support previous findings (2, 3, 4) that the facilitative effect of auditory feedback on pursuit rotor tracking among military personnel is temporary.

In view of the essentially equivalent distributions of performance scores for the five groups during Session 1, the data were analyzed in terms of "Gain Scores," i.e., gains in performance over Session 1. Table 1 is a summary of the results of the four Analyses of Variance of the Gain Scores for Sessions 2 to 5. Dependable differences were found among groups in all four analyses, and Duncan Multiple Range Tests were then conducted to determine which particular treatment means are dependably different. These results are summarized in Table 2 for Sessions 2 to 5

MEAN PERFORMANCES OF THE FIVE GROUPS
DURING THE FIVE SESSIONS

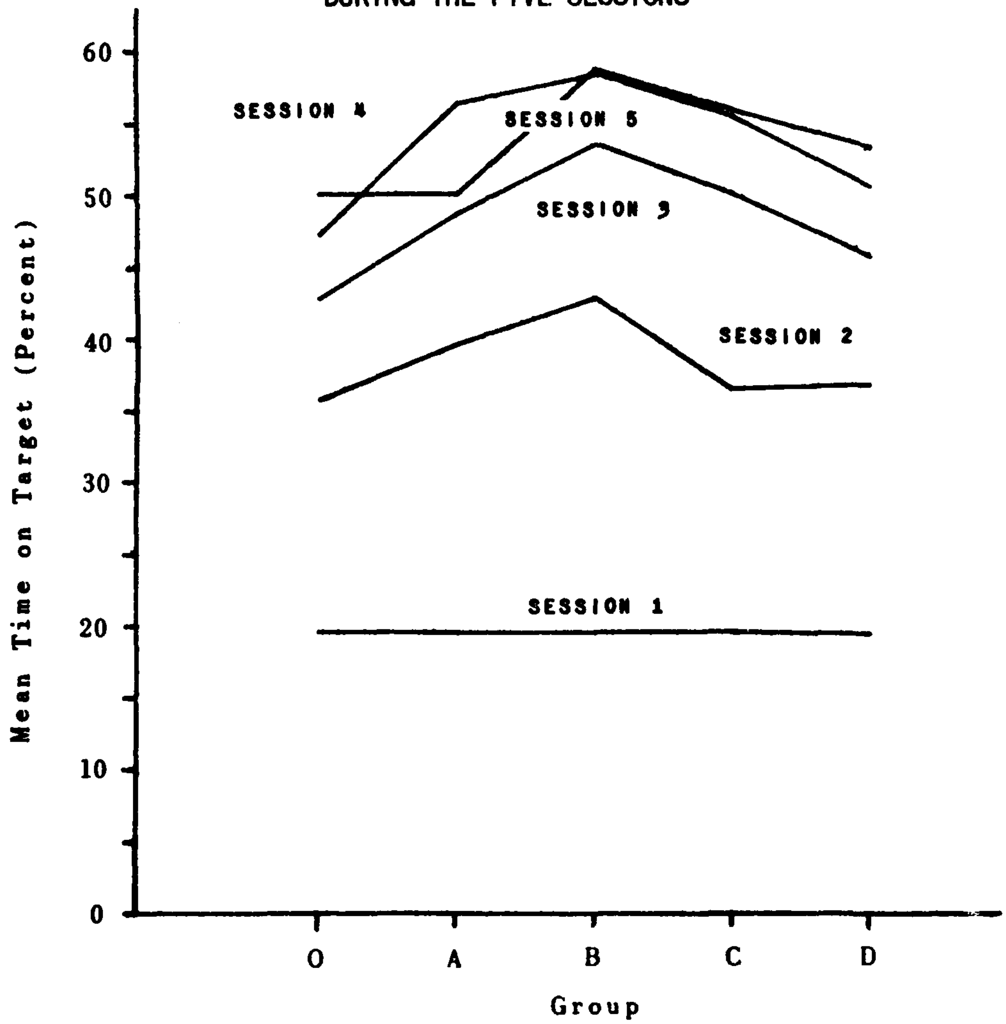

Figure 1

Table 1

Results of Analyses of Variance of Mean Gain Scores*
for the Five Conditions During Sessions 2 - 5

Session	F	df	p
2	3.14	4 and 95	$< .05$
3	4.07	4 and 95	$< .01$
4	4.30	4 and 95	$< .01$
5	2.51	4 and 95	$< .05$

*Gain in per cent of time on target compared with performance during Session 1.

respectively. During feedback, Sessions 2 to 4, the differences between the mean performance of Group B and that of the two groups at the ends of the inverted U's (Groups O and D) were found to be dependable at the .05 level. The only dependable difference ($p < .05$) among Groups A, B, and C during feedback was that between the performances of Groups B and C during Session 2. The indicated superiority of Group C over the control group during Sessions 3 and 4, and of Group A over the control group during Session 4, were the last three differences found to be dependable at the .05 level. During Session 5, when feedback was withdrawn, the only statistically dependable differences were those between the performances of Groups B and O and between Groups B and A.

In an earlier study (2) it was found that when subjects were dichotomized on the basis of initial tracking skill, the facilitative effects of feedback were markedly greater for those at the lower end of the continuum than for those at the higher end. Figure 2 is a summary of the performances of Low Performers and High Performers, the dichotomizing into equal subgroups for each condition being based on the time on target scores during Session 1. The curves, though similar, are characterized by a more pronounced inverted U relationship for the low performers than for the high performers. In other words, the low performers show relatively greater gains under the more frequent feedback schedules, and the high performers make relatively greater gains under the less frequent schedules. These trends, however, may not apply at all levels of proficiency for the individual. The marked improvement of the high performers in Group A during Session 4 might indicate that maximum auditory feedback plus the visible indication of their performance is most facilitating as subjects approach their peak level of skill.

Table A 3 shows the ranges and mean numbers of clicks received per trial during Sessions 2 to 4 by the low and high performers respectively. These data show that the indicated superiority of Group B was maintained in spite of the decrease in average amount of feedback over sessions. The average duration of hits during Sessions 4 and 5 are listed in Table A 4, and the differences among groups appear to reflect little or nothing more than the positive correlation between length of contact and percentage of time on target. There is therefore no indication that differential habit strengths were being conditioned under the various feedback conditions.

These results support the view that feedback facilitates pursuit rotor performance to the extent that it motivates the subject in an otherwise extremely monotonous situation. First of all, this interpretation is based on the greater gains of the low performers, as compared to the high performers, in Groups A, B, and C, throughout most of practice. Secondly, the differences in performance between each of the four experimental groups and the control group decrease as soon as feedback is withdrawn.

As in previous studies (4, 5) the apparently superior performance of subjects given an intermediate rate of feedback as compared with that of

Table 2

Results of Duncan's Multiple Range Test for Gain Scores, Sessions 2 - 5

Relations Between Group Scores* | Mean Differences for Significance**

SESSION 2

Group:	O	C	D	A	B
% Gain:	16.1	16.8	17.1	20.0	23.1
< .05:					
< .01:					

Rank	p < .05	p < .01
2	4.6	6.1
3	4.8	6.3
4	5.0	6.5
5	5.1	6.6

SESSION 3

Group:	O	D	A	C	B
% Gain:	23.0	26.1	29.0	30.4	33.9
< .05:					
< .01:					

Rank	p < .05	p < .01
2	5.8	7.6
3	6.1	7.9
4	6.3	8.1
5	6.4	8.3

SESSION 4

Group:	O	D	C	A	B
% Gain:	27.6	31.9	35.6	36.7	38.8
< .05:					
< .01:					

Rank	p < .05	p < .01
2	6.0	7.9
3	6.3	8.3
4	6.5	8.5
5	6.7	8.6

SESSION 5

Group:	O	A	D	C	B
% Gain:	30.4	30.5	33.6	36.2	39.0
< .05:					
< .01:					

Rank	p < .05	p < .01
2	6.6	8.7
3	6.9	9.1
4	7.2	9.3
5	7.3	9.5

*Means connected by a common line segment are not significantly different.

**The values shown, computed from the data, are the mean differences needed to reach significance, at the .05 and .01 levels, for means that are 1, 2, 3, and 4 ranks apart respectively.

MEAN PERFORMANCES OF THE FIVE GROUPS OF LOW AND HIGH PERFORMERS DURING THE FIVE SESSIONS

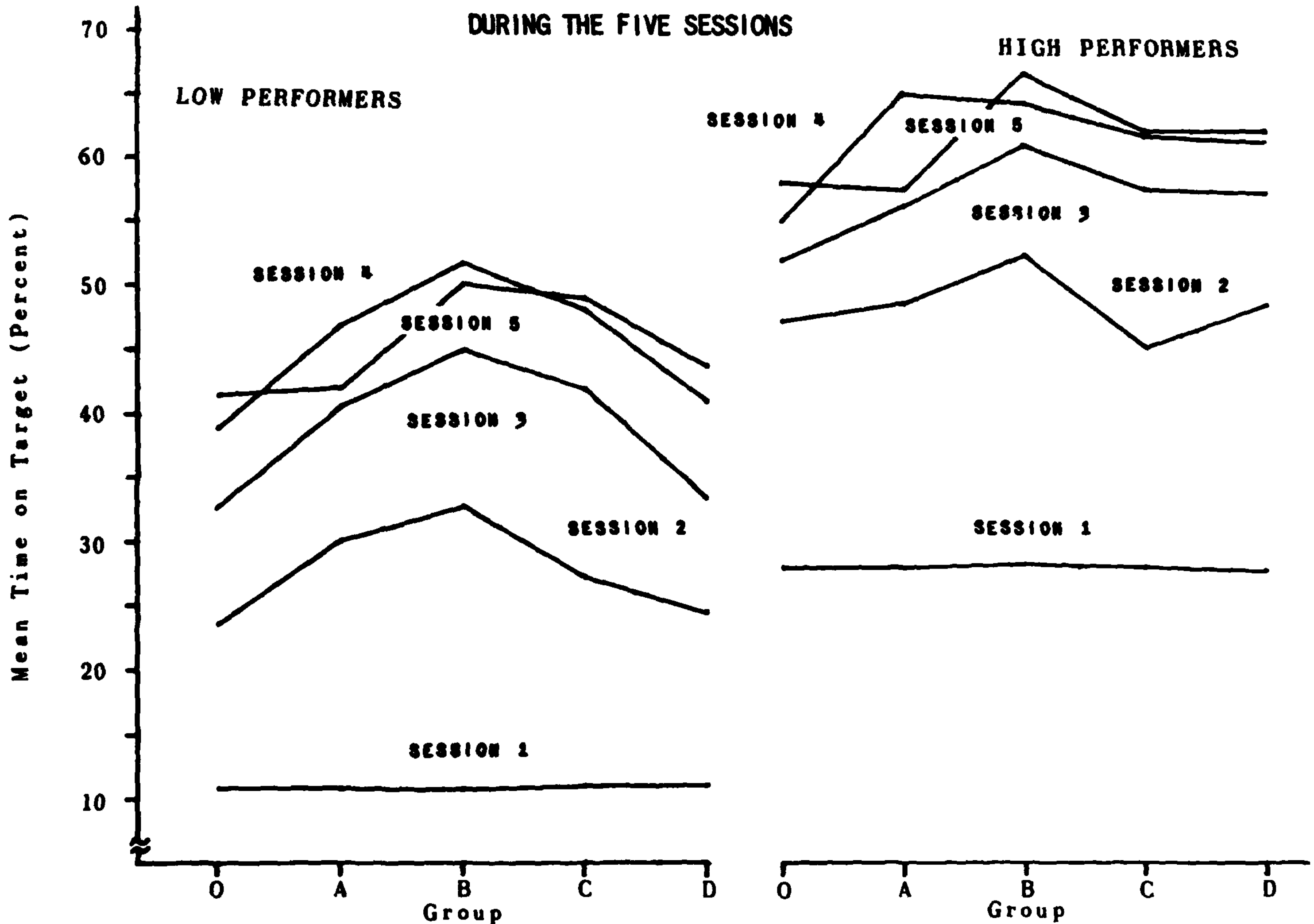

Figure 2

subjects given a greater rate was not statistically dependable. However, the results of this study confirm the finding of these previous experiments that a low rate of feedback, which requires better performance to obtain the feedback, results in a performance decrement. If it is assumed that a subject is increasingly aroused as the difficulty of obtaining feedback is increased, this performance decrement may be interpreted as showing a disruptive effect of excessive arousal as proposed most recently by Hebb (8) Alternately, the subjects may simply "give up," and their level of arousal is reduced when the task requirements exceed a critical level of difficulty. A possible test of these alternatives would consist of measuring muscle potentials and palmar conductance during performance. Stennet (9) found an inverted U relationship between auditory tracking performance and these physiological measures of arousal, which were found to vary with different incentive conditions--namely, monetary rewards, avoidance of shock, and giving subjects the impression that their performance was not being recorded.

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APPENDIX: Session 1 Data for Each Subject, Data for Figures 1 and 2, and Click and Hit Data for Low and High Performers

Table A 1

Percentages of Time on Target During Session 1 for All Subjects in the Five Groups

	Group				
Subject	O	A	B	C	D
1	2.7	3.2	5.1	4.4	3.5
2	4.8	6.4	6.0	6.0	4.8
3	7.6	7.3	6.5	7.1	7.9
4	8.4	7.6	7.4	8.0	9.7
5	11.2	8.9	7.7	8.7	9.9
6	13.5	10.1	11.3	11.7	11.5
7	14.0	11.7	13.5	13.8	14.4
8	14.3	16.3	14.2	16.2	15.1
9	15.2	18.1	17.6	16.7	15.5
10	17.6	18.6	18.3	17.0	18.8
11	20.6	19.6	20.5	18.8	21.2
12	21.8	19.9	20.9	20.5	21.4
13	23.2	21.3	22.7	24.5	22.5
14	23.2	21.4	24.7	26.2	24.9
15	24.0	22.9	25.4	26.6	26.6
16	28.2	26.2	28.4	28.9	28.4
17	30.0	27.7	29.2	30.1	29.3
18	33.6	32.0	30.2	30.5	29.6
19	37.9	40.3	40.8	31.7	34.5
20	40.0	51.2	42.3	44.7	40.8
Means for 1-10:	10.9	10.8	10.7	10.9	11.0
SD for 1-10:	4.6	5.0	4.7	4.5	4.7
Means for 11-20:	28.2	28.2	28.4	28.2	27.9
SD for 11-20:	6.6	9.8	7.2	6.8	5.8

Table A 2

Data for Figures 1 and 2: Mean Per Cents of Time on Target for the Five Groups of Subjects and for Low and High Performers for the Five Sessions

Group	Session 1	Session 2	Session 3	Session 4	Session 5
			Means for the Five Groups (N = 100)		
O	19.6	35.7	42.6	47.2	50.0
A	19.5	39.5	48.6	56.3	50.0
B	19.6	42.7	53.5	58.4	58.7
C	19.6	36.4	50.0	55.3	55.8
D	19.5	36.6	45.6	51.4	53.1
			Means for Low Performers (N = 50)		
O	10.9	23.7	32.7	38.9	41.5
A	10.8	30.1	40.6	46.9	42.0
B	10.7	32.8	45.0	51.9	50.2
C	10.9	27.3	42.0	48.3	49.2
D	11.0	24.4	33.5	41.0	43.8
			Means for High Performers (N = 50)		
O	28.2	47.6	52.3	55.3	58.4
A	28.2	48.9	56.5	65.5	57.9
B	28.4	52.6	61.8	64.9	67.1
C	28.2	45.4	57.9	62.2	62.3
D	27.9	48.7	57.6	61.7	62.4

Table A 3

Ranges and Mean Numbers of Clicks Received per Trial by Low Performers and High Performers in Groups A, B, C, and D During Sessions 2, 3, and 4

	Session 2			Session 3			Session 4		
	Click	Clicks/Trial		Click	Clicks/Trial		Click	Clicks/Trial	
Group	Interv.	Range	Mean	Interv.	Range	Mean	Interv.	Range	Mean
Low Performers (N = 50)									
A	0.067	54-297	141.7	0.067	76-295	185.6	0.067	97-328	211.1
B	0.20	0-53	18.7	0.30	0-57	18.1	0.50	0-39	10.8
C	0.50	0-8	1.2	0.50	0-19	4.9	0.50	0-27	7.0
D	0.50	0-7	1.5	0.75	0-5	0.8	1.00	0-3	0.5
High Performers (N = 50)									
A	0.067	128-341	221.7	0.067	177-373	252.8	0.067	193-396	289.7
B	0.20	12-84	37.2	0.30	7-66	29.5	0.50	0-39	13.4
C	0.50	0-26	5.8	0.50	0-33	12.1	0.50	2-37	14.9
D	0.50	0-19	6.3	0.75	0-15	4.6	1.00	0-12	2.5

Table A 4

Mean Durations of Hits for Low and High Performers During Sessions 4 & 5

	Low Performers		High Performers	
Group	Session 4	Session 5	Session 4	Session 5
O	.18 Sec.	.18	.29	.35
A	.23	.19	.40	.31
B	.31	.30	.38	.42
C	.24	.25	.37	.37
D	.21	.23	.33	.32