AN EXPERIMENTAL STUDY OF LEARNING ON THE AERIAL GUNNERY TRAINING DEVICE 3-A-2

57-1-5

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by
E. B. Knauft
C. E. Hamilton
K. W. Spence

Department of Psychology
State University of Iowa
Iowa City, Iowa

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I. Introduction

A. Statement of Problem

The present study is concerned with the investigation of the nature and extent of the learning process involved in the mastery of aerial-gunnery training device 3-A-2. Little information is available concerning learning on this device, especially with respect to (1) the limit of skill attainable, (2) the amount of practice required to reach this limit, and (3) the form of the learning curve.

B. Preliminary Experiment

A preliminary experiment was conducted in order to obtain a rough approximation of the length of time required to reach a ceiling of performance on the 3-A-2. Two subjects who had had 4 days of experience on the 3-A-2 and the 3-A-35 devices were given daily practice and test runs on the 3-A-2. These two subjects fired at standard port-side attacks, beam to tail only, with the blocks of attacks alternating between 200 knots and 260 knots. After 16 practice sessions, the following two conclusions were reached: (1) these subjects had not reached their maximum performance level, and (2) the nature of the learning function was complicated by the fact that the subjects fired alternately at film representing two different bomber speeds.

C. Description of Present Experiment

On the basis of information from the preliminary experiment, the main experiment was set up to study the learning functions for subjects firing at film representing one bomber speed (200 knots). This experiment consisted of two sub-experiments, hereafter designated as Experiments I and II. Experiment I utilized 12 subjects for 18 sessions, but was limited in time by the closing of the University for summer vacation. Analysis of the data from Experiment I indicated that a ceiling of performance was not evidenced during these 18 sessions. Eight of the original 12 subjects were again available when the Fall Term began at the University, so the study was continued as Experiment II for as many additional sessions as were required to reach maximum performance. Experiment II was discontinued after 17 additional sessions when the learning curve leveled off and additional gains did not appear likely under the conditions of the experiment. The two experiments and their results are described in detail.

II. Experiment I

A. Subjects

The subjects were 12 male graduate students enrolled in psychology courses in the State University of Iowa. Ages ranged from 22 to 27.

None of the subjects had had previous aerial gunnery or anti-aircraft training. They were paid 50 cents a period to serve in the experiment.

B. Equipment

A 3-A-35 set up similar to that described in Report No. 2, Contract No. N50ri, July, 1946, was employed in the study. For the 3-A-2 experiment, however, the projectors were not moved, and the image remained in a constant position on the curved screen. The subjects fired at dual-image, aerial free gunnery film containing only beam-to-tail attacks, 200 knots bomber speed.

C. Experimental Procedure

The subjects as a group were given an initial two-hour indoctrination period consisting of (1) a lecture on position firing, (2) reading of relevant material in the manual, "Sighting and Sights," May, 1944, Edition, (3) oral drill and questions over this material, and (4) a demonstration of the equipment. During the first three practice sessions, a minimum of coaching was given; after the third session, no coaching was given.

Each subject was required to fire a total of 4 identical blocks of 8 attacks each during the 22-minute daily sessions. The sessions were spaced on 18 successive days with the interruption of one day between Sessions 6 and 7, and a two-day interruption between Sessions 11 and 12.

Three of the four blocks in each session were fired as practice runs, i.e., the correct point-of-aim was visible to the subject when the trigger was pressed. The fourth block of each session was a test condition during which the correct point-of-aim was not visible to the subject at any time. The subjects were informed of their daily scores after each session, and a chart was posted showing percent hits scored on each test run by each subject. The following information was given: (1) number of rounds fired, (2) time on target, (3) number of hits, and (4) percent hits. The subjects were instructed to place major emphasis on the percentage of hits but that they should also try to make as great a number of hits as possible. From the interest subjects showed in these scores, it is reasonable to suppose that competition among the subjects was an important motivational factor.

The 18th session, which concluded the collection of data for this experiment, was utilized to measure the subjects' ability in other types of attacks than those presented in the previous sessions. During this session, each subject fired three blocks of eight attacks each, as follows: Block 1--Attacks as used in Sessions 1 through 17 (port-side, 200 knots bomber speed); Block 2--Portside attacks, 260 knots bomber speed; Block 3-- Starboardside attacks, 200 knots bomber speed. No correct point-of-aim was visible during this session.

D. Results

(1) Learning.

The principal data from the group of 12 subjects on the daily sessions are presented in Table I. The mean percent hits for practice are

based on the mean percent hits made by each subject for the three blocks of practice runs, while the mean percent hits and the mean number of hits for the test series are the means for the group of 12 for the single daily test block. The percent of hits data are presented graphically in Figure 1, percent hits being indicated on the ordinate and the ordinal number of the practice session along the abscissa. The lower, solid curve represents the percent hits for test trials, and the upper, broken curve represents the corresponding data for practice trials.

Learning curves for four of the subjects, selected as being representative of the practice and test performance of the group, are presented in figures 2 - 5. These curves have been smoothed by means of the method of moving averages in which each point on the curve represents the mean score obtained for three successive sessions. The solid curve represents percent hits made during test trials and the broken curve, percent hits made during test trials and the broken curve, percent hits made during practice trials.

TABLE I

Mean Scores of 12 Subjects by Sessions, Experiment I

	Practice	Test	
Session	Mean % Hits	Mean % Hits	Mean No. Hits
1	11.4	2.9	16.9
2	18.1	4.2	15.2
3	22.2	3.7	11.8
4	21.5	3.8	11.8
5	32.3	5.3	18.4
6	45.1	10.1	29.8
7	46.3	7.8	25.0
8	42.9	11.2	32.5
9	54.6	16.2	46.5
10	47.8	14.4	43.8
11	49.7	16.9	44.0
12	49.3	16.7	45.4
13	45.9	12.8	35.2
14	52.4	28.7	78.2
15	53.2	24.4	73.5
16	51.7	23.6	66.3
17	56.2	32.0	88.4

(2) Transfer

As noted in the section on Experimental Procedure, the 18th session of this experiment consisted in presenting subjects with new attacks at different speeds. These data provide information relative to the extent to which the practice subjects received during sessions 1 - 17 transfers to attacks on which the subjects have not had previous practice. The data are presented in Table II. The first column shows the percent hits for attacks, portside at 200 knots which were the standard attacks for Sessions 1 - 17;

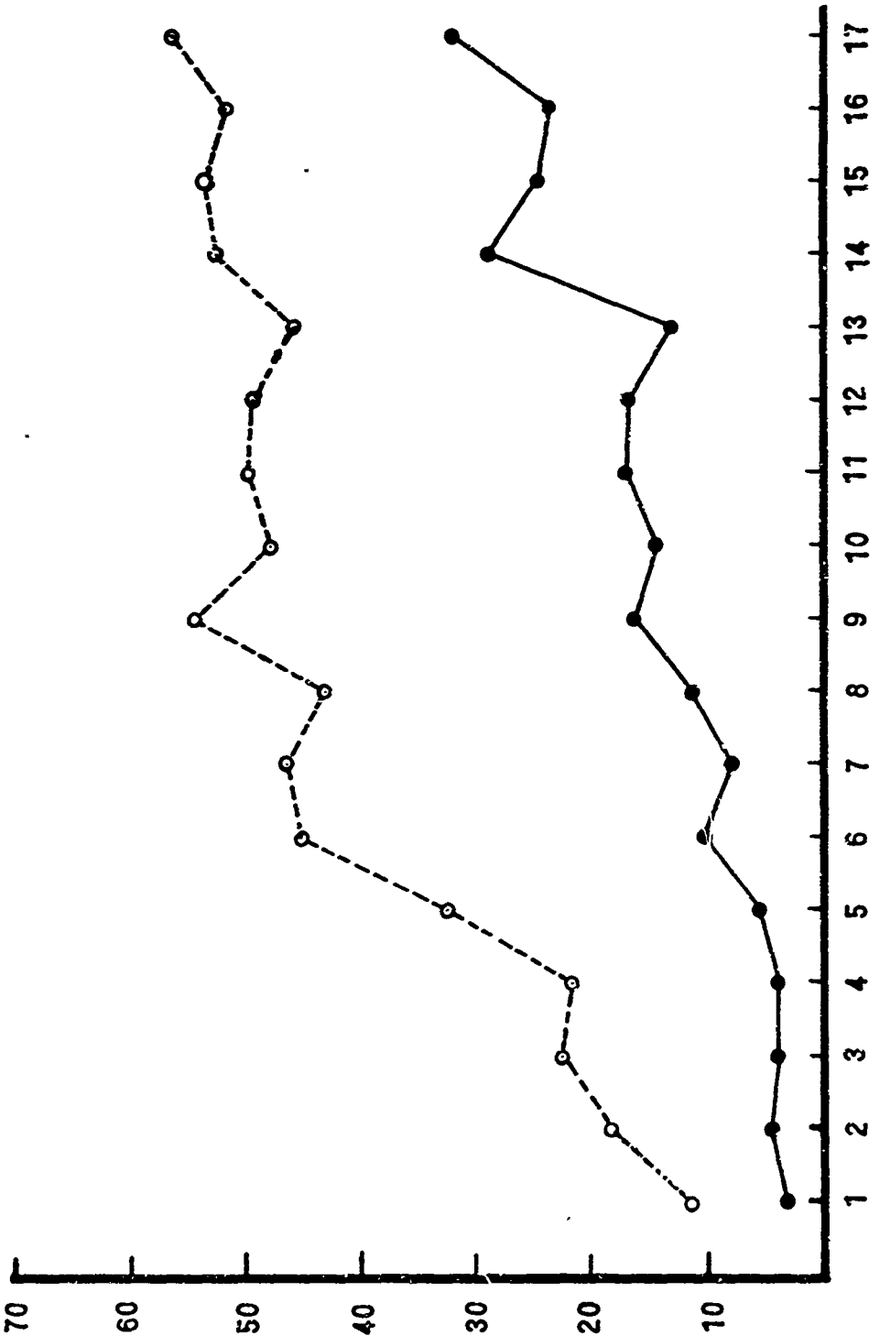
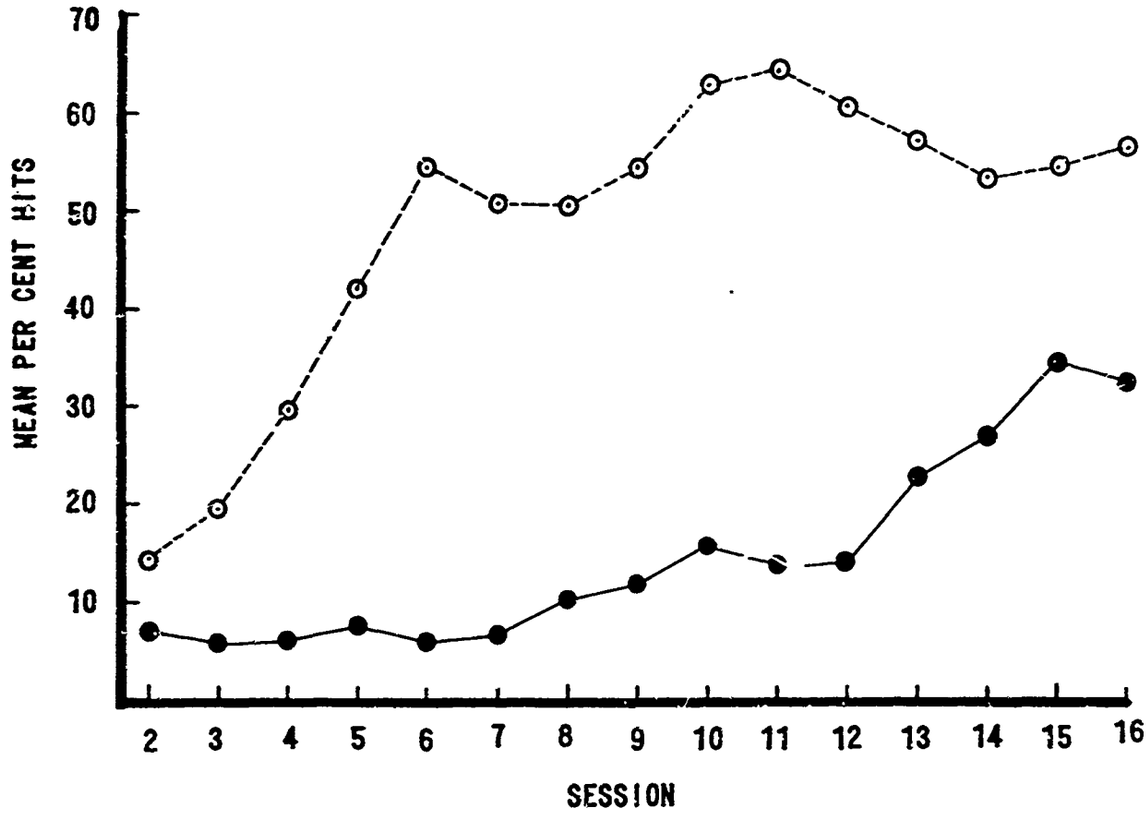
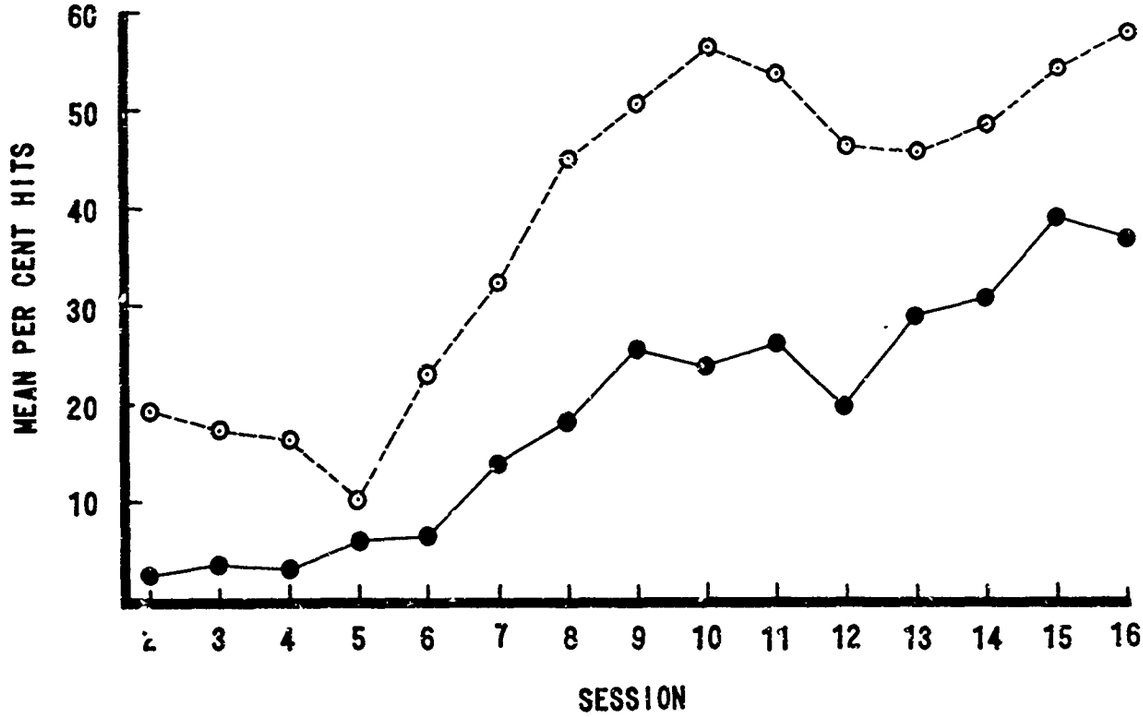
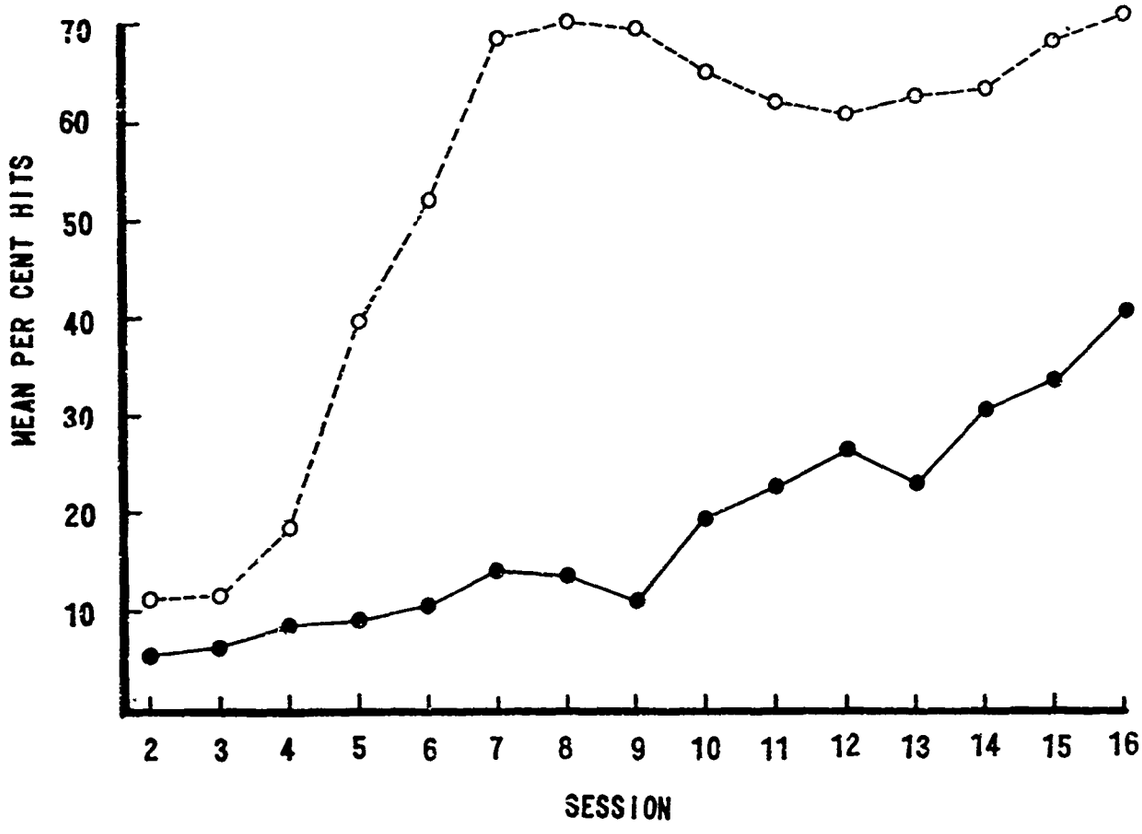


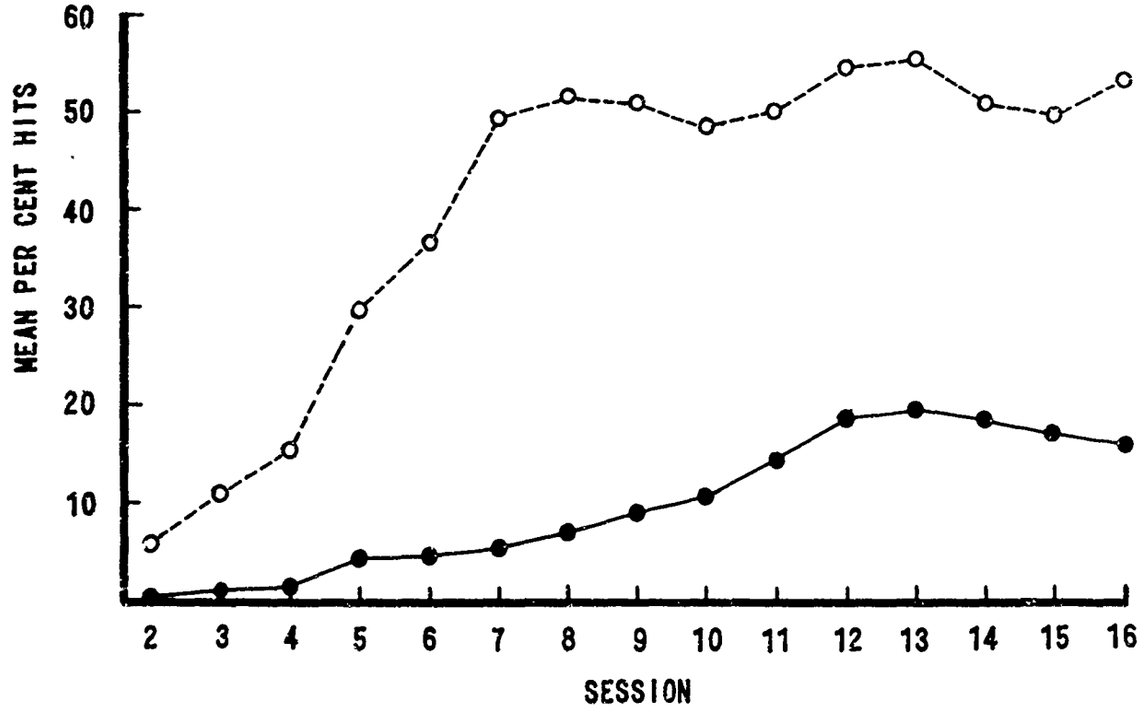
FIGURE 1. PER CENT HITS FOR 12 SUBJECTS DURING PRACTICE AND TEST TRIALS, EXPERIMENT I. THE UPPER BROKEN CURVE REPRESENTS PER CENT HITS FOR PRACTICE TRIALS AND THE LOWER SOLID CURVE PER CENT HITS FOR TEST TRIALS.





FIGURES 2 AND 3. PER CENT HITS DURING PRACTICE AND TEST TRIALS FOR INDIVIDUAL SUBJECTS. EXPERIMENT I. THE UPPER BROKEN CURVE REPRESENTS PER CENT HITS FOR PRACTICE TRIALS AND THE LOWER SOLID CURVE PER CENT HITS FOR TEST TRIALS. THESE CURVES ARE PARTIALLY SMOOTHED BY THE METHOD OF MOVING AVERAGES.





FIGURES 4 AND 5. PERCENT HITS DURING PRACTICE AND TEST TRIALS FOR INDIVIDUAL SUBJECTS, EXPERIMENT I.

THE UPPER BROKEN CURVE REPRESENTS PER CENT HITS FOR PRACTICE TRIALS AND THE LOWER SOLID CURVE PER CENT HITS FOR TEST TRIALS. THESE CURVES ARE PARTIALLY SMOOTHED BY THE METHOD OF MOVING AVERAGES.

the second and third columns show the percent hits for the new attacks.

It will be noted that the performance on the familiar attacks was considerably lower than that attained on the four preceding days. Undoubtedly, a major factor responsible for this lower score was the fact that the usual three blocks of practice runs were omitted on this test day. The subjects did not have the advantage of this practice and warm-up period.

Measured in terms of the performance on the familiar attacks, it will be seen that the subjects' scores on the new test attacks were approximately half as good. A score of 10 to 12 percent on these new attacks is to be compared with the scores made on the first practice day of 2.9 percent. When one considers that the attacks involving higher bomber speeds are probably somewhat more difficult than the original attacks, it is quite apparent that considerable transfer took place.

TABLE II

Mean Scores on Test Runs Fired at New Attacks, Session 18

	Bomber Speed and Direction of Attack		
	200 knots Portside	260 knots Portside	260 knots Starboard
Mean % Hits	21.5	12.4	10.2
Mean No. Hits	57.5	23.3	22.7

(3) Consistency of Performance

In order to obtain an indication of the consistency of the subjects' performance from one daily session to the next, rank difference correlation coefficients were computed between the percent hits made by subjects during test trials for each pair of adjacent sessions. These data are presented in Table III. Data obtained during the first three sessions were not used in this analysis because of equipment difficulties in the scoring system of the apparatus.

TABLE III

Correlations between adjacent sessions based on percent hits made on test runs

Session	r	Session	r	Session	r
4 vs. 5	-.10	9 vs. 10	.49	14 vs. 15	.40
5 vs. 6	-.21	10 vs. 11	.00	15 vs. 16	.62
6 vs. 7	.40	11 vs. 12	.19	16 vs. 17	.40
7 vs. 8	.35	12 vs. 13	.66		
8 vs. 9	.44	13 vs. 14	-.59		

Additional evidence bearing upon this matter of the consistency of performance in this skill is the rank order correlation coefficient of .76 obtained for the test trials between the odd and even day percent hit scores.

III. Experiment II

As noted in the results of Experiment I, the subjects reached an average of 32 percent hits and 88.4 actual hits on test runs by Session 17 with little evidence of a ceiling being approached. Experiment II was conducted to ascertain how much more practice would be required before the limit of improvement would be reached.

A. Equipment

The set-up described for Experiment I was modified for Experiment II as follows: (1) two new projectors and a new, more smoothly-operating turret were installed; (2) a flat beaded screen was substituted for the curved screen of Experiment I; (3) the film for blocks of attacks was reproduced from the original negatives onto a single, unspliced film length of uniformly controlled density.

B. Subjects

The subjects were 8 of the 12 subjects utilized in Experiment I. They were paid at the same rate as previously.

C. Experimental Procedure

Since the subjects had served in the previous experiment, no new indoctrination was given beyond the instructions to the subjects that they were being used in a continuation of the earlier experiment and that the same conditions would prevail.

The blocks fired and the attacks were as described in Experiment I for Sessions 1 through 17.

TABLE V

Mean Scores of 8 Subjects by Sessions, Experiment II

	Practice	Test	
Session	Mean % Hits	Mean % Hits	Mean No. Hits
1	35.4	19.1	53.6
2	46.1	31.7	90.0
3	47.2	33.8	99.6
4	46.7	31.4	93.0
5	48.6	35.9	103.7
6	51.4	40.6	128.3
7	53.3	40.6	122.1
8	55.3	54.5	151.8
9	53.0	50.2	151.2
10	54.7	52.4	168.0
11	55.9	57.8	156.5

(Table V contd. on next page)

TABLE V (Contd.)

	Practice	Test	
Session	Mean % Hits	Mean % Hits	Mean No. Hits
12	57.5	55.3	169.0
13	56.6	54.8	165.9
14	53.5	52.7	171.9
15	53.7	52.8	160.0
16	44.2	50.2	157.5
17	44.1	51.1	140.6

A questionnaire (see Appendix 1) was administered to the eight subjects at the end of Experiment II for the purposes of determining (1) what methods the subjects were attempting to use during practice and test runs to obtain a maximum percentage of hits during test runs, and (2) whether the subjects used different self-imposed training methods during different days or portions of the entire experiment.

D. Results

(1) Learning

The learning scores for the eight subjects of this group are presented in Table III. The scores are the same as those used in the first experiment - mean percent of hits for both practice and test runs, and, in the case of the test trials, the mean number of hits made on each session. Figure 6 provides an over-all picture of the performance of the eight subjects who served in both experiments. The scores (percent of hits) have been averaged in terms of successive two-day sessions, except for the last day of each experiment.

(2) Consistency of Performance

Further data bearing on the level of consistency of the test scores is the rank order correlation coefficient of .50 determined for the test scores (percent hits) obtained on odd and even days. This value is even lower than the comparable value, .76, obtained in the first experiment. Together, they suggest that scores on this test are somewhat lower than usually found in the commonly used tests of motor skills. However, the small number of cases limits the significance of this finding.

IV. DISCUSSION OF EXPERIMENTAL RESULTS

A. Limit of Learning Curve

It is apparent from Figure 6 that a definite limit or maximum level of performance on the test runs was reached by the group as a whole during the second experiment. Making allowance for the break in the training, the data suggest that, on the average, approximately 25-30 practice sessions of the type used in the present experiment are required to attain this maximum level

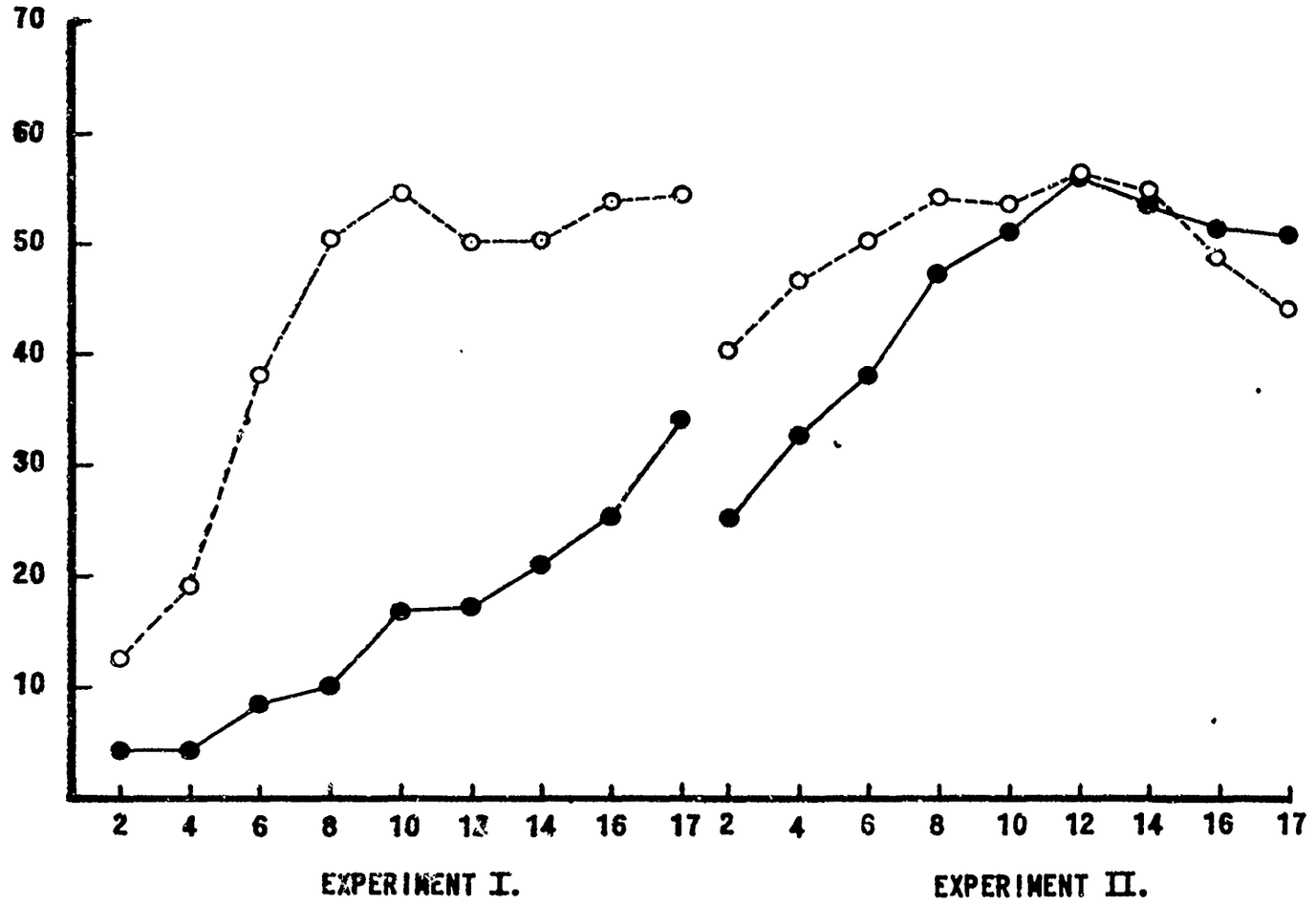


FIGURE 6. MEAN PER CENT HITS FOR 8 SUBJECTS DURING PRACTICE AND TEST TRIALS, EXPERIMENTS I AND II. THE UPPER BROKEN CURVE REPRESENTS PER CENT HITS DURING PRACTICE TRIALS AND THE LOWER SOLID CURVE PER CENT HITS DURING TEST TRIALS. THE MEAN PER CENTS SHOWN ARE AVERAGES FOR EACH TWO SUCCESSIVE DAYS EXCEPT FOR DAY 17 WHICH IS SHOWN SEPARATELY.

of performance. Inspection of smoothed individual curves indicated that all subjects but one seemed to have reached a limit, or at least a prolonged plateau.

It is of some interest also to note in Figure 6 that the group's limit of performance for the test runs in the second experiment closely approximates the limit of the group practice runs on the first experimental session. An examination of the smoothed curves for individual subjects showed that there was also fairly close agreement between these two sets of scores (practice I and test II) in the case of six of the subjects. Two subjects, however, reached a substantially higher level of performance (about 15 percent) on the test scores than they did on the practice runs of either the first or second experimental sessions.

In the case of one of these subjects, the higher test score could possibly be attributed to the fact that the subject greatly reduced the number of rounds fired on the test runs, tending to shoot only at the easier targets. However, the second subject did not do this but actually increased considerably the number of rounds he fired on the test runs as compared with practice runs. An examination of the answers of this subject to the questionnaire revealed no clue as to why his test scores reached a consistently higher level than his practice scores.

The subjects were evenly divided as to whether they believed further practice would bring improvement in their score, but even those who thought they might improve agreed that it was not likely to be very great.

B. Form of Learning Curves

A striking feature of both the group and individual learning curves for the test runs is the very slow progress made during the first few periods of practice. For some subjects this period of little or no improvement lasted for 12 days. Taking the curves for the two experiments and making allowance for the break of several months between them, the data suggest a fairly well defined S-shaped or ogive curve. A similar shaped function will be seen to describe the curve for the practice trials during the first experimental period. The initial phase of positive acceleration, however, is much shorter and rises much more sharply in this latter curve.

The shapes of these curves are interesting in that they differ from the more usual type of negatively accelerated curve obtained in most simple motor learning situations. They are more characteristic of the curves of learning which have been obtained with more difficult and complex learning situations.

C. Transfer of Training

The data obtained in Experiment I from the tests involving new attacks at different (greater) bomber speeds and from a different direction (starboard rather than portside) indicate that the subjects did transfer to some extent, their newly acquired skill with respect to position firing. Under the conditions employed in the present study of using the same attacks over and over, there is a tendency for the subjects to memorize the individual attacks and make use of this memory in anticipating the course of the target.

Nevertheless the results gave definite evidence that there was some learning of the general principles of position firing. It is probable that under training conditions in which a larger number and variety of different attacks were employed the subjects would not be able to depend upon memorizing the attacks and might exhibit an even higher amount of learning of the more general principles of position firing.

D. Consistency of Performance

The correlation data for the two experimental periods indicate relatively low consistency of performance from day to day. While this lack of consistency in performance is in part due to day-to-day and session-to-session variation in the sensitivity of the scoring device in the apparatus, it also reflects considerable variation in the abilities of the subjects to aim correctly. However, the small number of subjects do not provide adequate information either on the reliability of the learning device or the amount of day-to-day variability in the subjects' performances.

E. Method of Scoring

The subjects were instructed prior to the experiment that their performance would be measured primarily in terms of the percentage of hits. From the point of view of providing a measure of individual differences in skill, this measure has the disadvantage that it is influenced by an important factor other than the subjects' skill in proper aiming - namely, the extent to which he tends to fire selectively - choosing to shoot only on the easy attacks or at the easy portions of the more difficult attacks. That the subjects showed great variation in the number of rounds they fired is shown by the range of the averages of this measure from 227 to 353 for a block of test trials. On the average the group fired 10 fewer rounds on the test trials than they did on the practice trials, although three of the subjects actually showed an increase in the number of rounds fired on the test blocks.

1. A group of men with no previous gunnery experience were trained on the 3-A-2 device for 17 daily sessions (Experiment I). On the 18th session, these subjects were tested on new attacks at the same and a different bomber speed. One month later, 8 of the original 12 subjects were trained for 17 additional sessions on the 3-A-2 device (Experiment II).

2. During each session, the subjects fired at three blocks of attacks under practice conditions and at one block under test conditions (correct point-of-aim not visible). The subjects were scored in terms of the percent hits and number of hits they obtained during practice and test attacks during each session.

3. Making allowance for the break in training between Experiments I and II, the data suggest that approximately 25-30 practice sessions of the type used in the present experiment are required to attain a maximum level of performance on the 3-A-2 device. The average maximum score obtained by the subjects ranged from 50 to 55 percent hits.

4. The average performance of the whole group of subjects reached a limit in the test runs of the second experiment which closely approximated the group limit on practice runs in the first experiment. Two subjects, however, did not conform to the above pattern of performance.

5. The learning curves for the two experiments take the form of fairly well defined S-shaped or ogive curves such as have previously been obtained in more complex learning situations.

6. There is relatively low consistency of performance from day to day which may be explained on the basis of both (a) session-to-session variations in the sensitivity of the scoring system of the 3-A-2, and (b) individual variations in the performance of each subject.

7. Limited incidental data indicate that the subjects did transfer their training to new and different attacks. The exact extent of this transfer cannot be determined from the data of the present experiment.

8. There is some evidence that the use of percent hits as the criterion of performance has certain disadvantages because some subjects tend to fire selectively, i.e., they shoot only at the "easy" portions of the attacks.

APPENDIX 1

QUESTIONS ON GUNNERY TRAINING

1. (a) Do you think your performance will continue to improve with additional practice?
   (b) About what percent hits do you think will constitute your ceiling of performance?

2. (a) Describe the "method" you are currently using during practice runs.
   (b) Will you continue to use this method in future practice?
   (c) Describe methods you have previously used and discarded. Why did you discard them?

3. (a) Describe the "method" you are currently using during test runs to get the greatest possible percent hits.
   (b) Will you continue to use this method in future test runs?
   (c) Describe methods you have previously used in test runs and discarded. Why did you discard them?

4. Do you think there is a correlation between rounds fired and hits made on test runs? If so, what sign and what magnitude?

5. What suggestions do you have for improving training procedures with this apparatus and film (same attacks) so as to yield higher percent hits on test runs?

6. Any other comments about this experiment:

APPENDIX 2

EQUIPMENT VARIATIONS AND SCORING SENSITIVITY

Throughout the 3-A-2 learning experiment there was definite indication that the scoring sensitivity of the equipment was varying from day to day and even from hour to hour. In order to attempt to discover the causes of these variations in obtained scores, a number of equipment tests were conducted immediately after the learning experiment I. These tests, the results obtained, and other relevant comments are presented below.

1. Test of dual projector speed with 10-minute standard test film in right-hand projector, left-hand projector empty. At the time of this and succeeding tests, no additional load was imposed on the 115-volt regulated power supply. Time required for 10-minute standard film to pass through projector was 11 min. 1 sec., indicating that the projectors were 10 per cent slow.

The above test was repeated with both projectors threaded and again the time required for a 10-minute standard film was 11 min. 1 sec., indicating that apparently film drag was not responsible for slowing the projectors.

2. The projector speed was checked at 1295 frames per minute with a General Radio stroboscope. A comparison of the resulting 1295 frames per minute with the correct value of 1440 frames per minute substantiates the 10 percent speed loss indicated by the standard test film.

3. The line voltage was tested when both projector lamps and both projector motors were operating. Under these conditions the line voltage was 105 volts. Assuming that the projectors contain good synchronous motors, the drop to 105 volts should not cause a loss in the speed of the motors.

4. In order to determine if a portion of the speed loss might be due to the drag imposed by the synchronous rectifier, the rectifier was disconnected and the standard ten-minute test film was again run through the projector. The test film required 10 min. 55 sec. to pass through, and the projector speed was 1310 frames per minute. The difference between these values and the values obtained in (1) and (2) above is so slight that it may be concluded that the rectifier has almost a negligible effect on projector speed.

5. The projectors were operated with both projector lamps turned off. The resulting line voltage was 111 volts and projector speed was 1320 frames per minute. This indicates that the line voltage drop caused by the projector lamps has little effect on projector speed.

6. The flexible coupling shaft between the two projectors was disconnected and the speed of each projector was independently determined. The speed of the right-hand projector (used for airplane film) was 1230 frames per minute and the speed of the left-hand projector (used for point-

of-aim film) was 1380 frames per minute.

7. The causes of the differences in the speeds of the two projectors and below-standard speed of the projectors have not yet been determined. It is quite possible that the loss of speed of the projectors is due (a) to slippage in the friction drive between the motor and main projector drive shaft, and (b) defects in the motors.

8. Actual effects on scoring depend largely on the resonance characteristics of the filter in the scoring device 3-A-20-C. This filter is peaked at 72 cycles and if it is sharply tuned, a 10 percent variation in the projector speed could cause a large drop in the filter output voltage.

9. An investigation was made of the uniformity of illumination of the scoring area on the projection screen. Previous experience in running subjects on the trainer indicated that the scoring return from the center of the illuminated area on the screen was greater than the return from the periphery of the area. In order to measure this difference, a series of illuminometer* readings were taken from different portions of the screen. During these tests the lamp in only the left-hand projector was turned on, but no film was run through. The resulting intensity readings from the screen are indicated in Table I in units of apparent foot candles.

TABLE I

Top of Illuminated Area

	.647	.797	.456	
Left Edge	.839	.996	.515	Right Edge
	.581	.698	.257	

Bottom of Illuminated Area

The wide variations in illumination indicated above are probably due to the wide angle lens system employed in the projectors; a properly designed corrective filter would yield a more uniform illumination. It is almost certain that these variations in illumination have a pronounced effect on the precision and reliability of the scores obtained when personnel are operating the 3-A-2 device.

* These readings were secured from a MacBeth Illuminometer at the lens of the preamplifier which is mounted on the gun barrel.

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AUTHOR(S) : Knauft, E.B.; Hamilton, C.E.; Spence, K.W.
ORIG. AGENCY : State University of Iowa, Dept. of Psychology, Iowa City, Ia.
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Investigation of nature and extent of learning process involved in mastering of aerial gunnery with subjects firing at film representing different attacks. Subjects were scored in terms of percent hit and number of hits they obtained during practice and test attacks at each session. Average performance of whole group reached a limit in test runs of second experiment. There was relatively low consistency of performance from day to day. Extent of transfer of training to new and different attacks could not be determined.

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