AN INVESTIGATION OF THE LEARNING OF STALL PERCEPTION

by

F. C. Dockeray

and

David Bakan

A report on research conducted at The Ohio State University, Columbus, Ohio, under the auspices of the National Research Council Committee on Aviation Psychology, from funds provided by the Civil Aeronautics Administration.

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Washington, D. C

National Research Council

Committee on Aviation Psychology

Executive Subcommittee

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1948

LETTER OF TRANSMITTAL

NATIONAL RESEARCH COUNCIL

2101 Constitution Avenue, Washington, D. C.
Division of Anthropology and Psychology

Committee on Aviation Psychology

February 16, 1948

Dr. Dean R. Brimhall
Assistant to the Administrator
for Research
Civil Aeronautics Administration
Room 5217, Commerce Building
Washington 25, D. C.

Dear Dr. Brimhall:

Attached is a report entitled An Investigation of the Learning of Stall Perception, by F. C. Dockeray and David Bakan. This report is submitted by the Committee on Aviation Psychology with the recommendation that it be included in the series of Technical Reports of the Division of Research, Civil Aeronautics Administration.

This is one of a series of studies designed to furnish information with respect to the type of training to be given as an aid in avoiding inadvertent stalls. The findings of the present study are not such as to permit definitive recommendations with respect to this problem. It is anticipated that the integration of the results of this study with those of others now in progress will lead to positive recommendations with respect to effective methods of training in stall recognition and in the avoidance of inadvertent stalls.

Cordially yours,

Morris S. Viteles, Chairman
Committee on Aviation Psychology
National Research Council

MSV:rm

EDITORIAL FOREWORD

In recognition of the importance of the inadvertent stall as a causative factor in light plane accidents, the National Research Council Committee on Aviation Psychology has undertaken a series of investigations on stall recognition; on the effect of training on stall recognition; on the isolation of cues which are most efficient in giving warning of an impending stall; and on other aspects of the problem. The results of the first investigation in the series[1] indicated that the accuracy of recognition of the incipient stall, even among experienced pilots, was not high. The purpose of the present investigation was to examine the effectiveness of training on stall recognition.

Although the trend of the results in this experiment was positive in indicating apparent effectiveness for the training procedure, certain limitations in the design of the experiment (also noted in the report) require consideration in the interpretation and application of the findings. In the experiment the performances of two groups of subjects were compared, viz.: (1) an Experimental Group of subjects with limited flight experience who received 10 hours of special training in stall recognition; and a Control Group, containing subjects with considerably more flight experience, who were given no training in the perception of the stall. The assumption was made that the effect of the immediate flight experience of experimental subjects, incident to their training, would be more than offset by the greater past experience of the Control Group, and that therefore any superiority in performance on the part of the Experimental Group could be attributed to their special training rather than to immediate flight experience.

No experimental evidence supporting this assumption has been presented, however, and the lack of comparability of the two groups in terms of amount of immediately recent flight experience introduces the necessity of some reservation in considering the implications of the experimental findings, particularly in terms of formulating a requirement for specialized training in stall perception as a part of the formal flight training curriculum. These findings may acquire more meaning, however, as they are integrated with the results of other studies in this area which are now in progress.

The present investigation was conducted at The Ohio State University, under the direction of Dr. F. C. Dockeray and David Bakan.

February 5, 1948

Morris S. Viteles, Chairman
Committee on Aviation Psychology

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[1]Rulon, P. J. A study of the accuracy of recognition of the incipient stall in familiar and unfamiliar planes. Washington, D.C.: CAA Division of Research, Report No. 74, November 1947.

CONTENTS

SUMMARY

The problems under investigation in this experiment may be formulated in terms of three questions:

1. Can the accuracy of stall perception be improved by special training?

2. In terms of accuracy of stall recognition, how does the level of performance of experimental subjects after training compare with the performance of a Control Group of more experienced pilots, who have not undergone special training?

3. Is there any evidence to indicate that the training effects are transferred to situations in which there has been no special training?

The 30 experimental subjects, who were given special training in stall recognition, all had less than 5 hours experience as private pilots. Control subjects all had between 40 and 60 hours experience as private pilots.

Accuracy of recognition of the incipient stall was measured in terms of the ability of subjects intentionally to fly the plane close to the edge of the stall during certain maneuvers, without actually stalling the plane, as well as their ability to execute other maneuvers without approaching the stalled condition. Degree of approach to the stall was determined through use of an adaptation of a commercial stall warning indicator.

Subject to certain qualifications, the results of the study suggest that the special training was effective in improving the accuracy of stall recognition; that after training the level of performance of the experimental subjects on "assigned" maneuvers was superior to that of the control subjects; and that after training, improvement was evident in the performance of experimental subjects in certain of the maneuvers on which special training had not been given.

In evaluating these findings, however, consideration should be given to the tenability of the assumption on the basis of which Control and Experimental Groups were compared; viz.: that the effect of the immediate flight experience of experimental subjects, incident to their training, would be offset by the greater past experience of the Control Group, and that therefore any superiority in performance on the part of the Experimental Group could be attributed to their special training. The experiment provided no data in terms of which the validity of this assumption could be evaluated.

AN INVESTIGATION OF THE LEARNING OF STALL PERCEPTION

INTRODUCTION

Systematic studies by D. R. Brimhall and R. Franzen have indicated that the incidence of fatal accidents following an inadvertent stall in light planes is high.[1] Although marked engineering advances have been made as a result of which the stalling characteristics of planes have been improved, parallel research directed toward investigation of pilot behavior associated with the inadvertent stall also is necessary.

Research in this latter area is being conducted under the auspices of the National Research Council Committee on Aviation Psychology. Two primary questions which required an answer were: "Does the typical pilot succeed pretty well in identifying the incipience of the stall when he consciously tries?" and "Does the typical pilot frequently depart inadvertently from normal flight in the direction of the stall approach when he has no business doing so?"

An investigation bearing on these questions already has been completed.[2] The results of this study have indicated that the answer to the first question is in the negative. Even experienced pilots, including instructors, failed accurately to recognize the signs of the incipient stall, particularly in unfamiliar planes. In terms of this same investigation the answer to the second question was in the affirmative, i.e., during the course of the study the typical pilot frequently did depart, inadvertently, from normal flight in the direction of the stall.

The present study, although carried out simultaneously with the investigation just referred to, can be regarded as the logical consequent of this previous investigation. In as much as it has been demonstrated that the stall recognition of the typical pilot is inadequate, the question may well be asked: Can the ability of pilots to recognize the signs of an incipient or approaching stall be improved through training? It is this question that the present study was designed to answer.

FORMULATION OF THE PROBLEM

The problem of this experiment may be formulated in terms of three questions:

1. Can the accuracy of stall perception be improved by special training?

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[1]A preliminary report on this research is found in: Proceedings of the Annual Meeting of the Committee on Selection and Training of Aircraft Pilots. Washington, D.C.: CAA Division of Research, June 27, 1947.

[2]Rulon, P. J. A study of the accuracy of recognition of the incipient stall in familiar and unfamiliar planes. Washington, D.C.: CAA Division of Research, Report No. 74, November 1947.

2. How does the level of performance, as influenced by training, compare to the level of performance of subjects who have had at least an equivalent amount of flight experience, but no special training?

3. Is there any evidence to indicate that the training effects are transferred to situations in which there has been no special training?

Using an apparatus to measure the proximity to the stall, which is described on page 3, two groups of subjects were tested for the accuracy with which they could recognize the stall. Each subject in the Experimental Group was given ten hours of special training in stall recognition. The subjects in the Control Group, who were pilots who may be considered to have had at least an amount of flight experience equal to that of the subjects in the Experimental Group at the end of ten hours, were only tested and were given no special training in stall perception.

SUBJECTS

All of the subjects in the experiment were male pilots who had received a private pilot's license (PPL), and who had done some flying within a year of the time in which they participated in the experiment. The requirements for admission to the experiment for each group were:

1. Control Group.

   a. Between 40 and 60 hours of flight experience beyond the PPL.

   b. Approximately 30 hours of flight experience in a Piper Cub, or similar aircraft.

   c. A minimum of 5 hours of flight experience in a Piper Cub, or similar aircraft, within a year of the time of participation in the experiment.

2. Experimental Group.

   a. No more than 5 hours of flight experience beyond the PPL.

   b. Approximately 30 hours of flight training in a Piper Cub, or similar aircraft.

   c. Private pilot's license obtained within a year of the time of participation in the experiment.

It is evident that subjects in the Control Group had a greater amount of flight experience than had subjects in the Experimental Group. There were 17 subjects in the Control Group and 30 subjects in the Experimental Group.

EXPERIMENTAL DESIGN

Two Piper J-3 Cubs equipped with the stall measuring apparatus were employed in the experiment. Three check pilots also were employed, the check pilots also serving as flight instructors for the Experimental Group. The subjects were assigned to 6 sub-groups, i.e., Experimental and Control Group subjects, respectively, were assigned at random among the check pilots and planes. The design of the experiment is schematically represented in Figure 1. However, data from the supplementary flight test only were treated by analysis of variance. Data from the primary testing procedures were treated through development of learning curves.[3]

All the cells involving the Experimental Group contained 5 subjects each; all the cells involving the Control Group contained 3 subjects each, with the exception of one cell which had only two subjects. The purpose of this arrangement was to remove any bias which may have resulted from either check pilot or airplane variation.

STALL MEASURING APPARATUS

Complete description of the stall measuring apparatus is given in the report of the investigation conducted by P. J. Rulon.[4] Briefly, the apparatus as adapted for use in this investigation consists of three major parts.

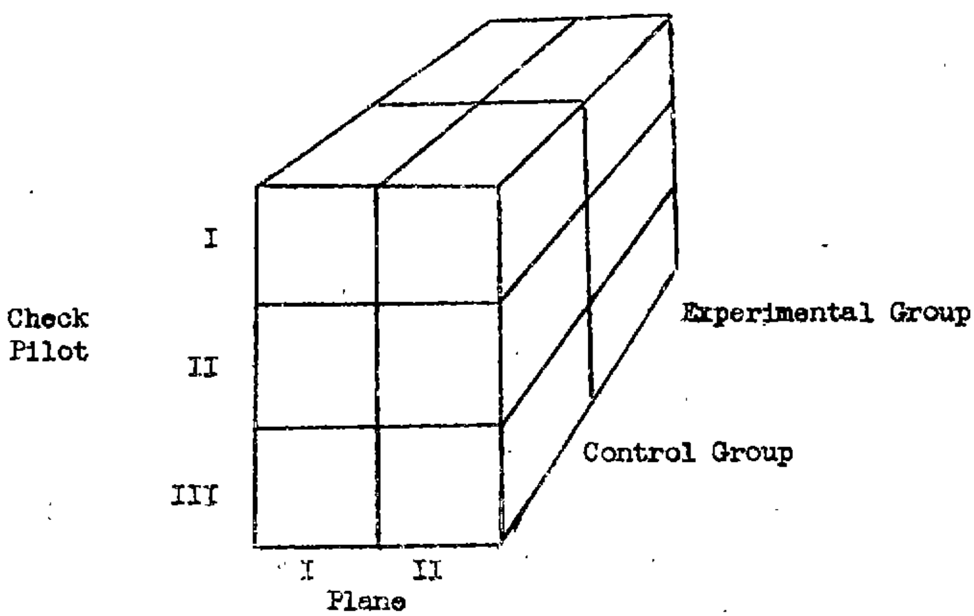

FIGURE 1

SCHEMATIC REPRESENTATION OF EXPERIMENTAL DESIGN

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[3]The nature of the "primary" and "supplemental" flight test procedures is discussed on pages 9 and 10.

[4]Rulon, P. J. Op. cit. The Safe Flight Corporation stall warning instrument was modified, for the purposes of this investigation, by P. J. Rulon.

1. Stall Warner Vanes. The degree to which the plane approached the stall was indicated by means of an adaptation of a commercial stall warning indicator. Five vanes of this instrument were mounted on the leading edge of the left wing (see Figure 2). These vanes were so arranged that as the angle of attack increased the vanes were successively "triggered" as a result of the change in direction of the airflow around the leading edge of the wing.

2. Subject's Indicator Lights. The 5 stall warner vanes were wired into a panel of 5 lamps placed in the subject's line of vision (see Figure 3). As the angle of attack increased and the airplane approached the stall the lamps were successively energized, thereby giving the subject an indication of the degree to which the stall was being approached. This bank of indicator lamps, however, was wired through a switch mounted on the subject's control stick. The circuit was closed, and the lamps rendered operative, only when the subject pressed this switch (see Figure 4). Also, the subject's lamps were wired through a switch available to the check pilot. The check pilot could make the subject's lamps inoperative for test purposes.

3. Check Pilot's Lamp Bank. An identical set of five lamps, connected to the vanes, was available to the check pilot. These lamps were installed on a clipboard which the check pilot held in his lap. The clipboard was used to hold the data sheet on which the check pilot recorded his observations. The subject could not at any time see the lamp bank held in the check pilot's lap. The switch, by means of which the check pilot could "cut out" the subject's lamp bank, was also installed on the clipboard (see Figure 5).

TRAINING PROCEDURES FOR EXPERIMENTAL GROUP

On the basis of a priori considerations and on the basis of extended conversations with skilled pilots, a lesson plan was developed for the ten hours of training. The check pilots were instructed to use the lesson plan as the basic training scheme, but were also encouraged to use any other methods which they believed might improve the subject's ability to perceive the stall. It was clearly pointed out to them that the major problem of the experiment was to find out if pilots could learn to perceive the stall more accurately, and that the best methods for achieving this purpose, on the basis of our present knowledge, should be employed.

Each subject in the Experimental Group was given ten lessons in stall perception on succeeding days (weather permitting). During these lessons his attention was carefully drawn to the various cues by which he could judge that the airplane was in a pre-stall attitude. Practice consisted of bringing the airplane up to the point where he judged himself to be on the edge of a stall, pressing the button, and observing the indicator lamps to inform himself of the accuracy of his judgment.

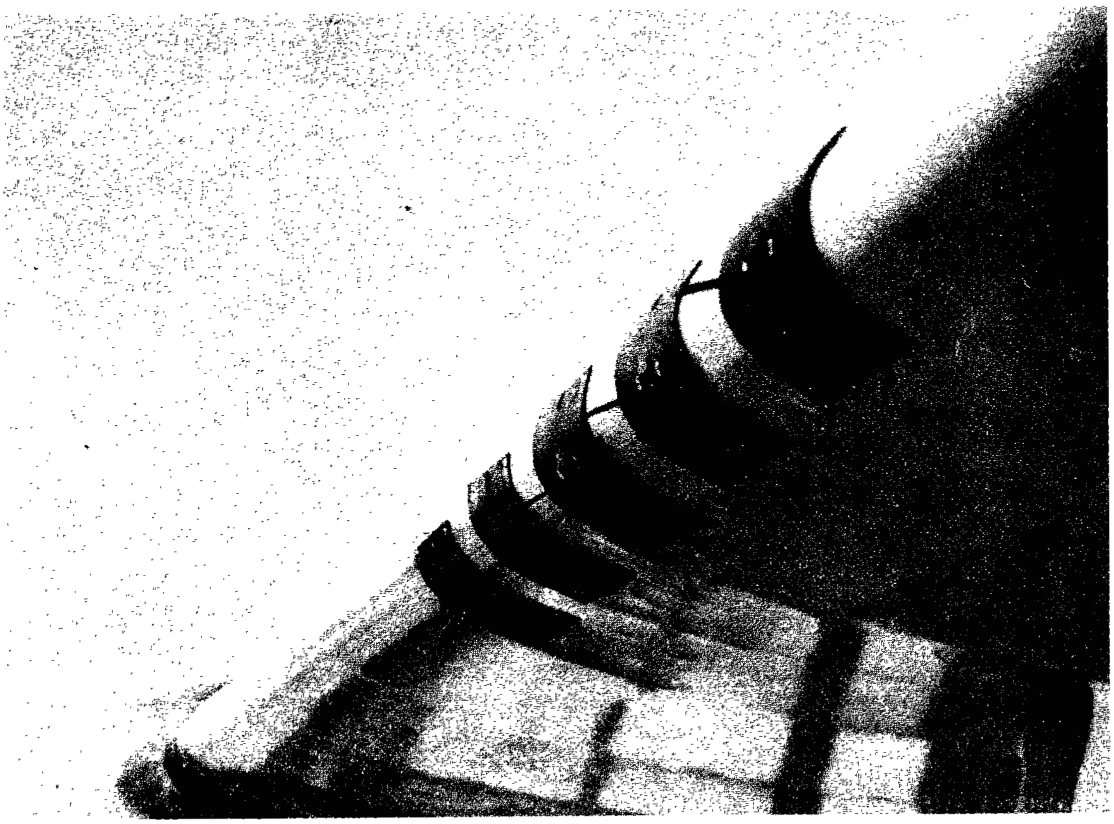

FIGURE 2

VIEW FROM BELOW OF VANE INSTALLATION ON LEADING EDGE OF WING

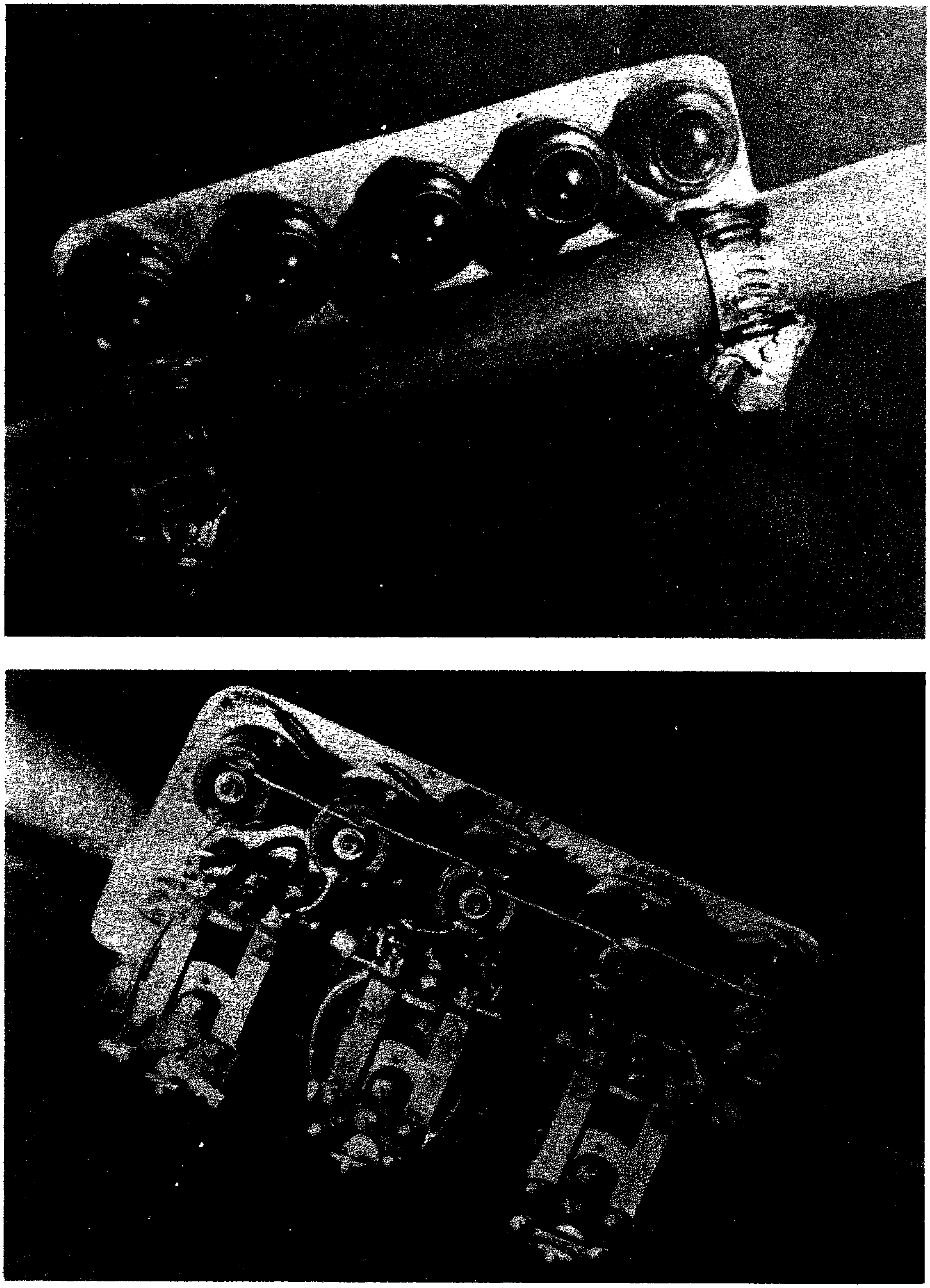

FIGURE 3

FRONT AND REAR VIEWS OF PANEL OF LIGHTS EMPLOYED IN THE LEARNING STUDY

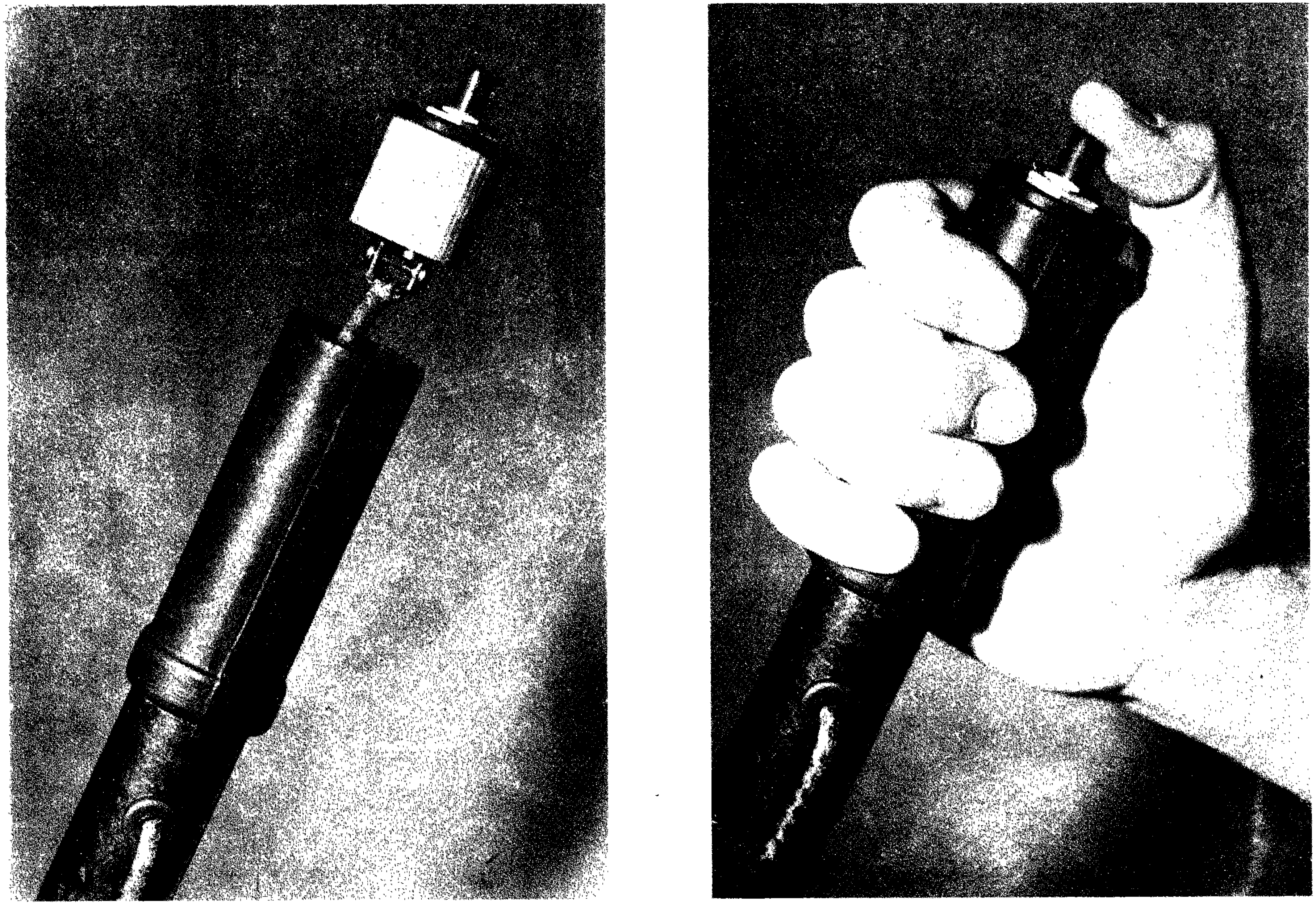

FIGURE 4

BUTTON ON SUBJECT'S CONTROL STICK

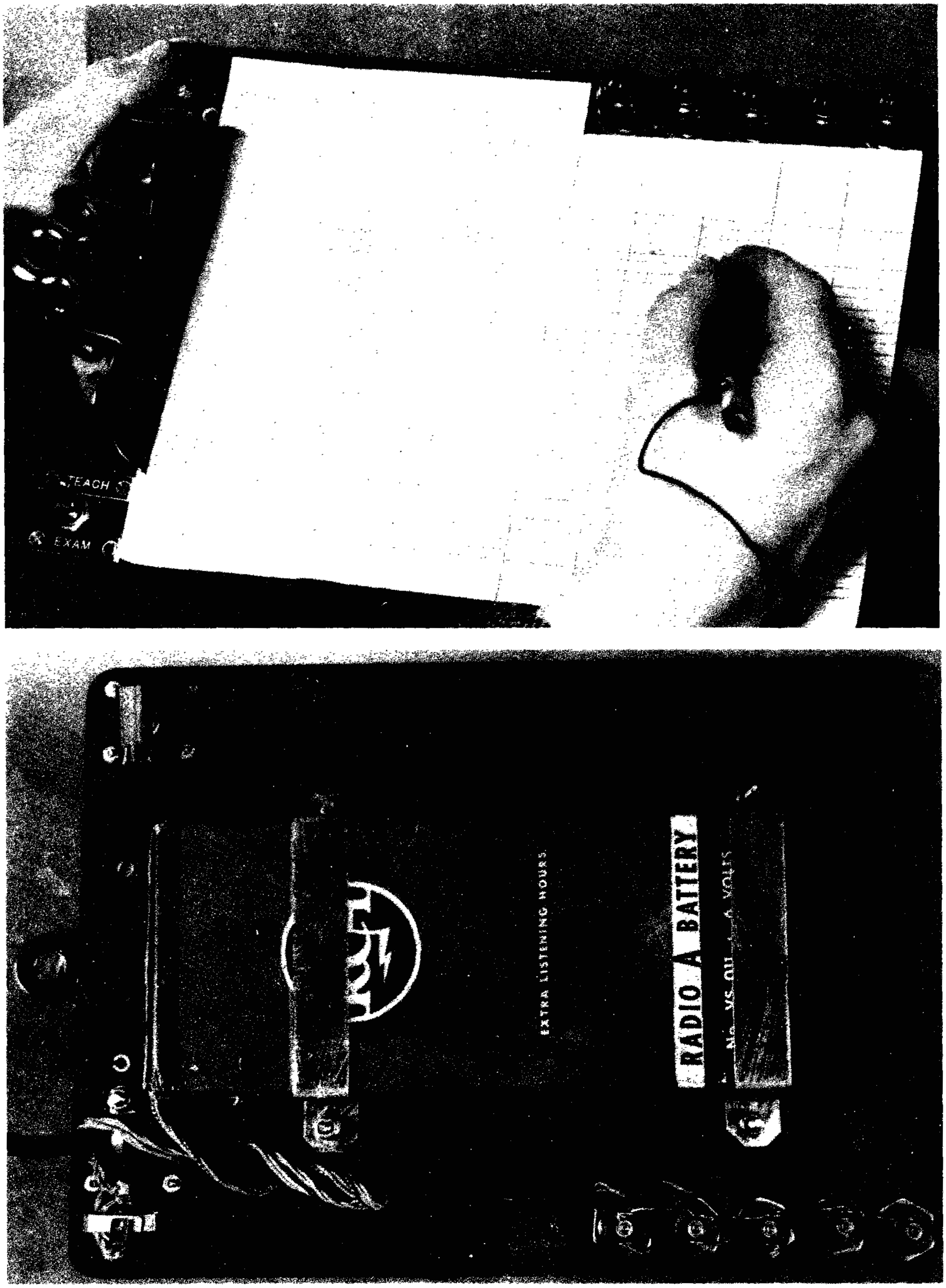

FIGURE 5

FRONT AND REAR VIEWS OF CLIPBOARD AND RECORD SHEET EMPLOYED IN THE LEARNING STUDY

The lesson plan is given in Appendix 1. Briefly, the first lesson was devoted to auditory cues; the second lesson to auditory and visual cues; the third lesson to auditory, visual, tactual, and kinesthetic cues. The remaining seven lessons were devoted to practice. In each practice trial, the task was to bring the airplane as close to a stall as possible without actually stalling the airplane.

TESTING PROCEDURES

The testing procedures used were of two types. These will be referred to as primary and secondary testing procedures. Both the primary and the secondary tests were administered to all subjects in the experiment.

The primary test was given to each subject in the Experimental Group eleven times, once prior to training, and once after each of the 10 lessons. The primary test was given to each subject in the Control Group twice, with a ten-day interval between tests. The secondary test was given to each subject in the experiment on the last flight hour, which was either the tenth or the second hour, depending on the group to which the subject belonged. The nature of these tests was as follows:

1. Primary Testing Procedures.

   a. Assigned Maneuvers. The subject's task, in each case, was to bring the airplane as close to a stall as possible without stalling. The maneuvers out of which the subject was to bring the plane to the edge of the stall were as follows, and were administered in the following sequence:

      (1) Straight ahead, cruising power
      (2) Straight ahead, power off
      (3) Left climbing turn
      (4) Right gliding turn
      (5) Steep left turn at altitude
      (6) Right climbing turn
      (7) Left gliding turn
      (8) Straight ahead, climbing power
      (9) Steep right turn at altitude

The check pilot recorded the maximum number of the signal lamps lit during each of these maneuvers. The maneuvers listed above will hereafter be referred to as assigned maneuvers. They are the maneuvers on which the subjects in the Experimental Group were given special practice, and on which the subjects in both groups knew that they were being graded.

   b. Unassigned Maneuvers. Besides being graded on these assigned maneuvers, the subjects were also graded on what may be called unassigned maneuvers. That is, four times during each test it was necessary for the subject to climb to altitude, make a clearing turn to the left and a clearing turn to the right. Unknown to the subject, the check pilot recorded the number of lamps lit during these maneuvers. Similarly, on the return to the field, the number of lamps lit in the traffic pattern, in the turn, and in the approach was also recorded without the subject's knowledge.

2. Secondary Testing Procedures. This secondary test consisted of having the subjects do the following six tasks in the following order:

a. A forced landing at 1000 feet.
b. A forced landing at 500 feet.
c. A strange field landing.
d. A "sign reading" test.[5]
e. Another forced landing at 1000 feet.
f. Another forced landing at 500 feet.

During the performance of these elements of the test flight the subject's bank of indicator lamps was disconnected by the check pilot, and the subject was not informed of the purpose of this test. In the course of the execution of these forced landings and the "sign reading" test the check pilot carefully observed and recorded the degree to which a stall was approached. These observations were, of course, made in terms of the maximum number of indicator lamps lighted.

RESULTS

Scoring of Over-all Results of Primary Testing Procedures. For the primary testing procedures, there were four scores developed for each test. These represented measures of over-all performance in stall perception. The four types of scores may be schematically represented by the cells of the following four-fold chart:

	Weighted Score	Unweighted Score
Assigned Maneuvers		
Unassigned Maneuvers		

FIGURE 6

The difference between assigned and unassigned maneuvers has already been discussed. As indicated, assigned maneuvers are maneuvers on which the subjects in the Experimental Group were given practice, and on which the

[5]This test was run above the Milleville Railroad Station near Columbus. The task for the subject was to read the sign on the Railroad Station. In order to do this, it was necessary for the subject to bring the plane down to approximately 300 feet.

subjects of both groups knew that they were being graded. The unassigned maneuvers were maneuvers on which no special practice was given, and on which the subjects did not know that they were being graded. The latter may be considered to represent transfer situations.

The unweighted scores represented the percentage of maneuvers executed correctly during each test flight, i.e., correct performance being that in which the optimum number of indicator lamps was lighted.[6] The weighted scores were determined as follows: the performance of a subject during the execution of each maneuver was scored in terms of the difference between the number of indicator lamps lighted and the optimum number which should have been lighted. For example, if 4 lamps represented the optimum number and only 2 were actually lit, the score for the performance would be 2. Possible scores ranged from 0 to 5. The weighted score was represented by the ratio of the weights obtained to the total possible weights, expressed as a percentage. (If the subject went too far and actually stalled the plane the performance was given a score of 0.)

Learning as Indicated by the Over-all Scores of the Primary Testing Procedures. In terms of the four types of scores described above, learning curves based on the mean Experimental Group performances were drawn. These curves are shown in Figures 7, 8, 9, and 10.

In Figure 7 is presented the learning curve for the Experimental Group in terms of the mean unweighted score on the assigned maneuvers. In addition, the mean unweighted scores for the two tests administered to the Control Group also are presented. Examination of these curves indicates quite unambiguously that learning has taken place in so far as the Experimental Group is concerned, and that the training raises the level of performance of the Experimental Group far beyond the level of performance of the Control Group. Similar results are found for the weighted scores on the assigned maneuvers, shown in Figure 8. On the basis of these two curves, the conclusion is definitely warranted that the accuracy of stall perception can be increased by special training and that the level of performance is raised to a point considerably above that of the Control Group.

It may be pointed out that even one lesson is very useful in improving stall perception as indicated by the differences in increment between the Control and Experimental Groups for the first two tests.

Figures 9 and 10 present the corresponding learning curves for the unassigned maneuvers. The unassigned maneuvers may be considered to be transfer situations. In the curves for both experimental and control subjects there seems to be an initial decrement in performance. This decrement for

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[6]The lamp which was correct for each maneuver was determined by the check pilots on the basis of preliminary flying, and on the basis of complete agreement among them. Of course the correct lamp for the unassigned maneuvers was 0. For the assigned maneuvers, the correct lamp differed somewhat from maneuver to maneuver, and from airplane to airplane.

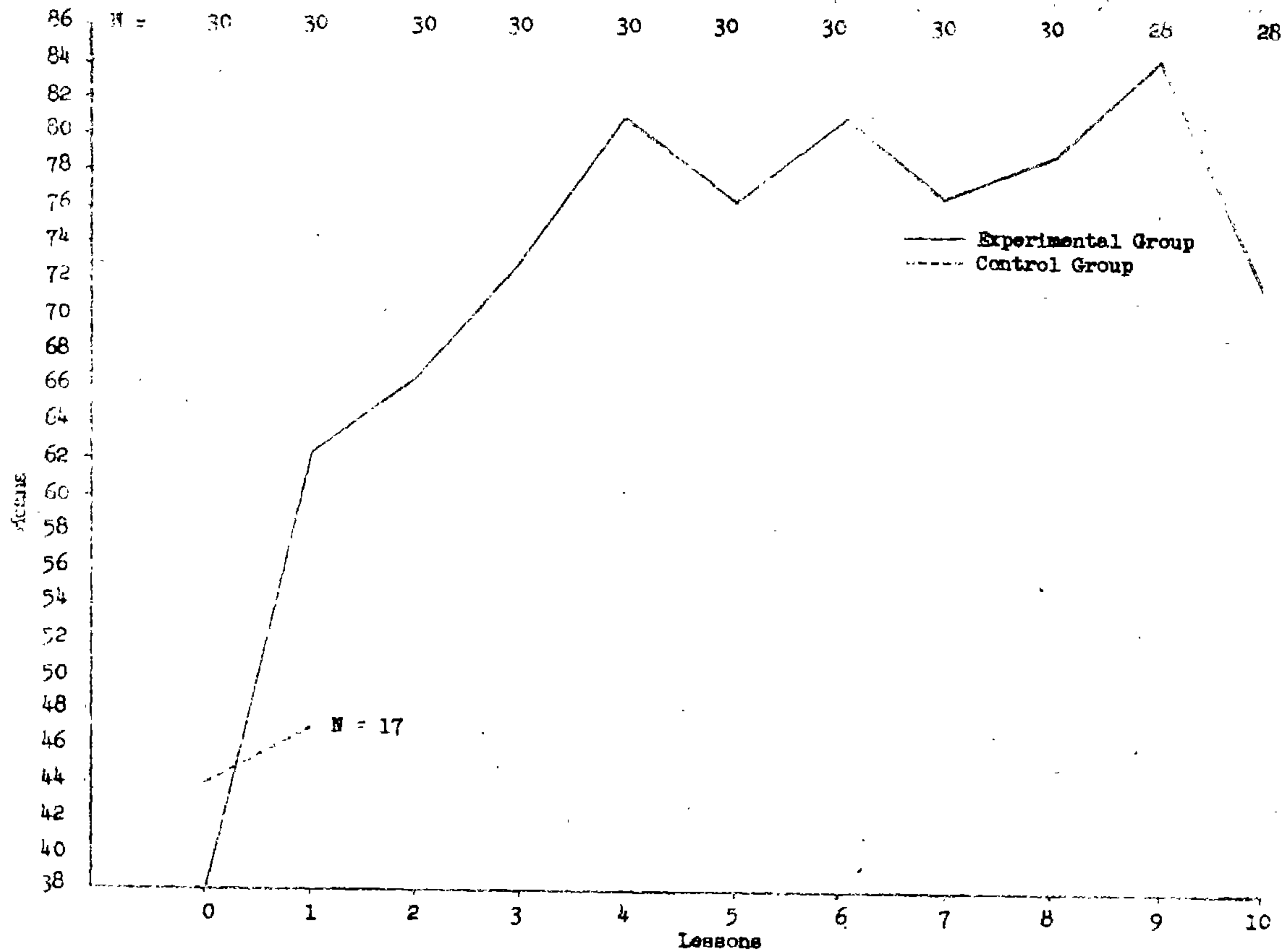

FIGURE 7

LEARNING CURVE FOR UNWEIGHTED SCORE ON ASSIGNED MANEUVERS

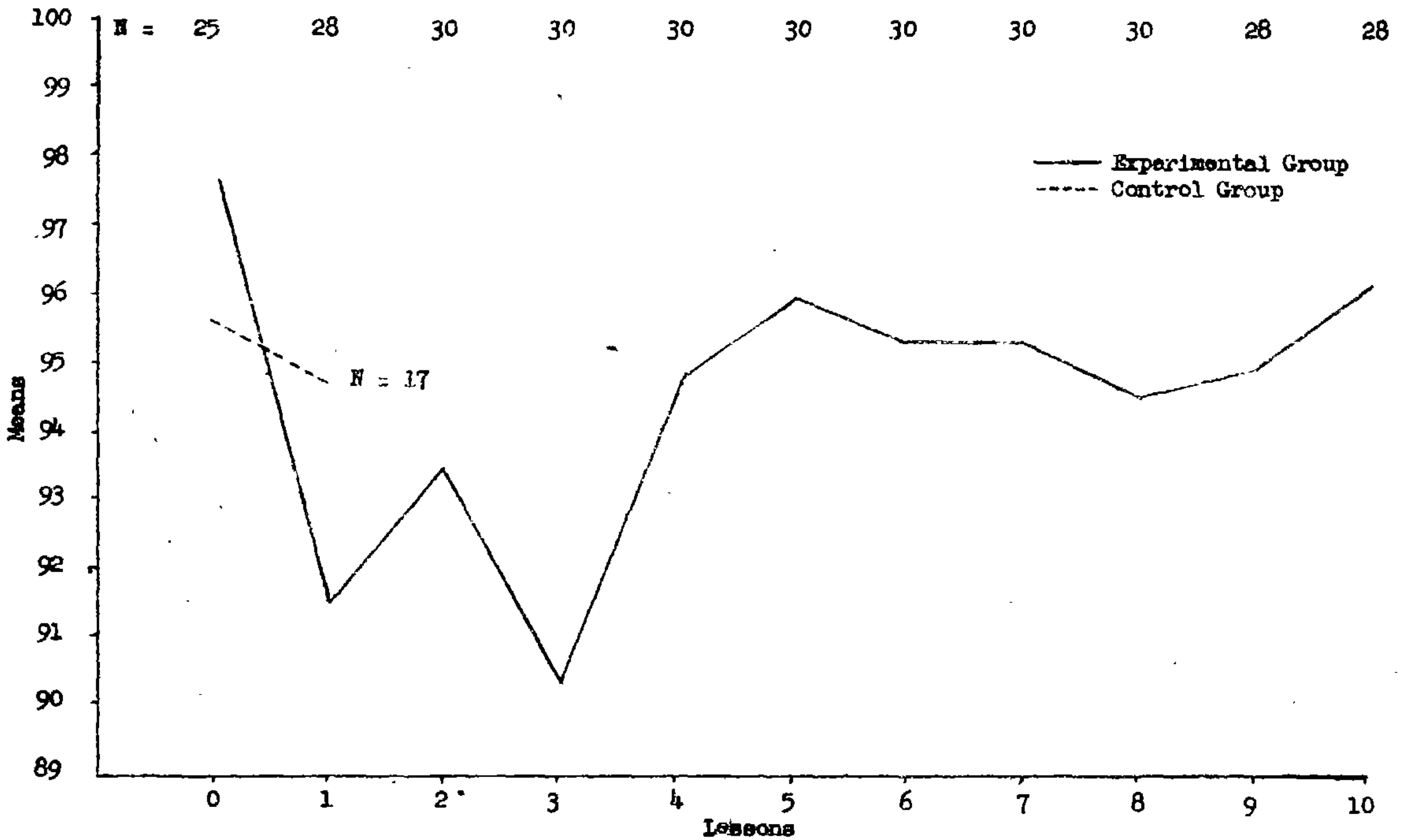

FIGURE 9

LEARNING CURVE FOR WEIGHTED SCORE ON UNASSIGNED MANEUVERS

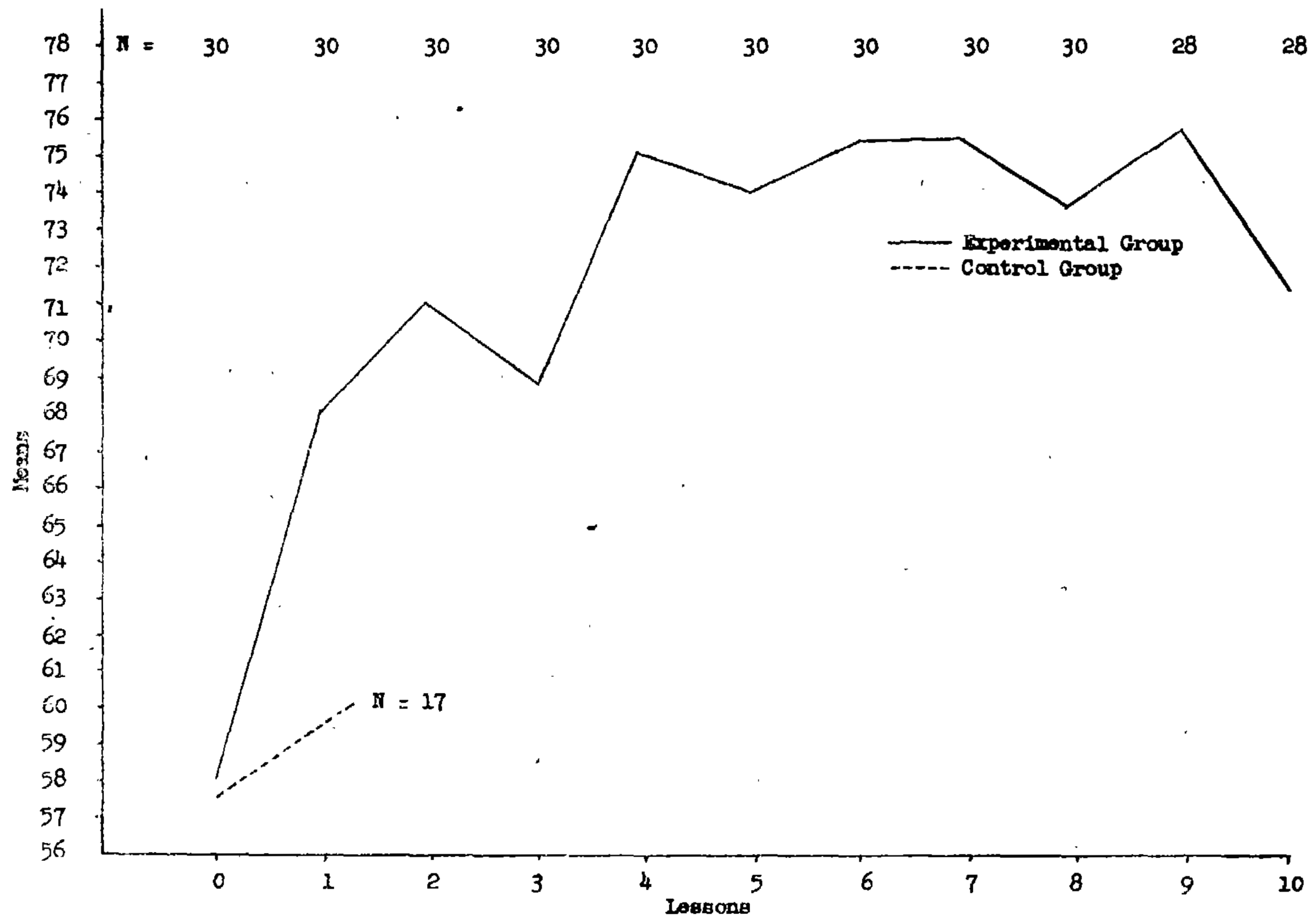

FIGURE 8

LEARNING CURVE FOR WEIGHTED SCORE ON ASSIGNED MANEUVERS

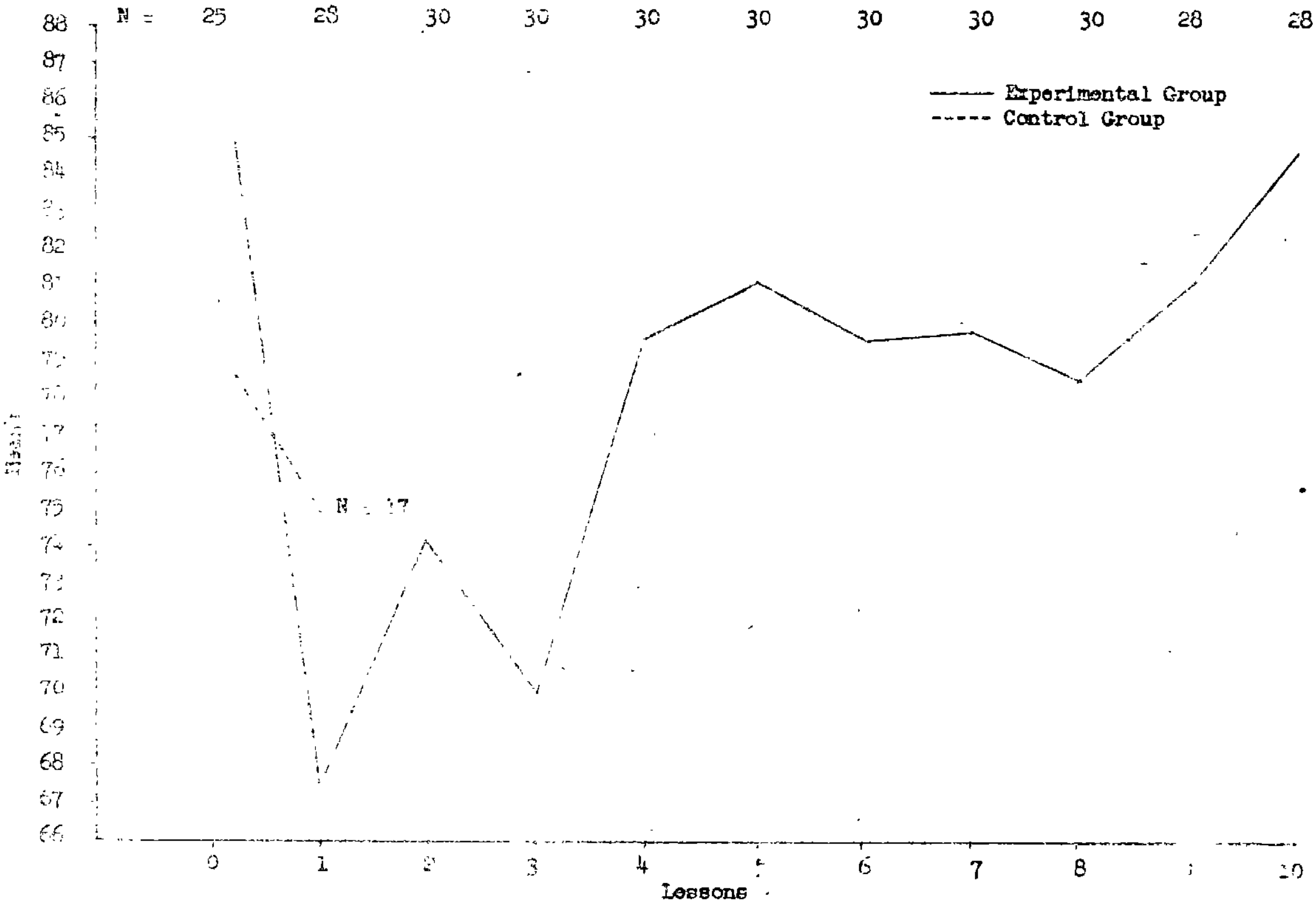

FIGURE 10

LEARNING CURVE FOR UNWEIGHTED SCORE ON UNASSIGNED MANEUVERS the Experimental Group continues through the third lesson. However, following the third lesson, there is apparently a definite improvement, i.e., a tendency for continuous increase in the level of performance of the Experimental Group up to the tenth lesson. This suggests the possibility that more training would have resulted in still better performance on the unassigned maneuvers.

An explanation for the initial dip in the learning curves on the unassigned maneuvers has been offered by the check pilots as follows: at the very beginning of training, the subjects were extremely cautious in their handling of the airplane. Particularly, they did not have confidence in the airplane since they did not know its stalling characteristics. The initial decrement in performance may have resulted from increasing carelessness with increased familiarity. However, as training increases, although there may be no further change in the attitude of the subject with respect to care in handling of the airplane, there is a definite increase in skill, which accounts for the progress in performance following Lesson 3.

It is clear that following the third lesson, the level of performance of the Experimental Group is certainly equal to or better than the level of performance of the Control Group. The evidence indicates that even on the unassigned maneuvers the training is effective.

<u>Learning as Indicated by Performance on Individual Assigned Maneuvers</u>. In Figures 7-10 the results in terms of over-all performance on all assigned maneuvers have been presented. Learning curve analyses have also been made in terms of individual maneuvers. Learning curves for these maneuvers are presented in Figures 14 to 22 in Appendix 2.

In considering the implications of these learning curves it should be remembered that in the assigned maneuvers the lighting of an optimum number of indicator lamps was desirable. Figures 14 to 22 in Appendix 2 are discussed below:

<u>Figure 14, Straight ahead, cruising power</u>, shows a fairly consistent improvement through the third lesson, and a leveling off thereafter. The level of performance of the Experimental Group is consistently superior to that of the Control Group.

<u>Figure 15, Straight ahead, power off</u>, shows a very slight upward rise, but with considerable fluctuation. The level of performance of the Experimental Group is consistently superior to that of the Control Group.

<u>Figure 16, Left climbing turn</u>, again shows a very slight upward rise with considerable fluctuation and superiority to the Control Group.

<u>Figure 17, Right gliding turn</u>, shows a rapid rise through the second lesson, followed by fluctuation at a superior level which never drops to the level of performance of the Control Group.

Figure 18, Steep left turn at altitude, shows a fairly consistent rise up to the seventh lesson, and a tendency to drop off thereafter. The Control Group shows a rise between the first and second tests. The level of performance of the Experimental Group is superior to the best level of performance of the Control Group at the fourth, sixth, seventh, and eighth lessons. With the exception of the initial level of performance, the Experimental Groups shows superiority to the initial level of the Control Group for every hour.

Figure 19, Right climbing turn, shows a general rising tendency, with considerable fluctuation in the early tests, and less fluctuation in the later tests. Superiority to the Control Group is indicated.

Figure 20, Left gliding turn, shows a steady rise, with little fluctuation, and consistent superiority to the Control Group after the first lesson.

Figure 21, Straight ahead, climbing power, shows a consistent rise through the fourth test and a slight drop thereafter, followed by a leveling off. However, at no point after the initial test does the level of performance of the Experimental Group fall below that of the Control Group.

Figure 22, Steep right turn at altitude, shows a rapid rise through the second lesson, a drop, and then a fairly consistent rise thereafter. Again, the Experimental Group shows superior performance to the Control Group following the first lesson.

Although there are several ambiguities in these data, the over-all picture seems to indicate that learning takes place and that the levels of performance reached by the subjects in the Experimental Group is in general superior to that of the subjects in the Control Group.

Learning as Indicated by Performance on Individual Unassigned Maneuvers. The corresponding learning curves for individual unassigned maneuvers are presented in Figures 23 to 30 in Appendix C.[7] Since, as noted previously, optimum performance in the unassigned maneuvers required that no lamps be lit, the lower the point on these curves the better the indicated performance.

Inspection of these curves indicates a considerable degree of fluctuation which renders difficult the ascertaining of any clear cut trends. However, the general indication is that for the Experimental Group following the fourth or fifth period either a downward trend of the curve or a general leveling off of performance occurred. In general, the performance of these experimental subjects appears to grow poorer up to about the fourth or fifth period and then improves. These curves are important since they represent a possible indication of the transfer of training from maneuvers in which specific training has been given to maneuvers towards which no such training has been specifically directed. It is perhaps significant in this connection that the performance of experimental subjects in these unassigned maneuvers is

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[7] With the exception of the Pattern, Last turn into the Field, and the Final Approach which are discussed separately.

not as unequivocally superior to the performance of the Control Group as was the case with the assigned maneuvers. This may perhaps result from the fact that the mean number of indicator lamps lit by both control and experimental subjects was relatively small.

Learning as Indicated on the Unassigned Maneuvers, Pattern, last turn into the field, and Final approach. The learning curves for these maneuvers are of particular importance in connection with the problem of the inadvertent stall, since it is in these maneuvers that inadvertent stalls are particularly dangerous. The curves for these three maneuvers are presented in Figures 11 to 13.

It will be noted that the levels of performance of these three maneuvers are, in general, inferior to the levels of performance on the other unassigned maneuvers, the curves for which are shown in Figures 23 to 30, although evidence of improvement for the Experimental Group is somewhat more clear.

The learning curve for the Pattern (Figure 11) shows a steady decline and a leveling off at the end of the sixth lesson. However, the level of performance reached by the subjects in the Experimental Group does not indicate superiority to the Control Group.

The learning curve for the last turn into the field (Figure 12) similarly shows a slight drop up to the end of the sixth lesson. The leveling off here seems to take place at the end of the seventh lesson at a point in between the two points of the Control Group curve.

The learning curve for the Final approach (Figure 13) shows a very consistent downward trend, to a point which is clearly superior to that of the Control Group.

On the basis of examination of these curves there is some indication that the training given to subjects in the Experimental Group has positive transfer value to these three maneuvers which may be regarded as particularly important with respect to safety. That is, performance on these unassigned maneuvers tended to improve throughout the training period despite the fact that specific instruction in terms of these maneuvers was not given. It should be noted, however, that this improvement was not as great as the improvement in terms of the maneuvers on which specific training was given. Except in the case of performance during the final approach it cannot be said unequivocally that the performance of the Experimental Group at the end of training was superior to the performance of the Control Group. Conversely, however, following training the Experimental Group clearly was not inferior to the Control Group, members of which had had considerably greater flight experience than had members of the Experimental Group.

Secondary Testing Results. It will be recalled that in the case of both experimental and control subjects during the last flight hour an additional (or supplementary) test was administered. This test consisted of having the subjects execute forced landings, strange field landings, and a

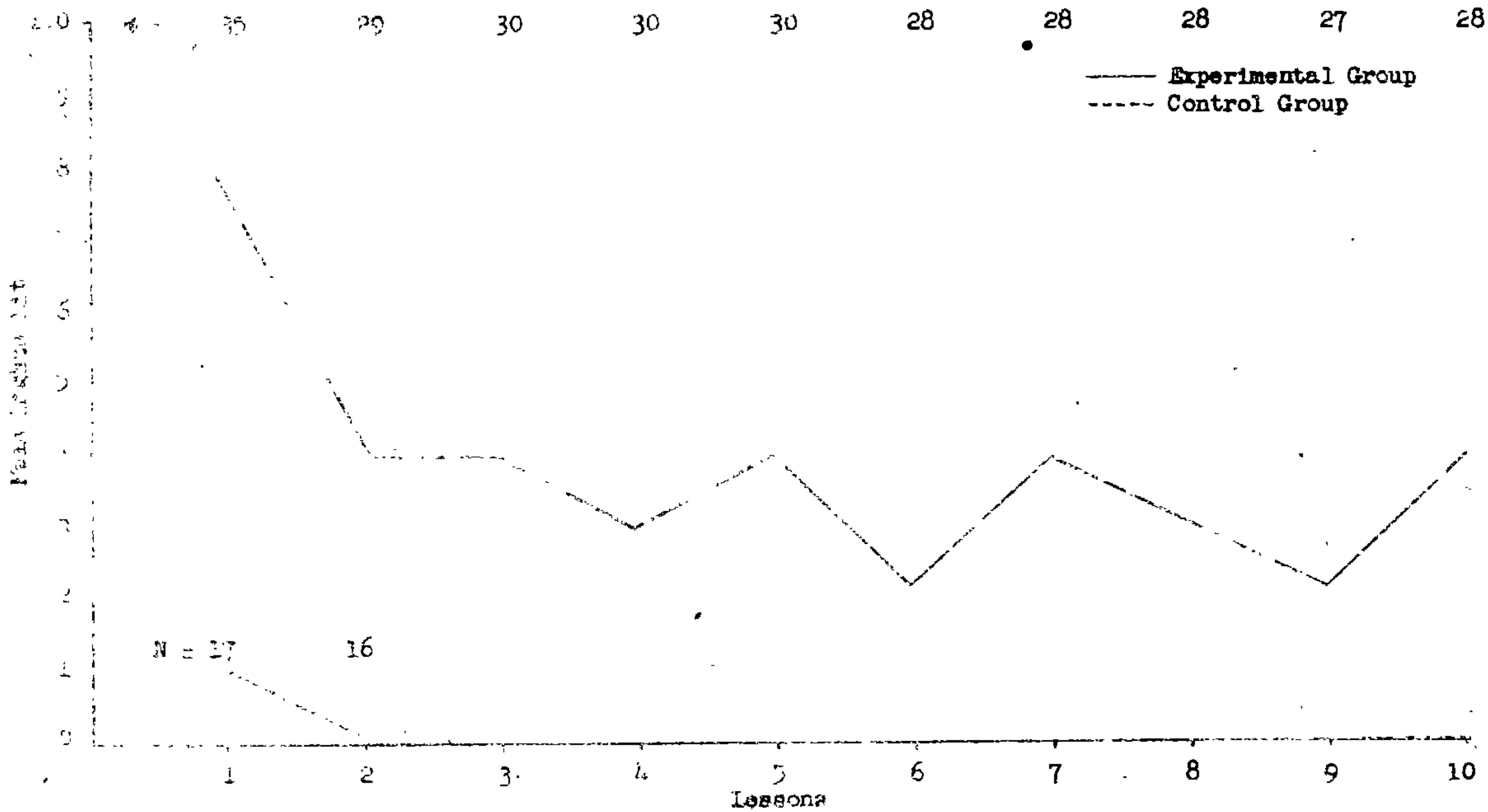

FIGURE 11

LEARNING CURVE FOR PATTERN

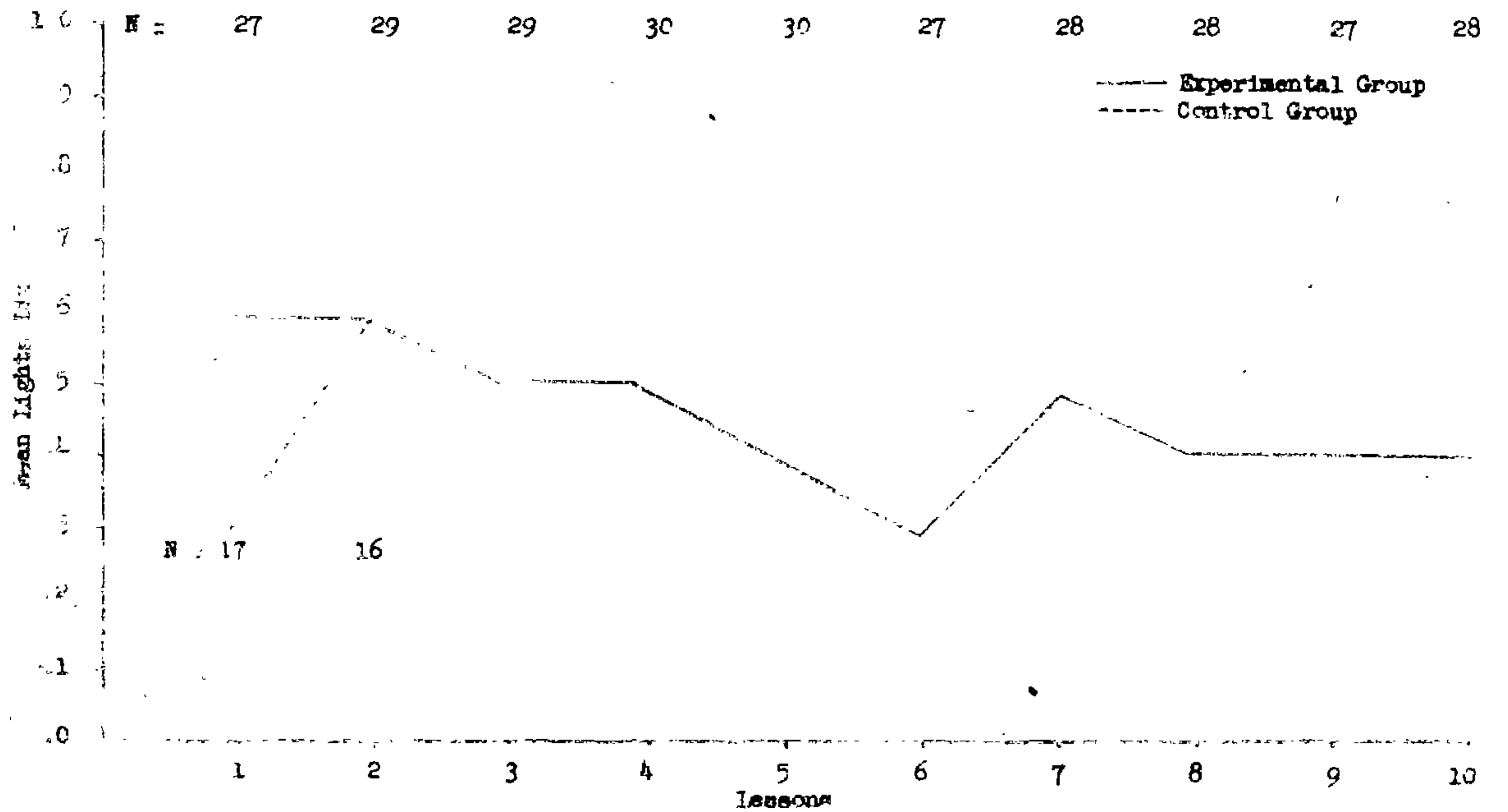

FIGURE 12

LEARNING CURVE FOR LAST TURN INTO FIELD

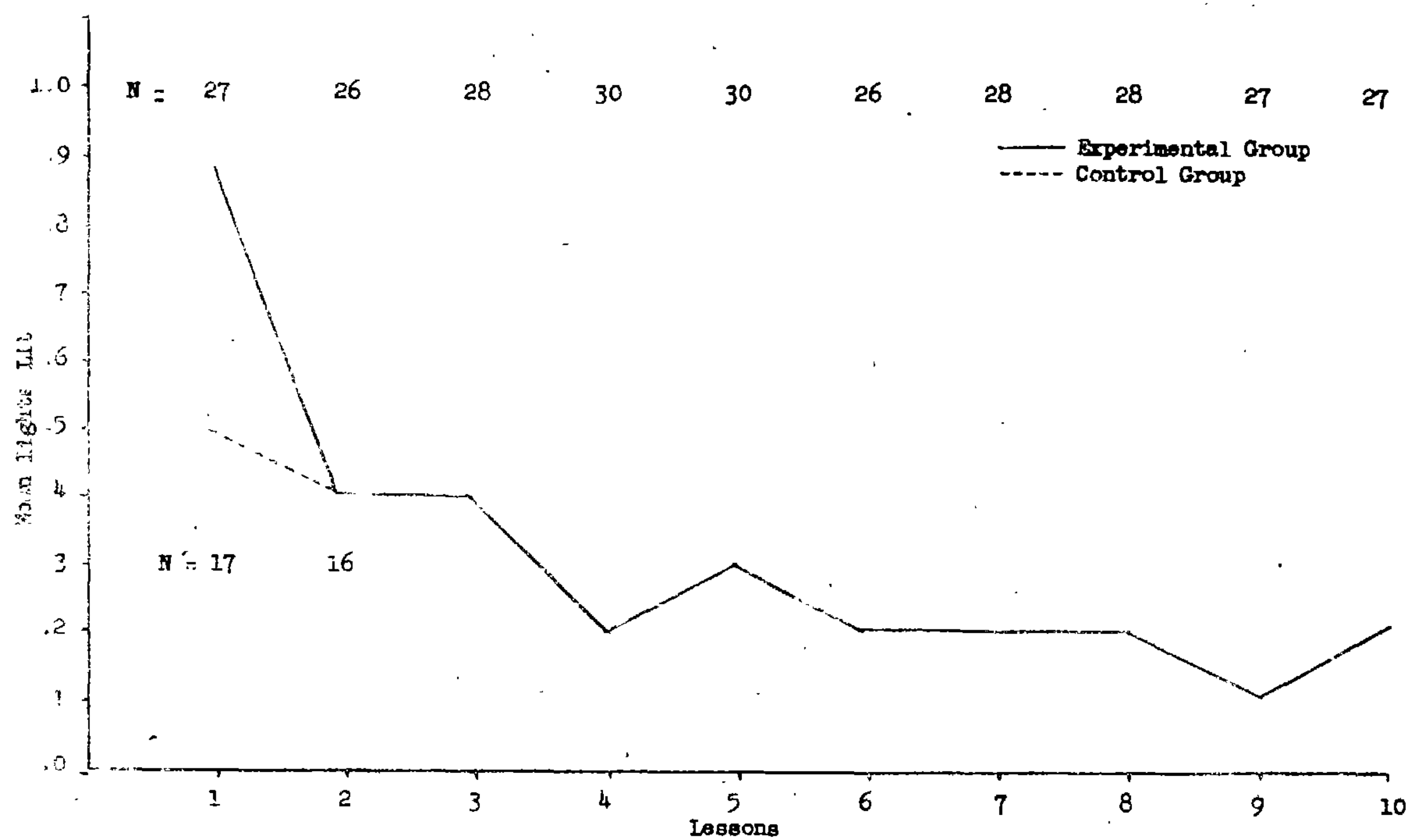

FIGURE 13

LEARNING CURVE FOR APPROACH

"sign reading" test. During each of these maneuvers, the check pilot recorded the number of lamps lit.

The results of this test were analyzed separately for each maneuver by the methods of analysis of variance and, in the instance of forced landings at 1000 feet, separately for the number of lamps lit above 500 feet and the number of lamps lit below 500 feet. The analyses were carried out in accordance with the design schematically represented in Figure 1. Variances due to check pilot, planes, groups, first order interactions, and the second order interaction were computed. In most instances, the error term used was the within cell variance. However, in some instances, the available data were so disproportional as not to permit this type of analysis. Instead, the means were computed for each cell, and the analysis was done in terms of the means. The error term used in this latter type of analysis was the second order interaction variance.

Table 1 presents the p-values obtained from the evaluation of each source of variation. Examination of this table indicates that only in the case of the final approach on the strange field landing was a significant group variance in performance found. In this instance, the Experimental Group showed better performance; that is, smaller mean number of lamps lit, than the Control Group. Examination of the direction of the difference between the means shows that out of the fourteen analyses, the Experimental Group shows better mean performance in ten of the instances. The general conclusion from these data is that the obtained trend is in favor of the Experimental Group. It may be concluded that either there is no true difference between the groups, or the true difference is in favor of the Experimental Group. The evidence does not supply any basis for believing that the Control Group is better than the Experimental Group, although the Control Group consisted of pilots considerably more seasoned than the pilots of the Experimental Group.

DISCUSSION AND CONCLUSIONS

From the data collected in the course of this investigation, there is evidence that all of the three questions which the experiment was designed to answer may be answered in the affirmative. First, the experiment indicated that the accuracy of stall perception can be improved by special training. Second, in general, the level of performance reached on "assigned maneuvers" by the experimental subjects after training was superior to the performance of control subjects having at least as much, and in general considerably more, flight experience, but no special training. Finally, there was evidence, at least in regard to performance in the Traffic Pattern, Last turn into the field, and Final approach, that training in "assigned maneuvers," possibly through the operation of a transfer effect, improved performance in "unassigned maneuvers" such as the three above, in terms of which special training was not given. This is particularly important with respect to these three maneuvers mentioned, which are all executed at a low altitude, and are frequently associated with accidents resulting from an inadvertent stall.

TABLE 1

STALL LEARNING STUDY - ANALYSIS OF VARIANCE OF FORCED AND STRANGE FIELD LANDING

Source of Variation	First Frcd. Land 1000 ft. Maxim Lts. Above 500 ft	First Frcd. Land 1000 ft. Maxim. Lts. Below 500 ft.	First Frcd. Land. 1000 ft. Lts. on final approach	First Frcd. Land. 500 ft. Maximum Lights	First Frcd. Land. 500 ft. Lts. on final approach*	Strange Field Land. Lts. on entry to pattern	Strange Field Land. Lts. on gliding turn
Instructors	P> .20	P> 20	.01> P> .001	P> .20	.20> P> .05	P> .20	P> .20
Planes	.20> P> .05	P> .20	P> .20	.20> P> .05	P> 20	.20> P> .05	P> .20
Groups	P> .20	P> .20	P> .20	P> .20	.20> P> .05	P> .20	P> .20
I x P	P> .20	P> .20	P> .20	.20> P> .05	P> .20	P> .20	P> .20
I x G	P> .20	P> .20	P> .20	P> .20	.20> P> .05	P> .20	P> .20
P x G	P> .20	.20> P> .05	P> .20	P> .20	.05> P> .01	P> .20	P> .20
I x P x G	P> .20	P> .20	.20> P> .05	.05> P> 01		P> .20	P> .20
Means							
Exp. Group	0.42	0.64	0.38	1.00	1.94	0.16	0.97
Con. Group	0.36	0.93	0.56	0.76	0.54	0.12	0.92

Source of Variation	Strange Field Land. Lts. on final approach	Second Frcd. Land 1000 ft. Maxim. Lts. Above 500 ft.	Second Frcd. Land. 1000 ft. Maxim. Lts. Below 500 ft.	Second Frcd. Land. 1000 ft. Lts. on final approach	Second Frcd. Land 500 ft. Maximum Lights	Second Frcd. Land. 500 ft. Lts. on final approach	Kileville Sign reading Test*
Instructors	.20> P> .05	.20> P> .05	.05> P> .01	P> .20	P> .20	.05> P> .01	P> .20
Planes	P> .20	P> .20	P> .20	P> .20	P> .20	P> .20	P> .20
Groups	.05> P> .01	P> .20	P> .20	P> .20	P> .20	P> .20	P> .20
I x P	P> .20	P> .20	P> .20	P> .20	P> .20	P> .20	P> .20
I x G	.20> P> .05	P> .20	P> .20	P> .20	P> .20	P> .20	P> .20
P x G	P> .20	.20> P> .05	.20> P> .05	P> .20	P> .20	P> .20	P> .20
I x P x G	.05> P> .01	.20> P> .05	P> .20	.20> P> .05	.20> P> .05	P> .20	
Means							
Exp. Group	0.38	0.37	0.71	0.38	0.88	0.46	0.13
Con. Group	0.81	0.41	0.73	0.69	1.06	0.62	0.27

*Second order interaction used as error term.

With respect to the data gathered in the "secondary" flight test, although the Experimental Group proved significantly better than the Control Group in terms of only one maneuver, examination of the differences in means indicated that for ten of the fourteen analyses the Experimental Group showed better mean performance than the Control Group. While these findings do not yield completely unequivocal interpretations, the evidence does not supply any basis for believing that the performance of the Control Group was superior to that of the Experimental Group, although the Control Group consisted of more seasoned pilots.

In addition to the quantitative evidence, the miscellaneous comments made by subjects in the Experimental Group support the indications of effectiveness of the type of special training in stall recognition which was employed. While, detailed records of these comments were not made, the nature of the comments indicated that the subjects quite generally were of the opinion that a better "feel" of the plane, during slow flight or under incipient stall conditions, was being obtained, as well as greater confidence in their ability.

It would appear, then, that the critical factor involved in the improvement of performance of the Experimental Group, and their superiority to the Control Group in the situations indicated, was the specialized training, involving the use of the stall indicating apparatus, which was employed. With reference to this apparatus, its chief advantage might seem to lie in the "knowledge of results" which its use provides.

However, two qualifications of this point of view might be noted. First, the improvement evident in the Experimental Group might merely have resulted from the increased familiarity with the plane gained by these subjects during the ten hours of training. Second, it could be argued that ten hours of training, without use of the stall indicating apparatus, might have yielded as effective results as were obtained in this experiment.

Regarding the first of these points, it is probably unquestionable that increased familiarity, <u>per se</u>, was responsible to some degree for the improvement in performance. The Control Group had, of course, more experience in planes comparable to the ones used, than had the Experimental Group. Nevertheless, the concentrated experience in a given plane obtained in the course of their training undoubtedly improved the performance of the experimental subjects. The degree to which this familiarity was responsible for their performance could not be determined in the present experiment.[8]

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[8]<u>Editor's Note</u>: This question might have been answered had the Control Group been given the same number of flight hours during the investigation as was the Experimental Group, but without the special stall training. This additional element of control was not, however, included in the design, in part for reasons of economy. However, control subjects all had more than 40 hours of experience as private pilots, whereas experimental subjects had a <u>maximum</u> of 5 hours experience as private pilots.

Regarding the second qualification, it may be questioned that ten hours of stall training, without the use of the stall indicating apparatus, would have proved as effective as did the type of training used. The investigation of the accuracy of stall recognition cited previously[9] indicated that in general even civilian instructors were unable accurately to judge the point of the incipient stall, i.e., were unable to recognize when the plane was right "on the edge" of the stalled condition. This would suggest that instructors, without relying on an indicator of the type employed in this investigation, could not as adequately point out the significant cues, or as adequately give the student effective "knowledge of results" as when such a stall indicator was employed.

It might also be noted that the present investigation does not provide information concerning the specific cues to which the experimental subjects learned to respond and learned to discriminate during the course of the training. This is clearly a problem for further investigation.

In view of the importance of the inadvertent stall as a causative factor in fatal light plane crashes, as indicated by the work of Brimhall and Franzen,[10] and in view of the findings as to the inadequacy of stall recognition among typical pilots, as indicated by the Committee investigation directed by Rulon[11] it seems reasonable to raise the question as to whether additional training in stall perception might not profitably be included in the flight curriculum. Although the present investigation indicates that the type of training employed was relatively effective, additional research designed to yield information on the detailed nature of cues involved in stall perception appears indicated. Results of such research could be used effectively as a basis for outlining improved procedures for training in stall recognition.

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[8](Continued) In designing the experiment it was assumed that the advantage in terms of past experience among control subjects would more than balance the effect of the immediate flight experience of experimental subjects, and that therefore any superiority of performance on the part of experimental subjects could be attributed to their special training, rather than to immediate flight experience _per se_. Unfortunately there is no experimental evidence on this point.

[9]Rulon, P. J. _Op. cit._

[10]_Op. cit._ (footnote 1).

[11]Rulon, P. J. _Ibid._

APPENDIX [illegible]

OUTLINE OF TRAINING PROCEDURES

APPENDIX 1

OUTLINE OF TRAINING PROCEDURES

Lesson 1. The instructor will explain to the subject (on the ground) what he will be expected to do. When the instructor is certain that the subject understands what is expected of him, the subject will fly the plane and perform a sequence of maneuvers until he and the instructor are satisfied that the subject is sufficiently acquainted with this particular plane

Preliminary research has indicated that the subject is familiar with the airplane by the time altitude (2500 feet) is reached.

Once altitude is reached, a test will be given on all of the maneuvers listed above, and in that order. At this time the student will have had no instruction on the lamps, and the lamps will be connected only to the instructor's clipboard. After the test has been completed, the following procedure will be used:

The instructor will first demonstrate the use of the lamps on the dashboard to the student, showing how he can determine the angle of attack by pressing the button at the end of the stick. He will also explain that lamp 4 generally indicates the greatest angle of attack before a stall. Lamp 5 is energized after it is too late to recover.

> Exceptions have been noted to this, and should be pointed out to the subject as follows: in power-off maneuvers, lamp 3 seems to indicate the point immediately before the stall. In steep turns all 5 lamps can be on without stalling the plane.

The instructor will, then, tell the subject the following:

> "Your task is to put the plane in the attitude which will energize all of the lamps up to the point where the plane stalls. That will be lamp 4, except in 2 cases. In power-off maneuvers, you will try to light number 3. In steep turn, you will be allowed to light all 5 lamps. But you must not stall! I will demonstrate each maneuver for you and you can practice it twice. Remember, when you want to get knowledge of how you are doing, press the button on the stick, and the lamps will be lighted. You should do this each time you practice a maneuver."

He will then introduce each maneuver to the student by saying:

> "Now, I am going to demonstrate to you how to approach a stall out of __________. You will notice that when lamp ___ is lit, I recover, so that the plane does not completely stall. Now you try to do the same thing."

During this lesson, the instructor will direct attention of the subject to the changing sound of the motor as the angle of attack is increased. The subject should be required to report verbally on any changes in pitch or intensity of the sounds he hears.

The instructor will insist that the subject press the button, and inform himself as to how he did at each practice trail during each lesson.

After the subject has had demonstrated to him, and has practiced twice all of the maneuvers, the test will be repeated. At this time the instructor will disconnect the lamp bank which has been visible to the subject. This is done by flipping the switch from "teach" to "examination." The test will then be given exactly as before.

Lesson 2. This will be similar to Lesson 1 except in Lessons 2 through 10, the examination is given only at the end of the period. Also, in these lessons each maneuver will be demonstrated once and the subject will be allowed to practice it once more.

During Lesson 2, emphasize the visual cues which are available and which provide information concerning the on-coming stall. For example, point out the sinking of the horizon as the angle of attack increases, and any other visual cues which you believe are helpful to the subject to improve his perception of the pre-stall attitude of the airplane.

The sound changes emphasized in Lesson 1 also should be reviewed. The subject should be reminded that the should make frequent use of the bank of lamps to check his judgment as he approaches a stall, though he should not keep the button depressed all the time. However, he should use the lamps during each practice trial.

The test will be given at the end of the lesson exactly as prescribed for Lesson 1.

Lesson 3. The cues of Lessons 1 and 2 will be reviewed along with emphasis on tactual and kinesthetic cues (the feel) associated with pre-stall conditions. The instructor should direct the attention of the subject to changes in vibration that he can feel and to changes in pressure of various parts of his body as he approaches a stall. Also, the instructor will point out how the plane responds less to the ailerons and rudder movement. The instructor will point out how the resistance in the controls is reduced and that greater control movements are necessary.

The test procedure will be the same as that at the end of the preceding lessons.

Lessons 4-10. These lessons will be devoted to the practice of pre-stall maneuvers and demonstration by the instructor as often as he considers it advisable. He should also quiz the subject from time to time concerning the cues used in detecting the pre-stall conditions. During the practice, the subject should press the button at the time he believes the plane is as close to the stall as possible.

The order of presentation of maneuvers should not be varied at any time, and conditions should remain as constant as possible, except to allow more time between maneuvers in case the student appears to be ill.

All power-on maneuvers will be performed at cruising speed with the exception of straight ahead-climbing power

APPENDIX 2

LEARNING CURVES FOR INDIVIDUAL ASSIGNED AND UNASSIGNED MANEUVERS

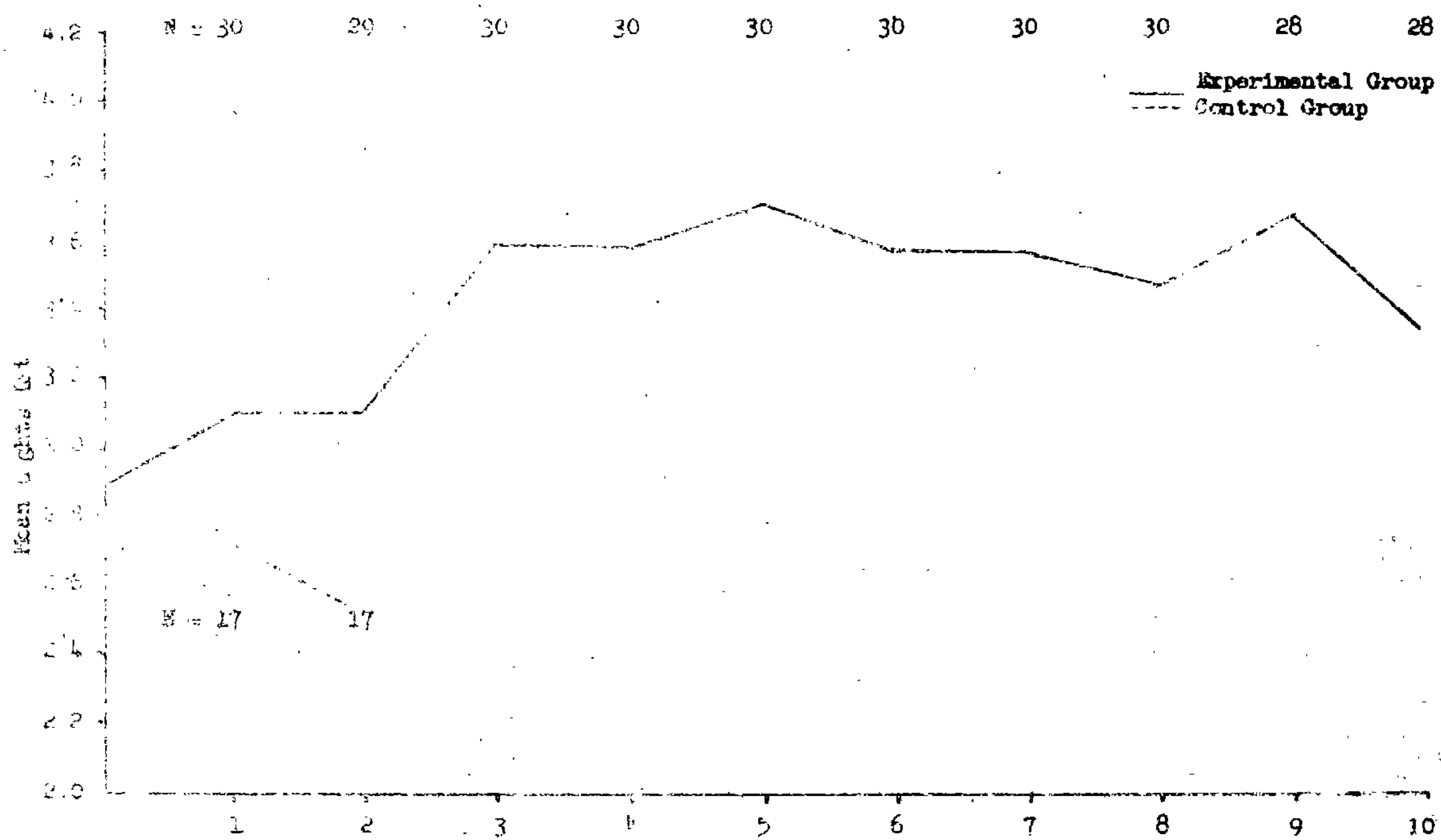

FIGURE 14

LEARNING CURVE FOR STRAIGHT AHEAD, CRUISING POWER*
(assigned)

*When plane stalled a zero score was given.

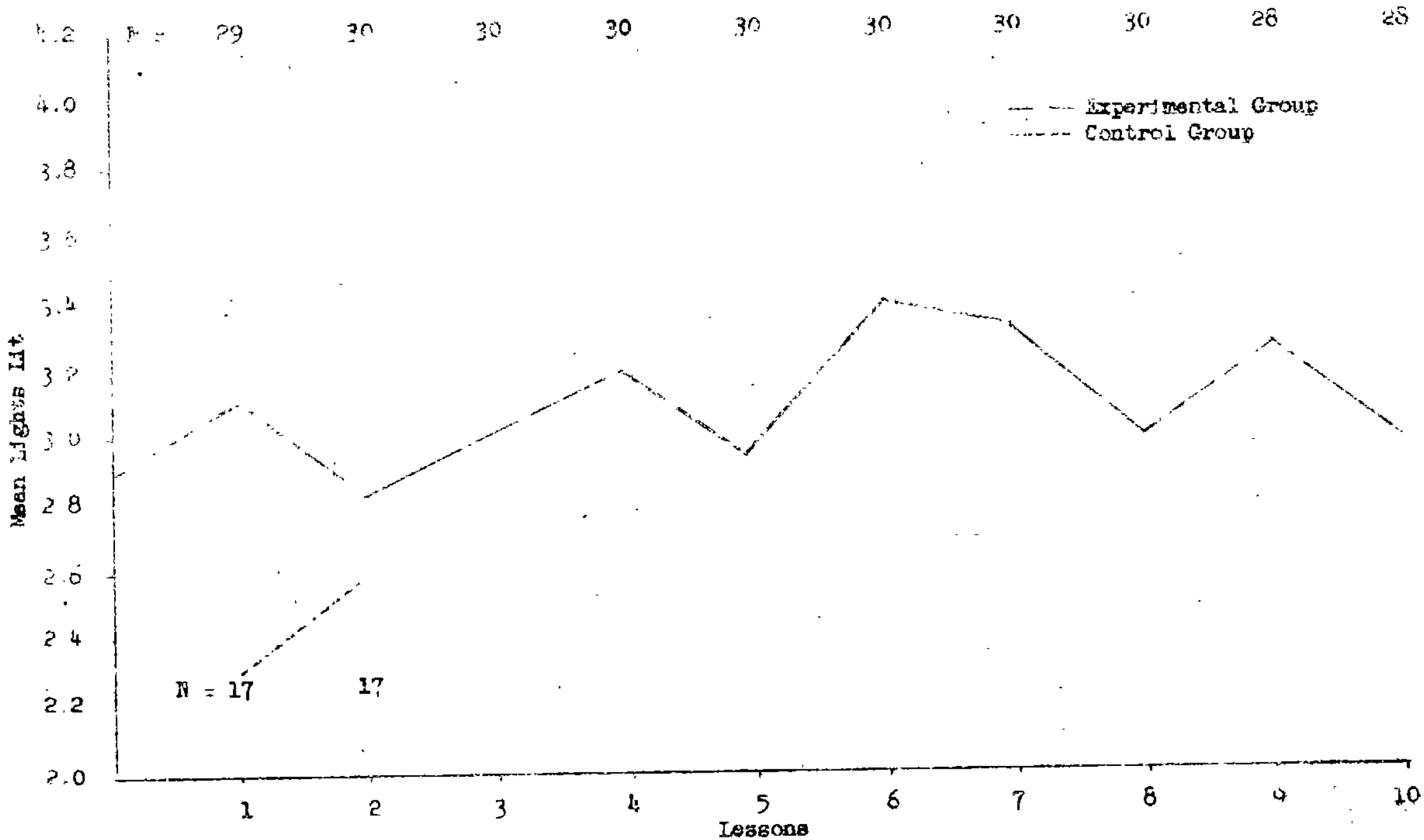

FIGURE 15

LEARNING CURVE FOR STRAIGHT AHEAD POWER OFF*
(assigned)

*When plane stalled a zero score was given

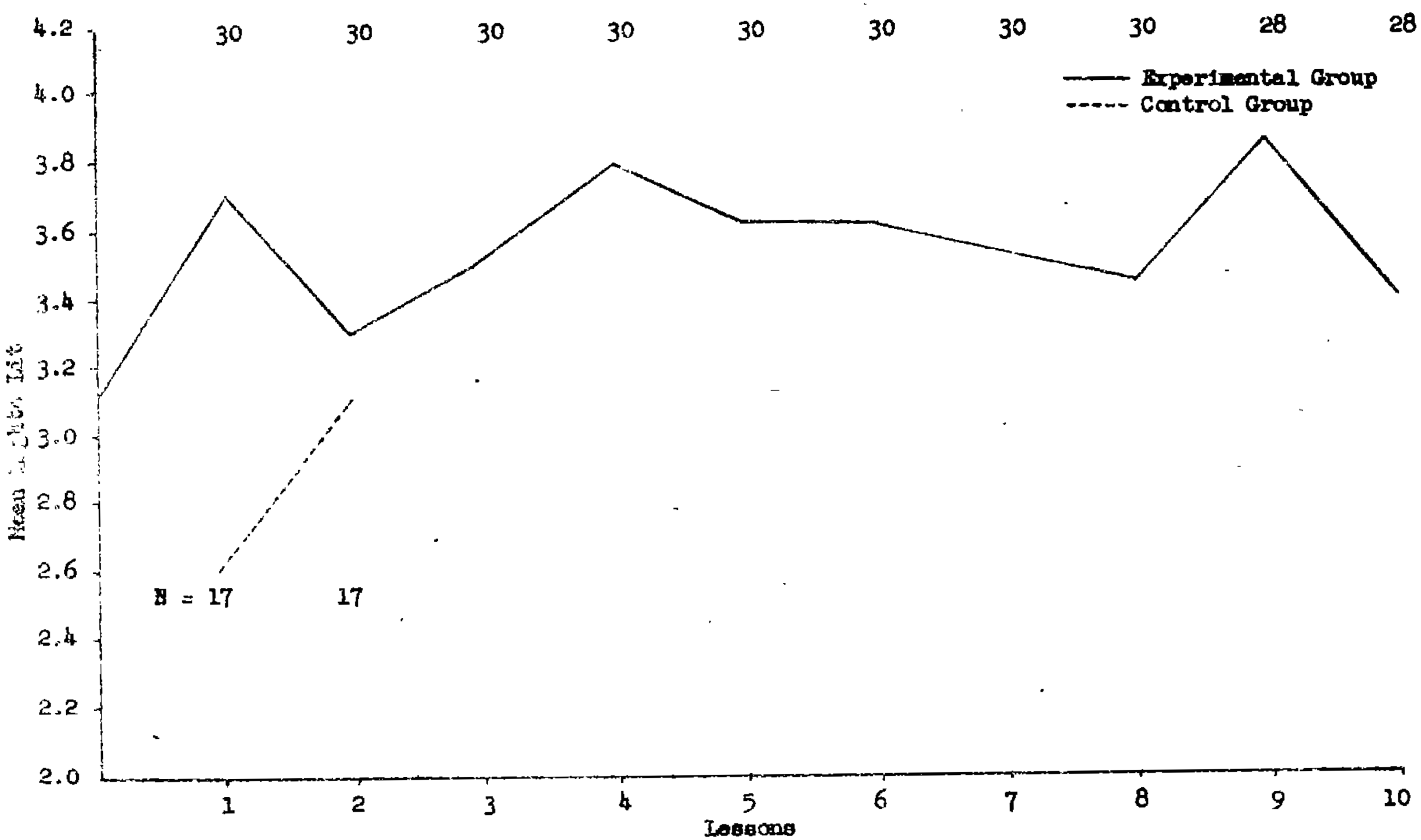

FIGURE 16

LEARNING CURVE FOR LEFT CLIMBING TURN*
(assigned)

*When plane stalled a zero score was given

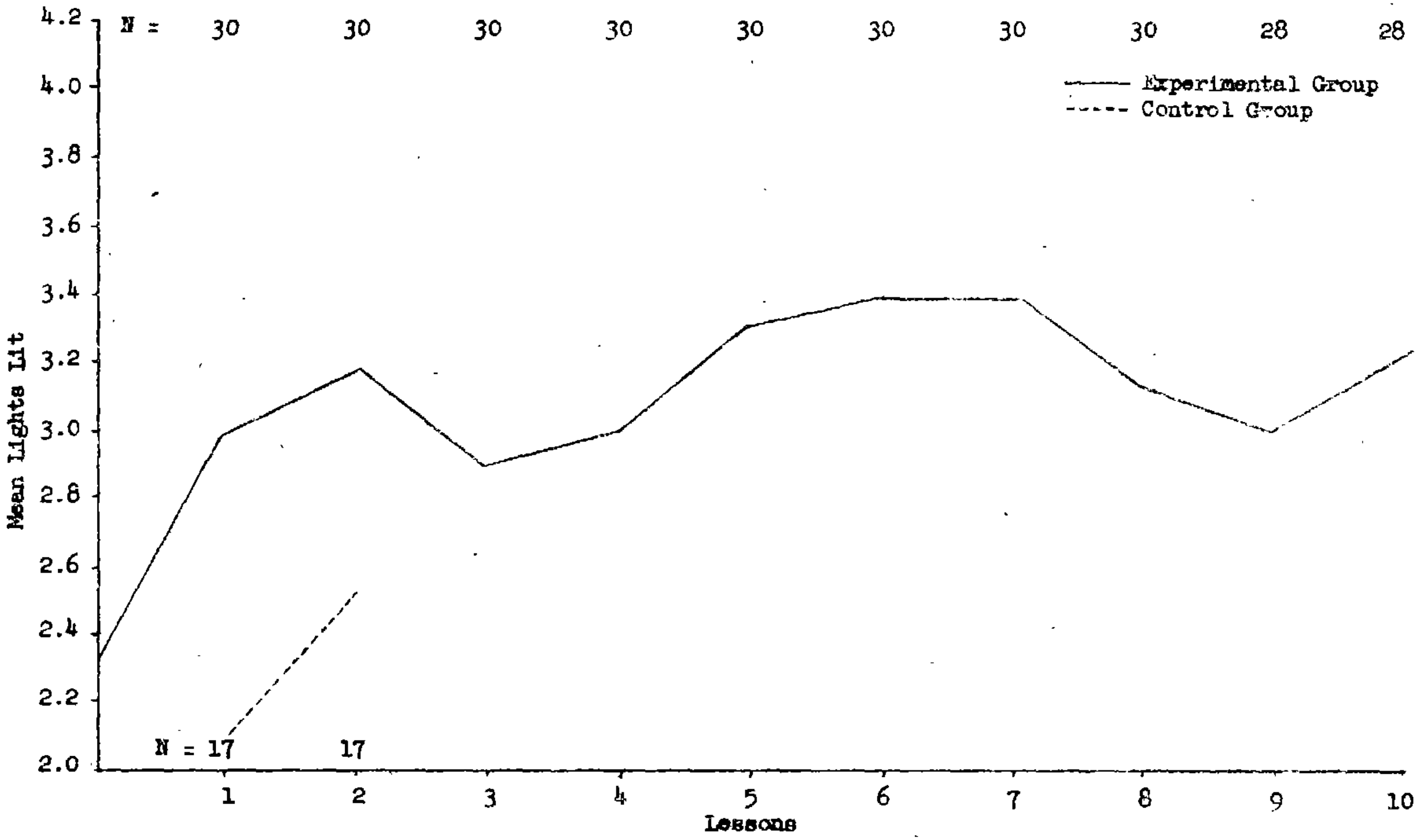

FIGURE 17

LEARNING CURVE FOR RIGHT GLIDING TURN*
(assigned)

*When plane stalled a zero score was given

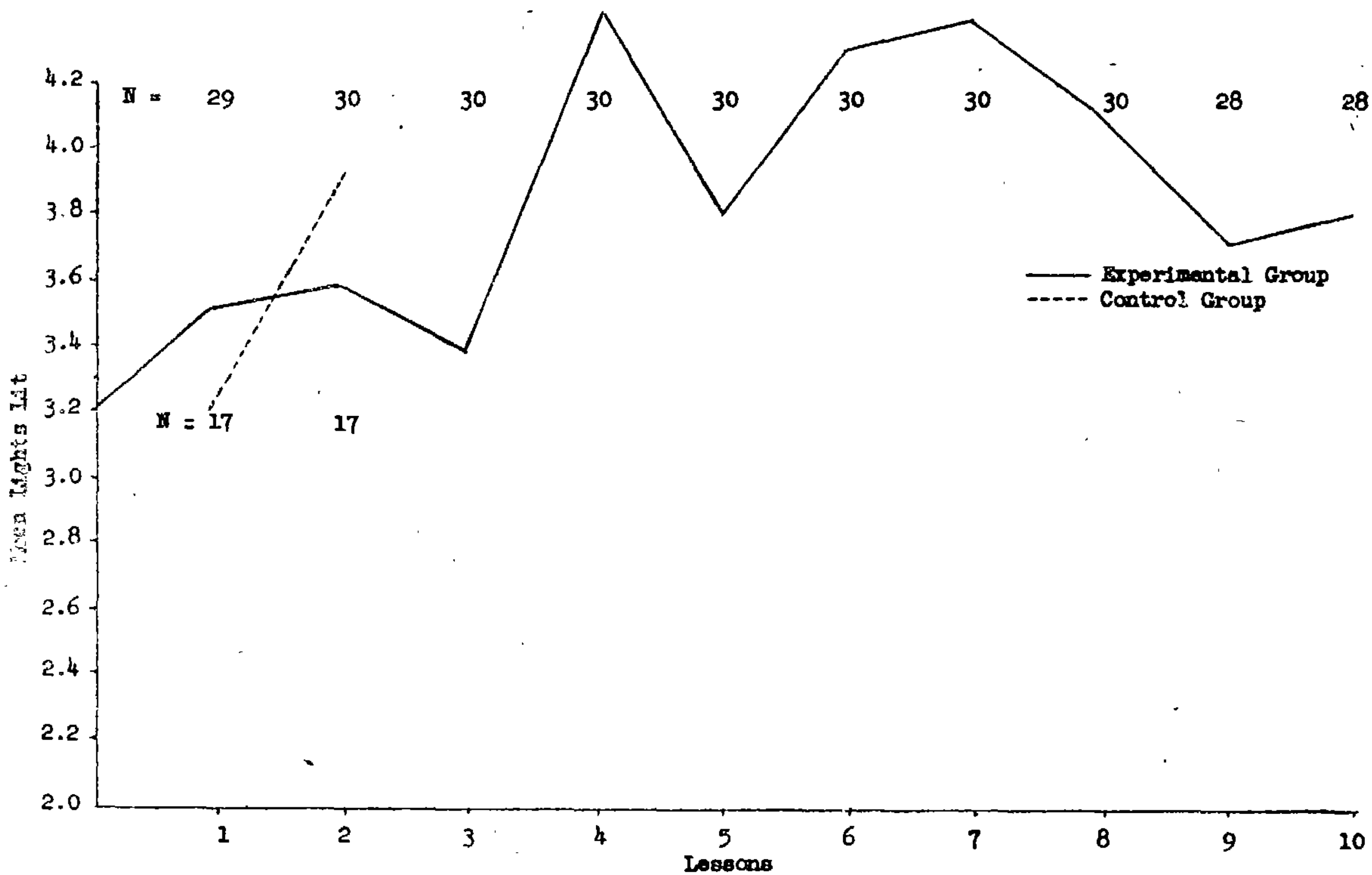

FIGURE 18

LEARNING CURVE FOR STEEP LEFT TURN AT ALTITUDE*
(assigned)

***When plane stalled a zero score was given**

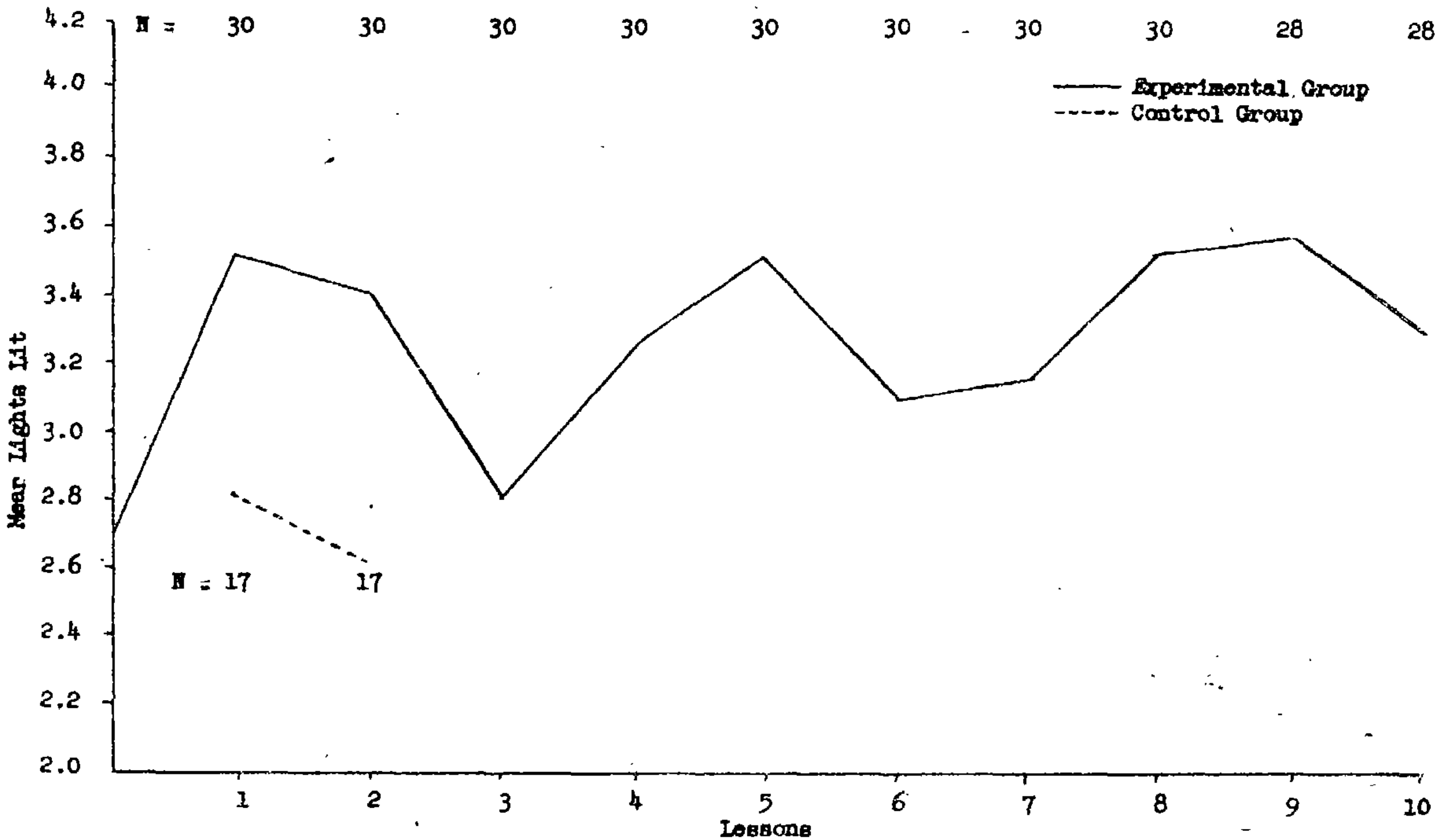

FIGURE 19

LEARNING CURVE FOR RIGHT CLIMBING TURN*
(assigned)

*When plane stalled a zero score was given

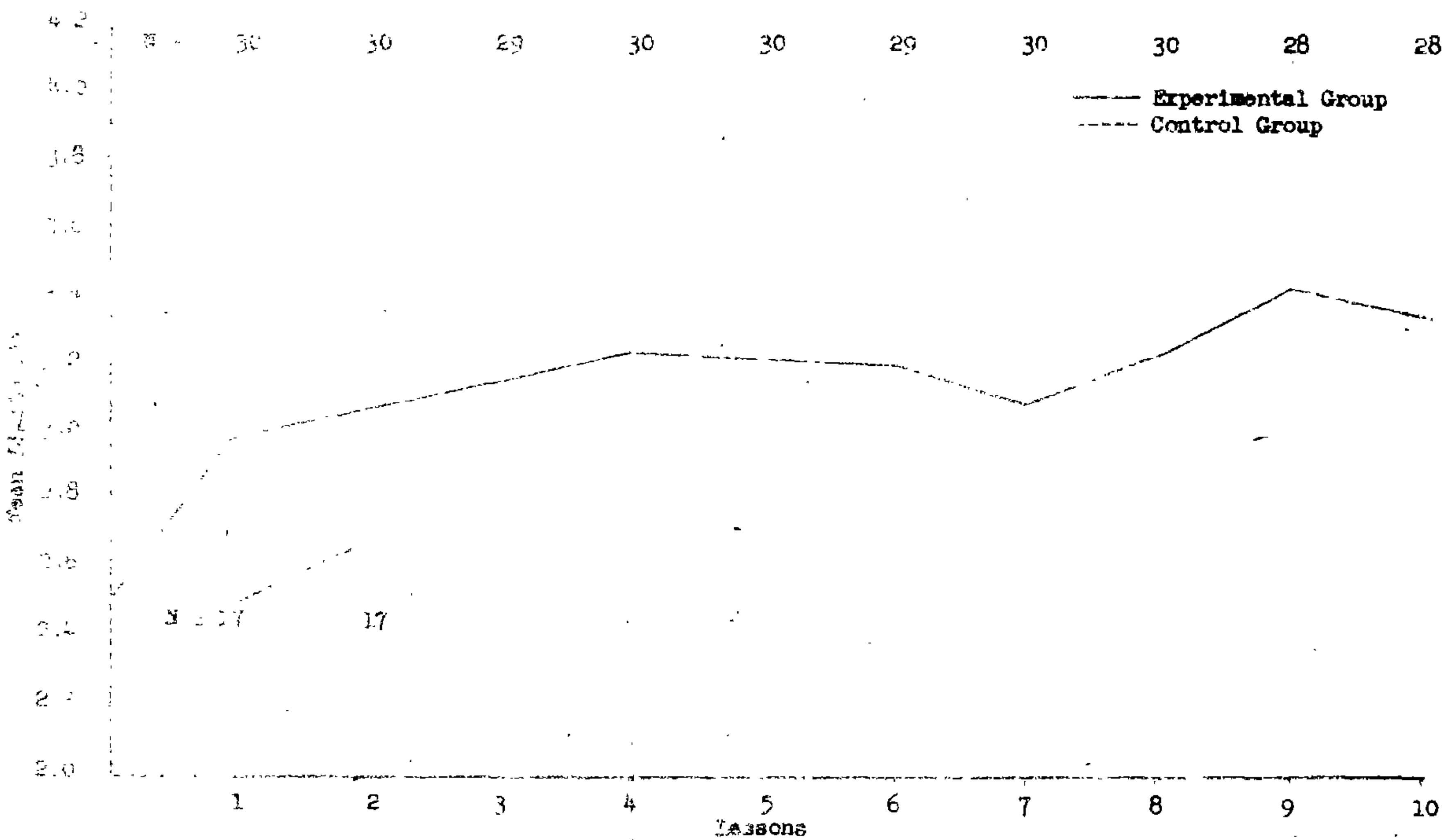

FIGURE 20

LEARNING CURVE FOR LEFT GLIDING TURN*
(assigned)

*When plane stalled a zero score was given

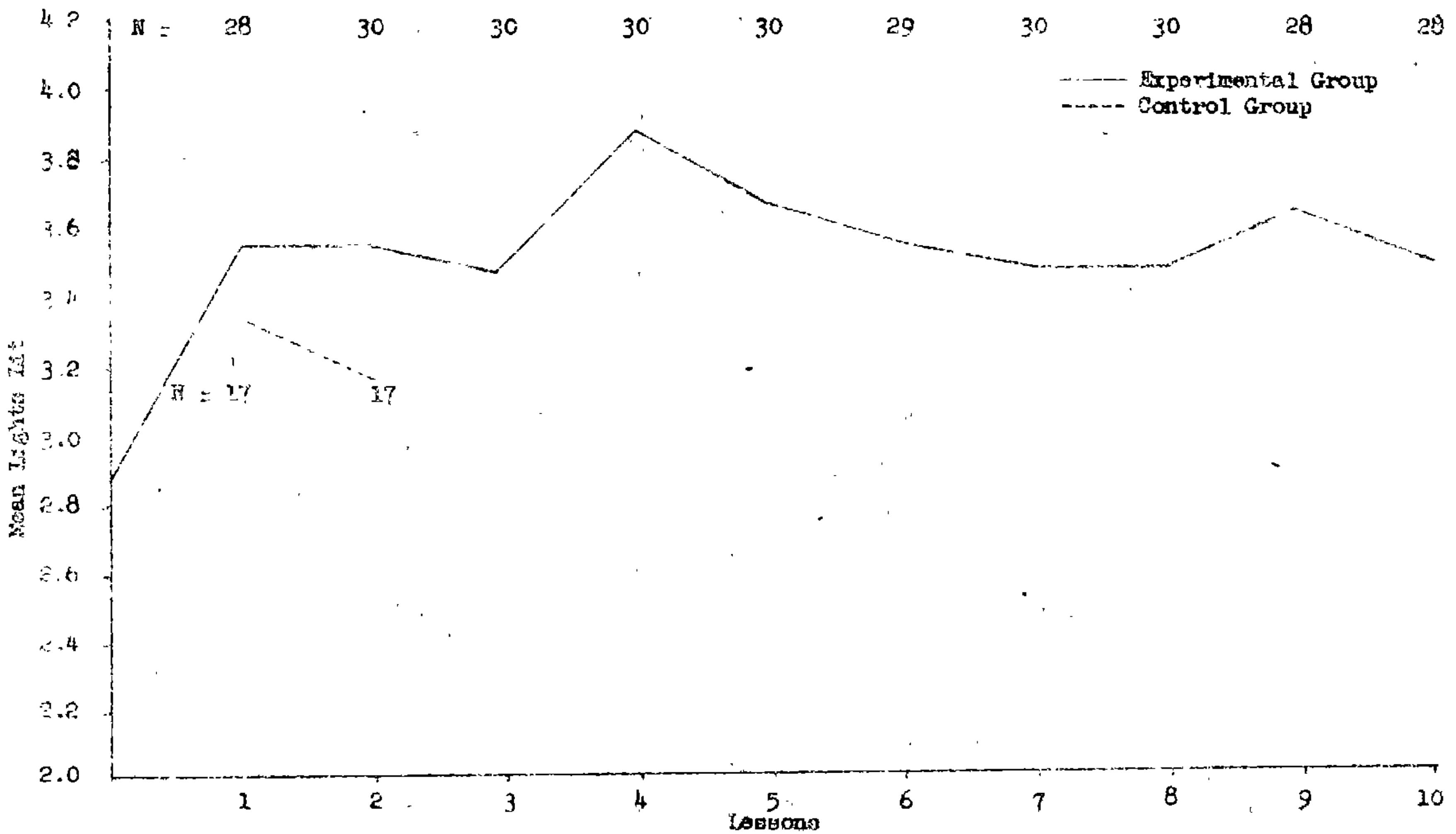

FIGURE 21

LEARNING CURVE FOR STRAIGHT AHEAD, CLIMBING POWER*
(assigned)

*When plane stalled a zero score was given

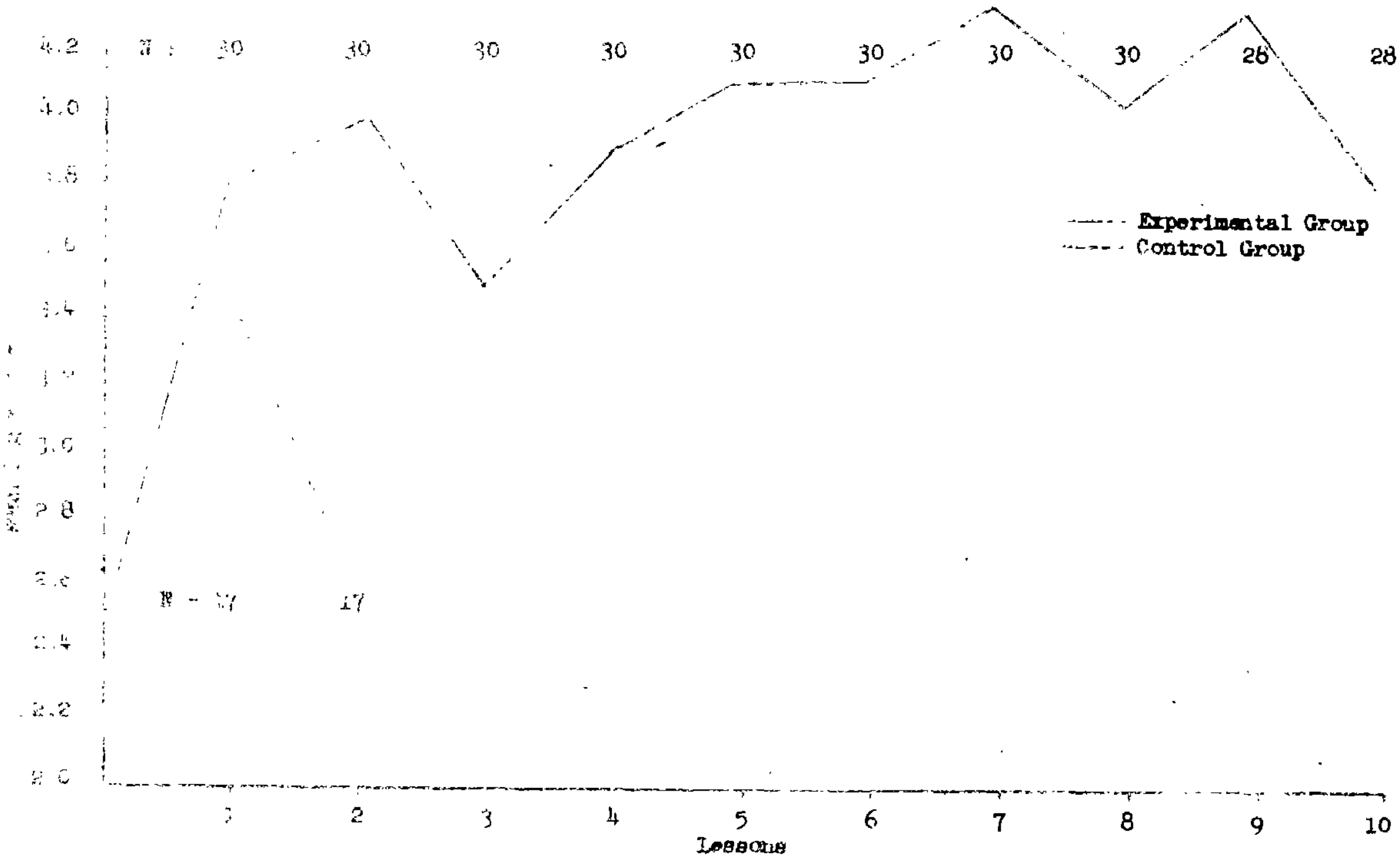

FIGURE 22

LEARNING CURVE FOR STEEP RIGHT TURN AT ALTITUDE*
(assigned)

*When plane stalled a zero score was given

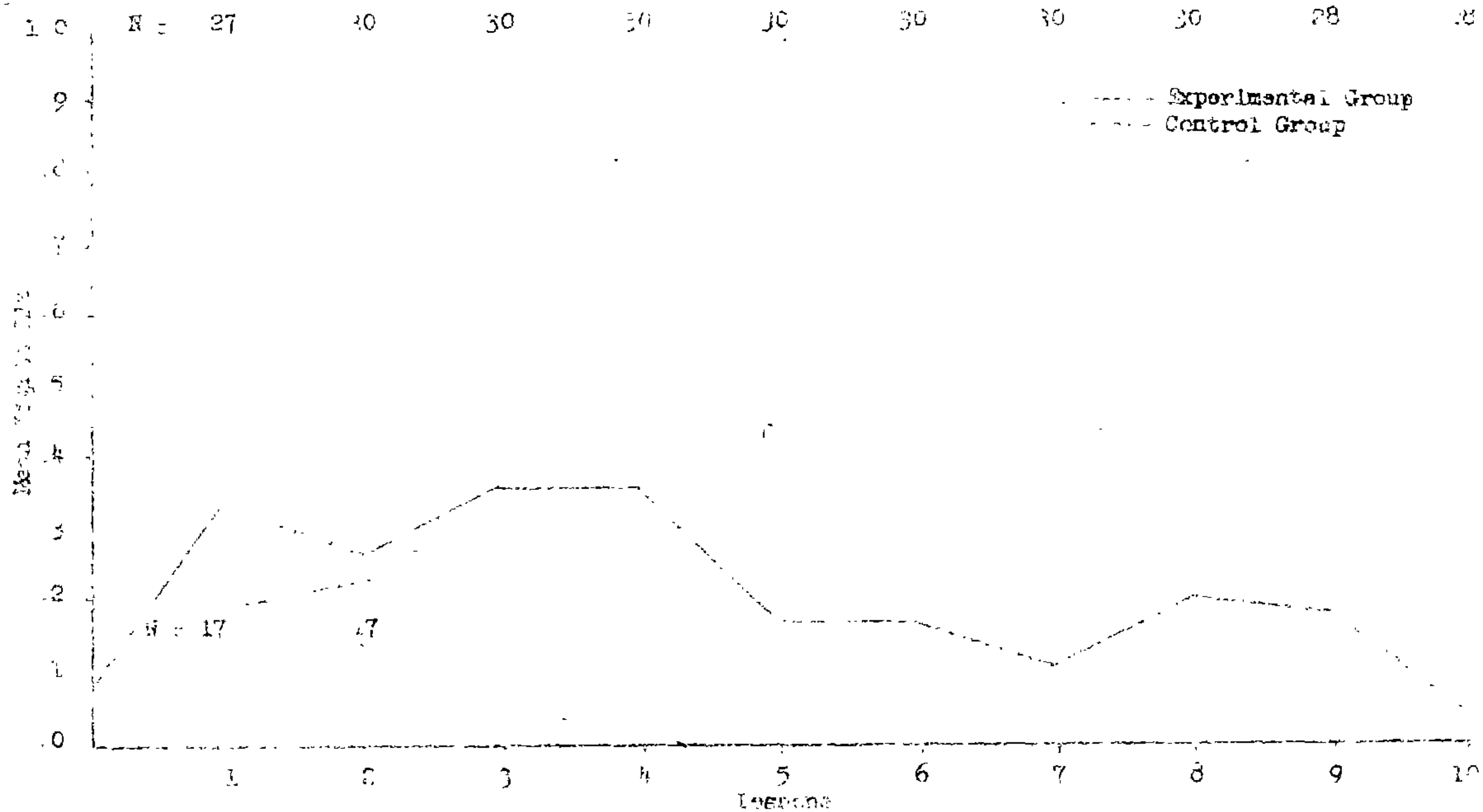

FIGURE 2?

LEARNING CURVE FOR CLEARING TURN TO THE LEFT PRIOR TO MANEUVER #1
(unassigned)

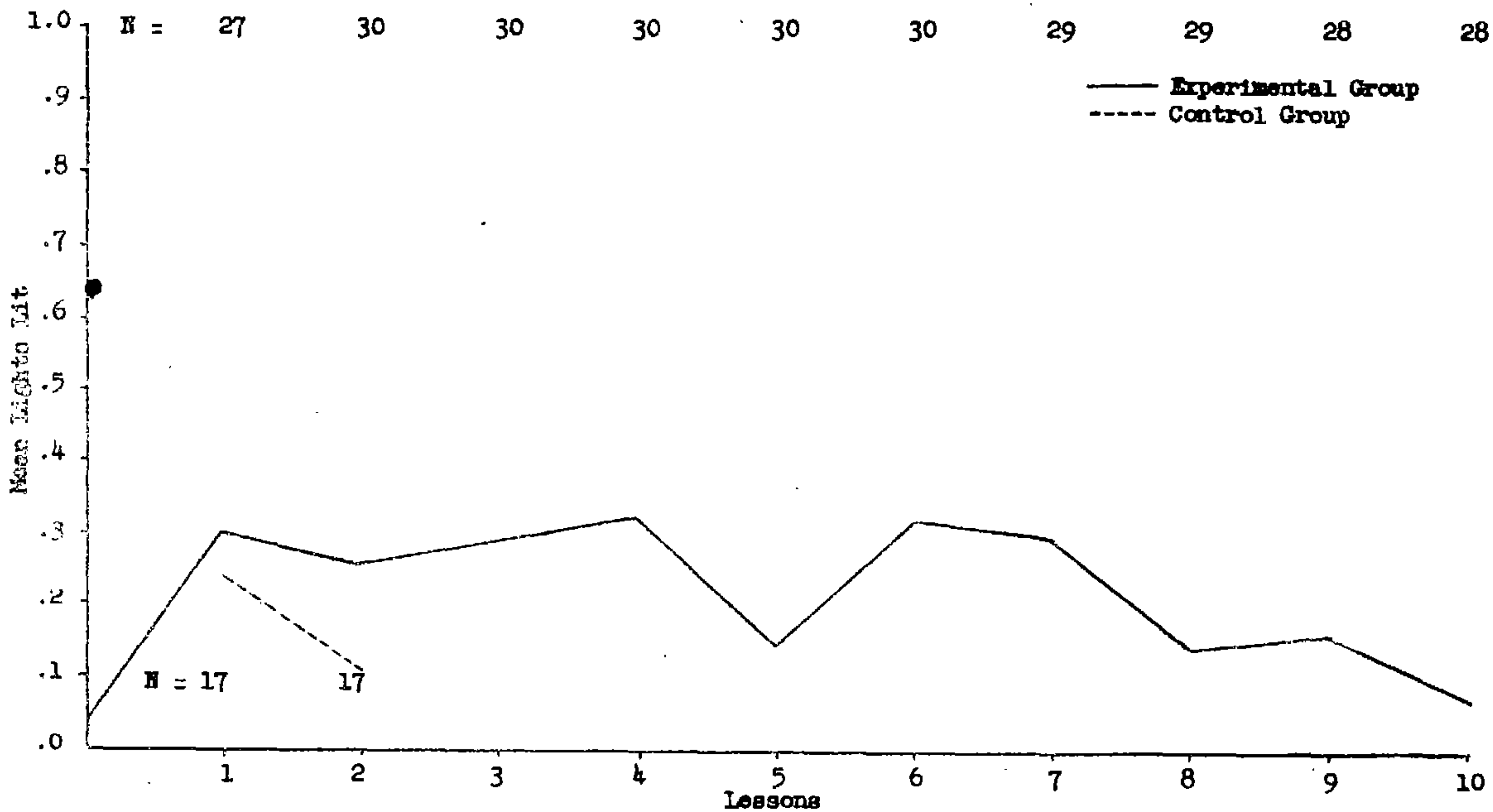

FIGURE 24

LEARNING CURVE FOR CLEARING TURN TO THE RIGHT PRIOR TO MANEUVER #1
(unassigned)

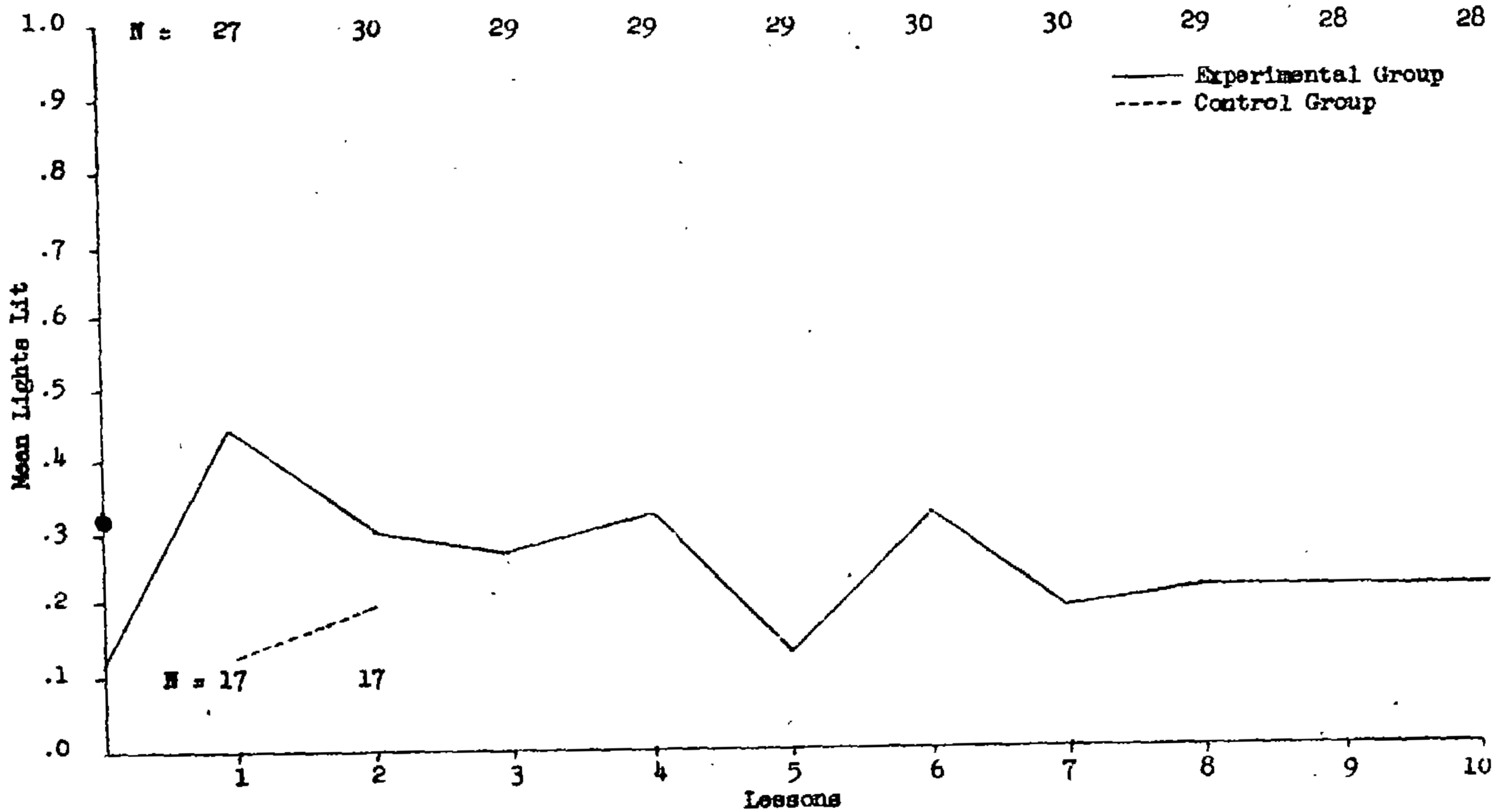

FIGURE 25

LEARNING CURVE FOR CLEARING TURN TO THE LEFT AFTER MANEUVER #2
(unassigned)

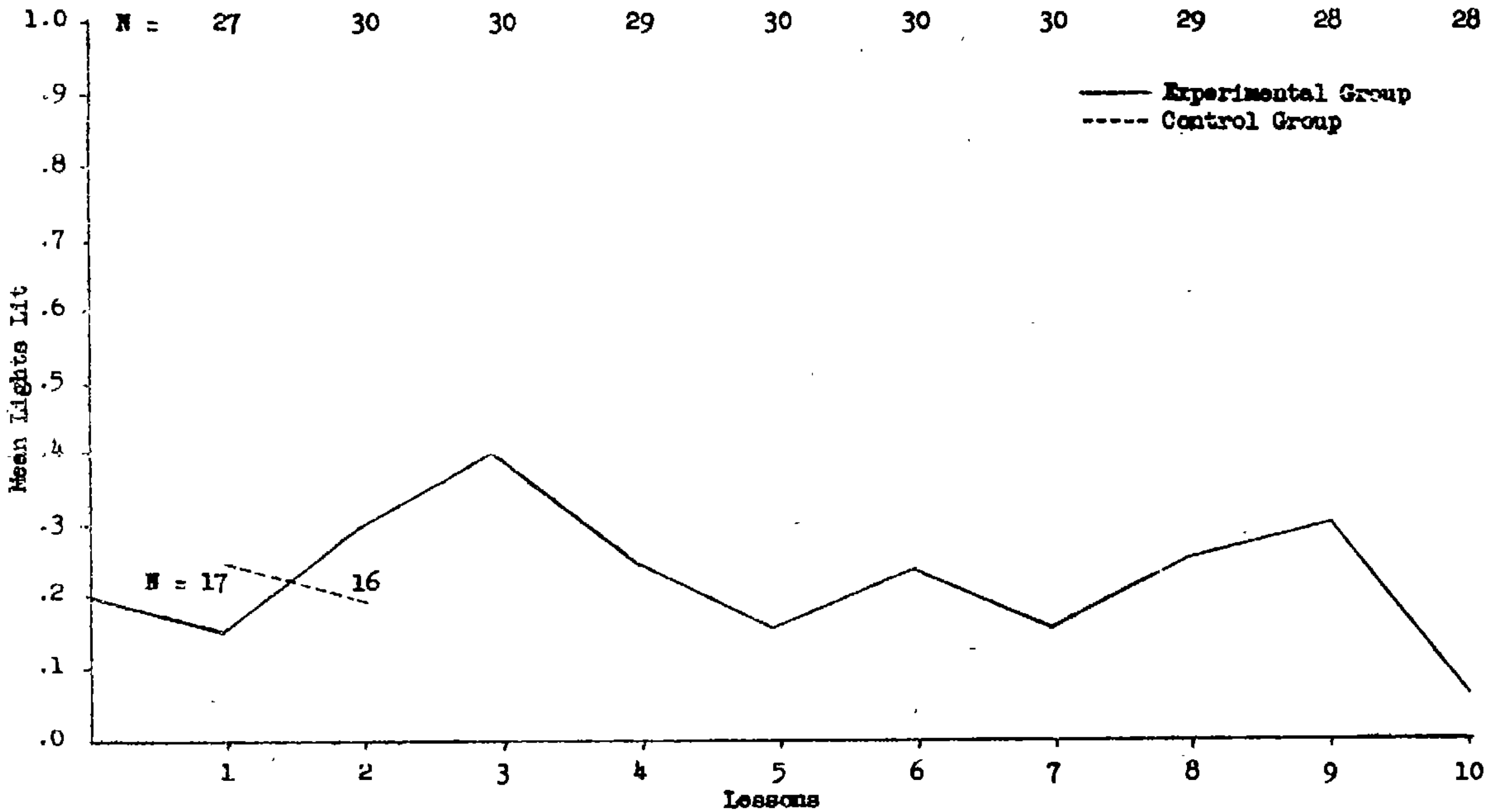

FIGURE 26

LEARNING CURVE FOR CLEARING TURN TO THE RIGHT AFTER MANEUVER #2
(unassigned)

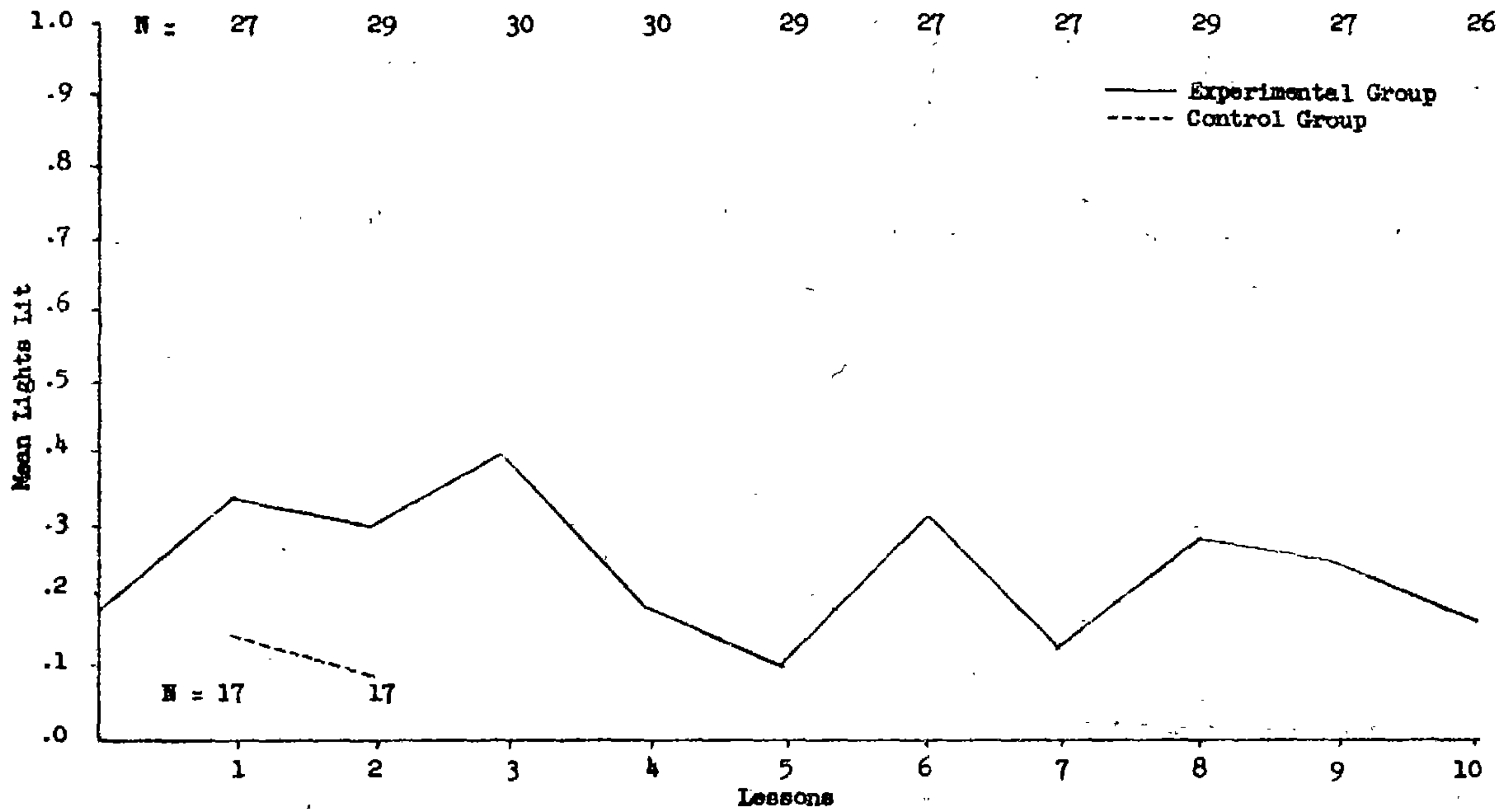

FIGURE 27

LEARNING CURVE FOR CLEARING TURN TO THE LEFT AFTER MANEUVER #4
(unassigned)

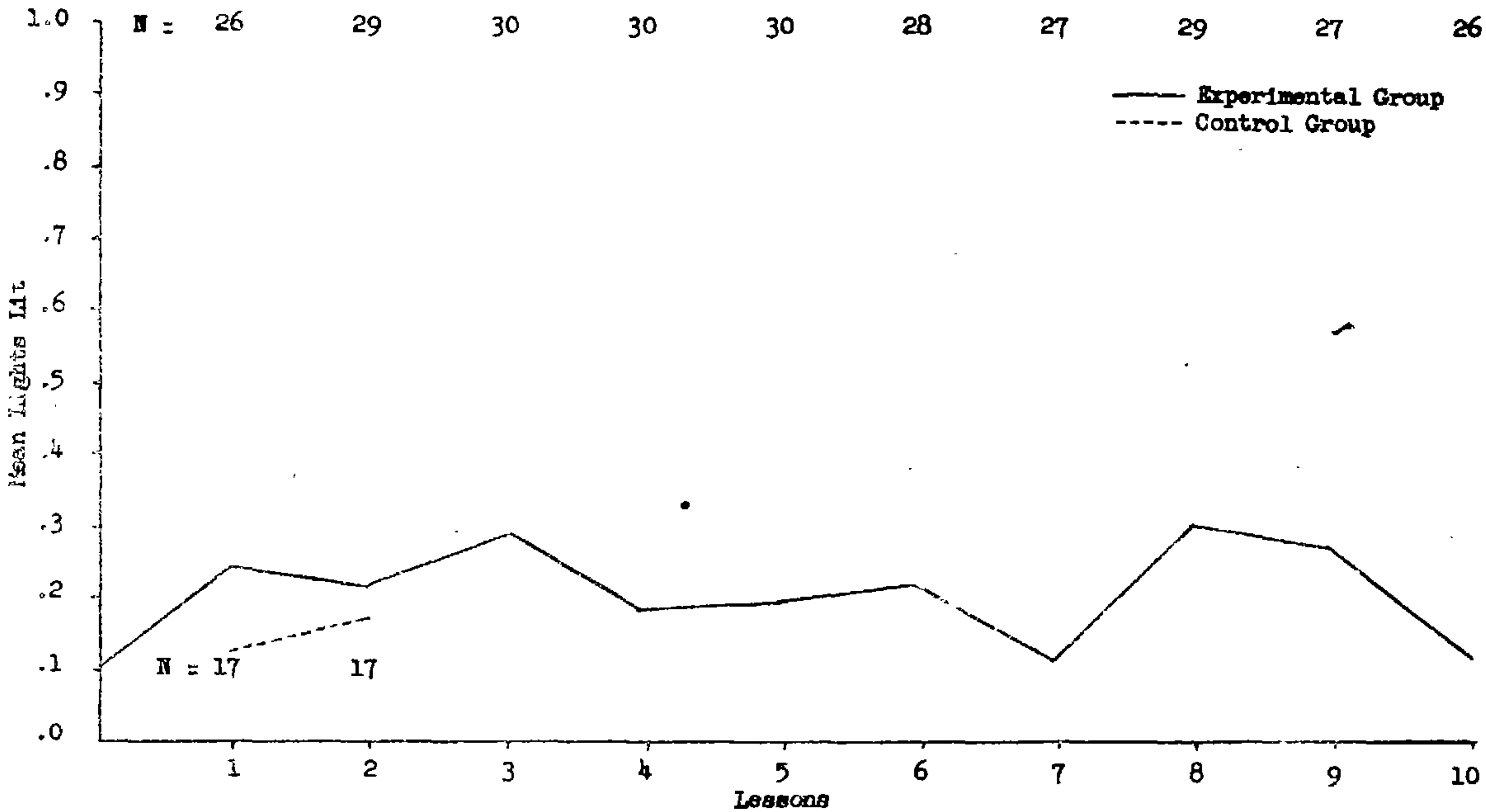

FIGURE 28

LEARNING CURVE FOR CLEARING TURN TO THE RIGHT AFTER MANEUVER #4
(unassigned)

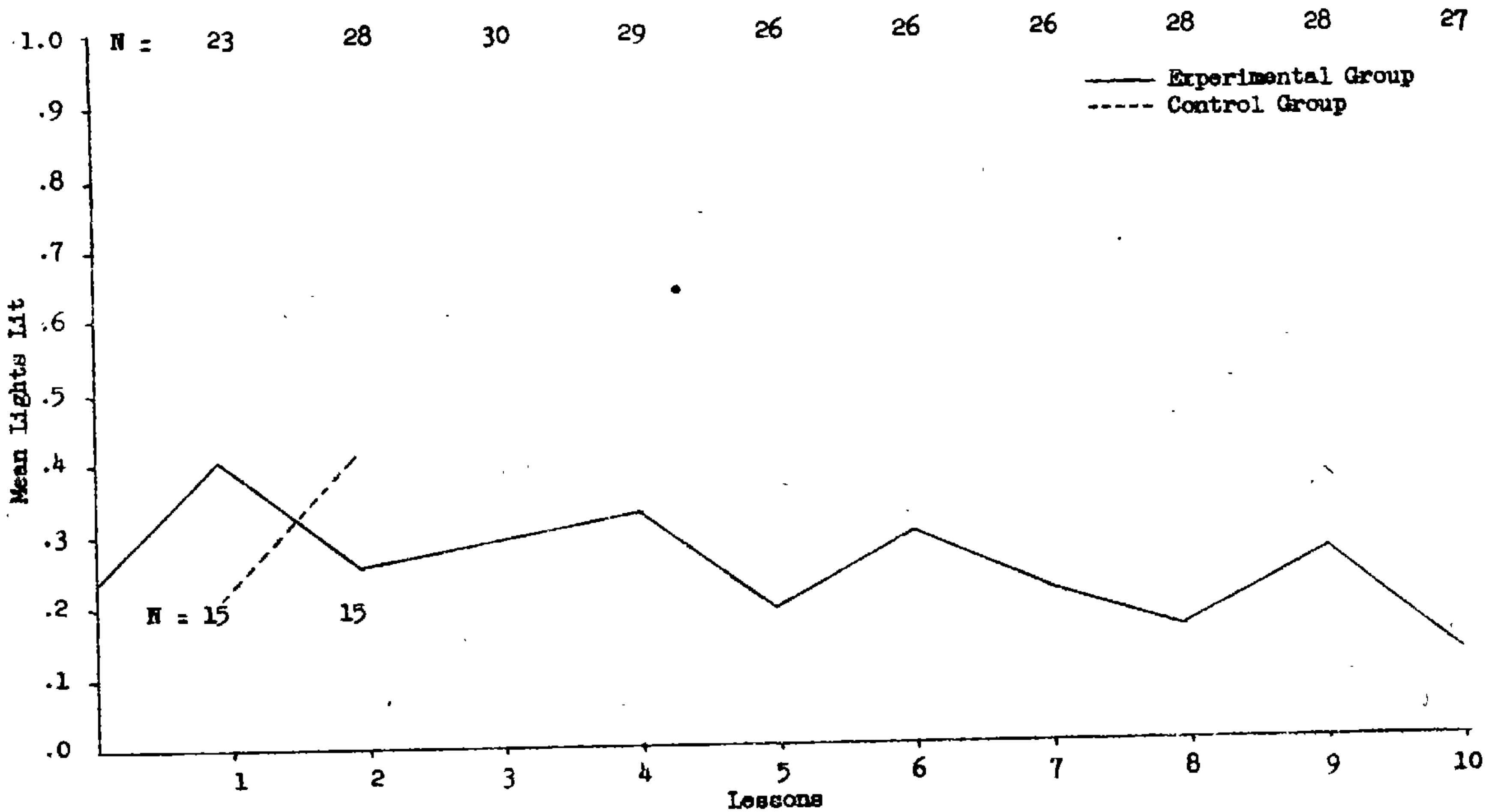

FIGURE 29

LEARNING CURVE FOR CLEARING TURN TO THE LEFT AFTER MANEUVER #7
(unassigned)

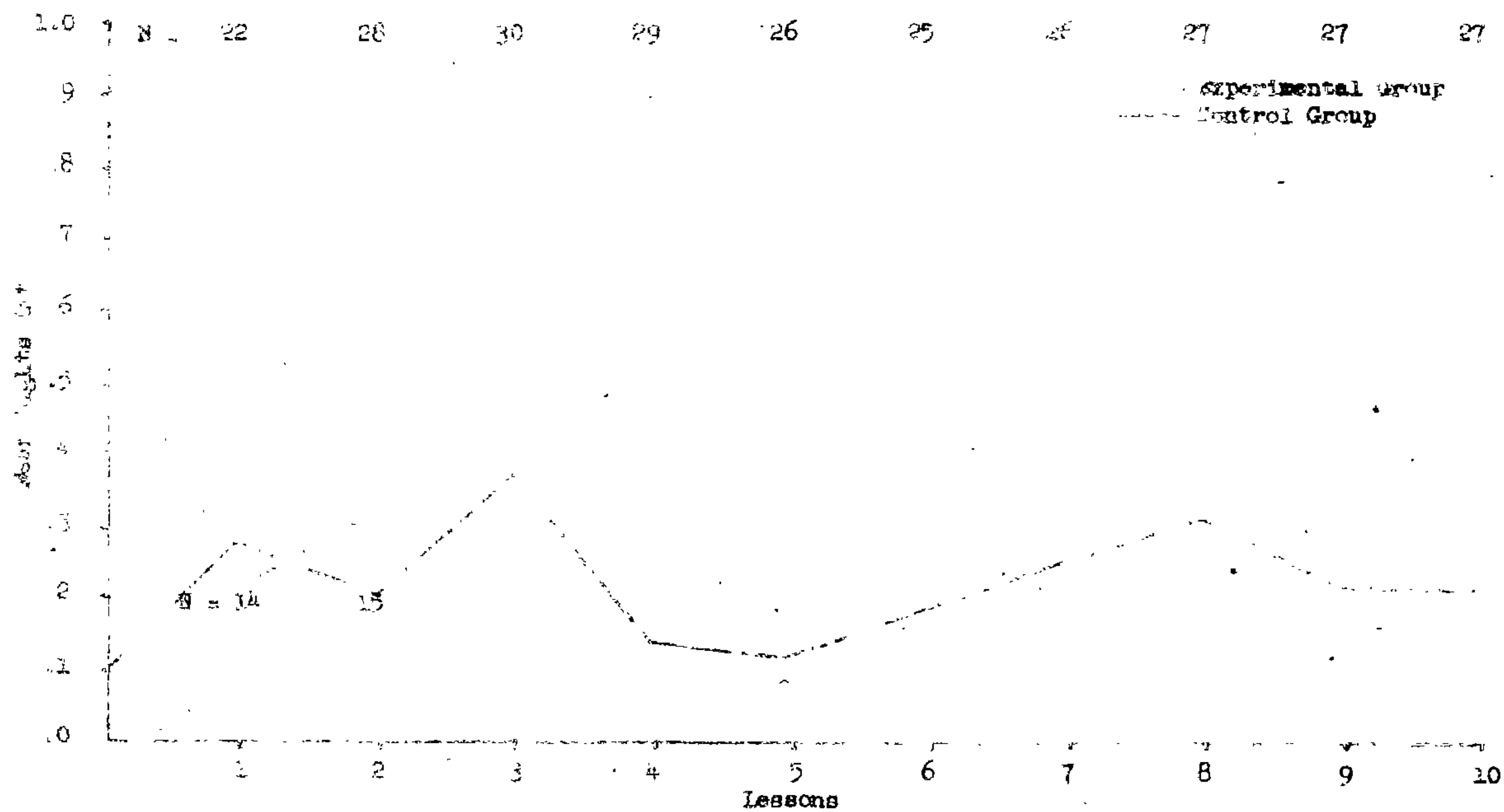

FIGURE 30

LEARNING CURVE FOR CLEARING TURN TO THE RIGHT AFTER MANEUVER #7
(unassigned)