AN INVESTIGATION OF THE RELATIONSHIP BETWEEN VISUAL ABILITY AND FLIGHT PERFORMANCE

Prepared

by

National Research Council
Committee on Aviation Psychology

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Committee on Aviation Psychology

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LETTER OF TRANSMITTAL

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

Committee on Aviation Psychology

July 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 Relationship Between Visual Ability and Flight Performance, 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.

The study described in this report represents a pioneering effort to obtain, through rigorous field experimentation, objective evidence pertinent to the establishment of visual standards in the licensing of pilots. Of particular interest is the fact that the investigation represents the coordinated effort of psychologists, ophthalmologists, physiologists, and of others who combined their scientific resources for the impartial and objective analysis of this aspect of private pilot licensing procedures.

Cordially yours,

M S Viteles

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

MSV:rm

ACKNOWLEDGMENT

The investigation described in this report was conducted under the direction of the National Research Council Committee on Selection and Training of Aircraft Pilots (now the Committee on Aviation Psychology) as a cooperative effort. It is not the work of any single individual. The study was initiated at the request of Dr. D. R. Brimhall, assistant to the Administrator for Research, Civil Aeronautics Administration, following inquiries as to the possibilities of such an investigation from the Civil Aeronautics Board. The study was designed by a Committee on the Visual Study of the Committee on Selection and Training of Aircraft Pilots, including Dr. W. R. Miles, chairman, Dr F. C. Flanagan, Dr. Raymond Franzen, Dr. Peter Kronfeld, and Dr. M. S. Viteles. Dr. Peter Kronfeld and Dr. W. O. Fenn, representing National Research Council Committee on Medical Problems of Civil Aviation, and Lt. Col. John L. Matthews, from the Aero Medical Association, helped in defining the limits for the visual groups and in planning the visual tests and the ophthalmological examination. Dr. P. J. Rulon, a member of the Executive Subcommittee of the Committee on Selection and Training of Aircraft Pilots, and Dr. Raymond Franzen acted as special consultants on the statistical aspects of the study. The investigation was conducted at the School of Aviation, Ohio State University, under the general supervision of Dr. Floyd C. Dockeray, with the assistance of Dr. G. Gorham Lane and Mr. David Bakan. The details of the ophthalmological examination were formulated by Dr. Peter Kronfeld, and the administration of the visual tests was supervised by Dr. Glenn A. Fry, Ohio State University. Brigadier General E. G. Reinartz, AAF School of Aviation Medicine, cooperated in making available the services of a staff ophthalmologist, Col. M. J. Reeh. The statistical analysis was conducted by Mr. D. Bakan. The report was written, in the main, by Dr. M. S. Viteles, Mr. E. S. Ewart, and Mr. D. Bakan. In general, the study was in every sense a cooperative effort, involving the collaboration of psychologists, physiologists, ophthalmologists, and medical practitioners, using funds provided through the Division of Research, Civil Aeronautics Administration.

EDITORIAL FOREWORD

The investigation described in this report, undertaken by the Committee on Aviation Psychology[1] at the request of the Civil Aeronautics Administration, was designed to determine the relationship between visual measures and flight performance.

Both the Civil Aeronautics Board and the Civil Aeronautics Administration have taken the position that private or non-commercial flying should be made more easily available to the individual. A crucial problem in this connection is that of setting standards for the certification of pilots at a point which will permit the certification of all those who can learn to fly and are able to meet the ordinary demands of safe flying following flight instruction.

Such a point cannot be established with complete satisfaction for any physical measure without experimentation. The NRC Committee on Aviation Psychology was asked by the Civil Aeronautics Administration to undertake the necessary research for reasons which are stated in correspondence from the Civil Aeronautics Board to the Civil Aeronautics Administration which led to the development of the present experiment.

> "We have noted with great interest the strides which have been made by your Division and your contractor, the National Research Council, in formulating objective standards for determining the requirements for piloting a plane. We are particularly impressed with the methods which have been developed for improving the objectivity of instructors' and inspectors' judgments of student pilot performance and in providing photographic and other objective devices for measuring pilot performance.
>
> "It occurs to us that the availability of such objective indices of pilot performance places you in an excellent position to explore further, under controlled conditions, the relationship between physical standards and performance in learning to fly during flight. In particular, we are interested in having you do a carefully designed study of the relationships between visual standards and flight performance with respect to the certification of civilian pilots, bearing in mind any justifiable differences in standards between private and commercial pilots.
>
> "You can be assured of our full cooperation in such experimental work if it is acceptable to you and to your contractor."

Prior to the research described in this report, D. R. Brimhall and R. Franzen, of the Civil Aeronautics Administration, had conducted a study in-

[1] Formerly the Committee on Selection and Training of Aircraft Pilots.

volving an examination of the consistency of visual measures and their significance in relation to accidents. Under the direct auspices of the Committee on Aviation Psychology, there had been two studies of the relationship between visual measures and progress in learning to fly on the part of RAF cadets, who received training in this country during World War II, which pointed to the absence of any significant relationship between established visual standards and flight performance. Neither of these studies, however, yielded results directly pertinent to the problem of establishment of standards for certification of private pilots.

The results of the present investigation provided evidence of a relationship between visual efficiency and proficiency in learning to fly a light aircraft. It also showed clearly, however, that many individuals with marked defects in vision were able to learn to fly sufficiently well to be granted licenses as private pilots. At the same time the investigation gave indications of specific areas in which visually deficient student pilots experience difficulty and suggested the desirability of research in the development of instructional procedures, particularly with respect to landings, adapted to the training of visually handicapped students.

From the findings and analysis presented in this report the Committee on Aviation Psychology has recommended that individuals with visual defects characteristic of subjects in the experimental groups who are seeking training at their own expense, be accepted as student pilots for the private flight certificate under two conditions:

1. that they be informed that the probability of obtaining a license is lower than for persons with better visual efficiency.

2. that in flight testing such applicants for certification as private pilots, particular emphasis be given to performance on landings.

It is also recommended that consideration be given to the development of specialized training procedures, directed at those areas in which visual defectives appeared significantly less proficient.

July 16, 1948

M. S. Viteles, Chairman
Committee on Aviation Psychology

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SUMMARY

The purpose of this investigation was to determine the relationship between measures of visual efficiency and flight performance; that is, to determine whether there is any demonstrable relationship between the visual efficiency of subjects (covering a wide range of visual abilities) and their proficiency in learning to fly light aircraft, as measured by a number of criteria of flight performance.

The subjects employed in the investigation were drawn from the student body at The Ohio State University and from the Columbus, Ohio, area. One hundred ninety-four subjects were selected from 843 applicants. All subjects were males, between 17 and 29 years of age, inclusive.

Subjects were assigned to four visual groups. Group A consisted of subjects whose vision was "normal" without glasses; Group B, of subjects whose vision was essentially "normal" providing correcting glasses were worn; Group C, of subjects with considerable visual deficiency not necessarily correctible to normal even with glasses; and Group D, of effectively monocular, or one-eyed, individuals. All subjects except those in Group A wore glasses during training. There were 80 subjects in Group A, 38 subjects in Group B, 40 subjects in Group C, and 36 subjects in Group D.

Subjects were given flight training in accordance with the requirements of a controlled course of primary flight instruction approved by the Civil Aeronautics Administration, the experiment being conducted during six academic quarters at The Ohio State University. Flight proficiency during, and at the completion of, the training course was assessed by means of a number of criterion measures, covering both general and specific aspects of flight performance. Each subject also was administered the private pilot flight test by a CAA Flight Inspector or Flight Examiner.

The results of the investigation provided evidence of a relationship between visual efficiency and proficiency in learning to fly light aircraft. This was indicated by the significantly greater incidence of failure in flight training among subjects in Groups C and D, than among subjects in Groups A and B, as well as by significantly poorer performance of the marked visual defectives in terms of six of the thirteen specific measures of flight proficiency.

The study also showed clearly, however, that many individuals with marked defects in vision were able to learn to fly sufficiently well to be granted licenses as private pilots, and that a number of the subjects in Groups C and D exhibited flight proficiency equal or superior to the average of subjects in Group A, in terms of specific criterion measures. Analysis of data from subjects who passed the course indicated that when only those subjects who were licensed were considered, the number of specific criterion measures in terms of which differentiation of visual groups was evident was reduced to two. These two measures pertained to landing performance. Additional analyses were made to determine specific aspects of flight performance in which visually deficient subjects might be inferior.

From the findings and analysis presented in this report the Committee on Aviation Psychology has recommended that individuals with visual defects characteristic of subjects in the experimental groups who are seeking training at their own expense, be accepted as student pilots for the private flight certificate under two conditions:

1. that they be informed that the probability of obtaining a license is lower than for persons with better visual efficiency.

2. that in flight testing such applicants for certification as private pilots, particular emphasis be given to performance on landings.

It is also recommended that consideration be given to the development of specialized training procedures, directed at those areas in which visual defectives appeared significantly less proficient.

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN VISUAL ABILITY AND FLIGHT PERFORMANCE

INTRODUCTION

The purpose of this investigation was to determine the relationship between measures of visual efficiency and flight performance; that is, to determine whether there is any demonstrable relationship between the visual efficiency of subjects (covering a wide range of visual abilities) and their proficiency in learning to fly light aircraft, as measured by a number of criteria of flight performance.

This study was undertaken in accordance with the position of both the Civil Aeronautics Board and the Civil Aeronautics Administration that private or non-commercial flying should be made more easily available to the individual. One crucial problem in this connection is that of setting standards for the certification of pilots at a point which will permit the certification of all those who can learn to fly and are able to meet the ordinary demands of safe flying following flight instruction. Such a point cannot be established with complete satisfaction for any physical measure without experimentation.[1]

While the original request for research, from the Civil Aeronautics Administration, applied to physical standards in general, the present study is limited to an investigation of the relationship between visual measures and measures of flight performance. Subjects for the investigation (all males, between 17 and 29 years of age) were selected on the basis of four categories of visual efficiency previously established, with particular reference to visual acuity. Essentially, Group A consisted of subjects with normal vision; Group B, of subjects with uncorrected vision somewhat less than normal but correctible to normal; Group C, of subjects exhibiting greater refractive error than Group B; and Group D, consisting of subjects who were effectively monocular.

An estimate of the incidence, in the general population, of subjects falling in, and between,[2] the four visual groups established for this ex-

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[1]This is particularly true with respect to measures of visual efficiency. Although several investigations have been conducted which throw some light on the question of the relationship between visual ability and flight performance, little experimental work has been conducted, and such previous work as has been done cannot be considered conclusive. Furthermore, considerable "folklore" has developed regarding the effect of visual deficiency on flight performance.

[2]As noted subsequently (see page 4) a discontinuous, rather than a continuous distribution in terms of visual efficiency was considered most suitable to the purposes of the experiment.

periment is presented in Table 1.[3]

EARLIER STUDIES ON THE RELATIONSHIP BETWEEN VISUAL CHARACTERISTICS AND FLIGHT PERFORMANCE

A survey of the literature reveals little that may be taken as conclusive concerning the relationship between vision and flight performance. Essentially, two methods of investigation have been used. One method has been to classify the subjects on the basis of their visual characteristics and to compare available flight performance records. The other method has been to classify the subjects on the basis of flight performance and to compare them on the basis of their vision.

One of the major reasons for the inconclusive nature of these investigations is that, in every instance, there has been some pre-selection of pilots on the basis of their vision, thereby eliminating individuals from the low end of the visual continuum. Such pre-selection would tend to bias the outcome of these investigations.

Following is a brief summary of some of the more important investigations bearing on the relationship between visual ability and flight performance. **A selected bibliography is presented in Appendix 2.**

In 1929, Ickstadt (2) found that the percentage of failures among 486 Navy students in flight training did not increase as the degree of visual defect increased. Ickstadt also investigated the visual characteristics of 69 outstanding successes and 202 failures, and could find no significant tendency for either group to be superior on any of the visual measures used, with the possible exception of hyperphoria. In this instance, he found that 71% of his successes, as compared with only 58.3% of his failures, did not have hyperphoria.[4]

McFarland, Graybiel, Liljencrantz, and Tuttle (6) examined 200 civil airline pilots, having an average of 5659 flying hours and ranging in age from 20 to 47. These pilots were found to have vision well within the standards set up for pilots in 1939. The fact that the means of these pilots were well above minimum standards may not necessarily be taken as indicative of a relationship between visual ability and flight performance because of the probable operation of pre-selection as a biasing factor.

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[3]This estimate was made by Dr. Peter C. Kronfeld, a member of the subcommittee on the Visual Study, established by the Committee on Selection and Training of Aircraft Pilots (now the Committee on Aviation Psychology). Dr. Walter R. Miles was the Chairman of this subcommittee.

[4]This difference is significant at the 10% level of confidence. (Ickstadt does not himself report any statistical test of the significance of this difference.)

Padden (8) reviewed data on 700 male pilots and found considerable variability in depth perception ability. These pilots all had unblemished flight records. He does not report the incidence of defect.

Brimhall and Franzen (1) examined the medical records of 750 Royal Air Force cadets who were being trained in the United States. The visual requirements for the Royal Air Force cadets were lower than the American standards. No relationship could be found between flight performance and the degree to which pilots met the American visual standards. One of the weaknesses of this investigation was that medical records were lacking for subjects who were eliminated early in training.

A similar investigation (9) followed the former one, in which some of the shortcomings of this earlier investigation were corrected. In this study, medical records were available for all cadets entering training. Again the results did not indicate any relationship between visual characteristics and measures of flight performance. However, the incidence of serious defects in the sample studied was extremely slight.

In 1944, McFarland and Franzen (5) reported an investigation on 1002 Naval cadets and officers at Pensacola who had passed 10 hours of preliminary flight training. The relationship between success and failure in flight training and three visual tests developed by the Dartmouth Eye Institute for measuring space perception, as well as measures on dark adaptation and eye fixations were studied. No significant relationships between visual measures and flight performance measures were found.

Peckham (4) directed the examination of 252 of the Naval cadets at Pensacola. Whether the results he reports are for the same subjects as those reported by McFarland and Franzen (5) could not be determined from Peckham's report. He reports results somewhat contradictory to those reported by McFarland and Franzen. With one of the Dartmouth tests, the eikonometer, no significant difference was found between thirty-three failures and fifty-seven successes. However, with two kinds of apparatus measuring space perception (the leaf room and the frontal plane), he found a difference significant at the 2% level of confidence. He concludes that the results indicate that aniseikonia does impair flight performance to a statistically reliable degree, on the condition that poor space perception be considered a true measure of aniseikonia.

Somewhat related to this are the questions as to whether binocular cues are essential for space perception, and whether aircraft can be successfully flown by monocular pilots. Jarman (3) administered a depth perception test to monocular pilots known to be successful. He found a few were successful in passing the test. He observed that a substitute for binocular parallax was found by shifting the head slightly in order to use one eye from two positions to obtain the parallactic angle.

An investigation on the relationship between visual characteristics and flight performance is reported in the proceedings of the 15th Annual Meeting of the Associated Committee on Aviation Medical Research of the

National Research Council of Canada (7). The relationship between visual characteristics and success in training for 1428 pilot trainees was investigated. It was found that low visual acuity, hyperphoria, convergence inefficiency, and refractive error were significantly related to performance in flight training.

In view of the contradictory nature of these findings a carefully controlled experimental study of the relationship between visual efficiency and flight performance seemed to have particular significance. This seemed especially true since previous work has not been concerned directly with the establishement of visual standards with reference to private, civilian flying.

ESTABLISHMENT OF VISUAL GROUPS

One of the first questions which arose in designing the experiment was whether to use (a) subjects giving a continuous distribution of visual efficiency, from no defect to serious defects, throughout the entire range of visual acuity, or (b) groups of subjects, each with a defined range of visual acuity, representing levels of visual efficiency.

The second alternative seemed best suited for this investigation and it was decided to use groups of subjects, representing levels of visual efficiency suitable for revealing such differences in flight performance as may be associated with visual deficiency.[5] These included a control group with "normal" uncorrected vision and three experimental groups with varying degrees of visual defect. The detailed requirements for subjects in the several visual groups are presented in Table 2.[6]

Candidates in Group A did not wear glasses during the period of flight training, whereas subjects in other groups wore glasses as prescribed by the ophthalmologist.

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[5] The second alternative seemed best because one of the requirements for the groups can be so formulated as to provide different degrees of visual defect for comparison in terms of flight performance while, at the same time, relative economy in the number of subjects required can be achieved. In addition, an attempt to select subjects covering a continuous range of visual acuity is complicated by the fact that even though a continuum in terms of acuity might be set up, there would still be no assurance that a continuum existed in terms of defects associated with loss of acuity, i.e., that a continuum in terms of visual efficiency existed.

[6] For purposes of the visual testing routine, Group D was divided into 3 sub-groups, D_1, D_2, and D_3. However, so far as the analysis of data is concerned, these sub-groups constitute the single classification, Group D.

TABLE 1

ESTIMATED PROPORTION OF TOTAL POPULATION FALLING INTO EACH VISUAL GROUP

Group A	50%
Between A and B	24.5%
Group B	13%
Between B and C	3%
Group C	3%
Between C and D	2%
Group D	4.5%

TABLE 2

DETAILED REQUIREMENTS FOR SUBJECTS IN EACH OF THE VISUAL GROUPS

Group A: Unaided vision of 20/20 or better in each eye with high acuity of stereopsis and a refractive error under cycloplegia of less than 0.50 D. of myopia in any meridian, 1.50 D. of hyperopia in any meridian and 1.00 D. of astigmatism.

Group B: Unaided vision of 20/50 or worse in each eye corrected with forward glasses to 20/20 or better in each eye, with a high acuity of stereopsis corrected (3 cm. at 6 meters) and a refractive error under cycloplegia of less than 3.00 D. in any meridian, less than 2.00 D. of astigmatism and less than 2.00 D. of difference between any parallel meridians in the two eyes.

Group C: Unaided vision of 20/100 or worse in each eye, corrected with forward glasses to 20/50 or better in each eye, with a corresponding acuity of stereopsis (10 cm. at 6 meters) and a refractive error under cycloplegia exceeding 4.00 D. in any meridian.

Group D_1: One eye correctible to 20/20 with a refractive error less than 3.00 D. in any meridian and less than 2.00 D. of astigmatism; the other eye uncorrected 20/100 or worse not correctible to 20/50, or having been removed at least 5 years prior to application for flight training.

Group D_2: Same as D_1 except that the candidate must also be a squinter.

Group D_3: A 10° or greater horizontal tropia with less than 10° of vertical tropia and with each eye correctible to 20/20 with a refractive error less than 3.00 D. in any meridian and less than 2.00 D. of astigmatism.

SUBJECTS

The subjects employed in the experiment were drawn from the student body at Ohio State University and from the Columbus, Ohio, area. All subjects were males, between 17 and 29 years of age, inclusive. Admission to the experiment and assignment to visual groups were in accordance with the procedures outlined subsequently. None of the subjects had previous flight training.

PROCEDURES

Visual Tests. The tests and visual testing procedures employed are presented in detail in Appendix 3 of this report, "Manual of Visual Tests." In summary, the visual tests used included measures of central acuity, phorias and vergences, stereopsis, tests for paralytic motor disturbances, central color vision, night vision, and range of accommodation. The ophthalmological examination, administered to subjects passing the screening tests, included determination of objective refraction under cycloplegia; a post cycloplegic test; determination of prescription for the individual, if any; an appraisal of any disease; and finally, a diagnosis.

Psychological Tests. Each subject in the investigation was given a battery of psychological tests. The purpose of administering these tests was to supply a basis for determining whether the groups differed significantly in characteristics, other than vision, which might be related to flight performance. The psychological tests administered were:

1. Mashburn Serial Reaction Test
2. Two-Hand Coordination Test
3. Desire to Fly Inventory
4. Biographical Inventory
5. Otis Test of Mental Ability
6. Test of Aviation Information
7. Test of Mechanical Comprehension
8. Lane Test[7]
9. Greene Test[7]
10. Dockeray Test[8]

In addition, the Ohio State Psychological Examination was administered and no applicant was accepted unless his score on this test was at or above the fifteenth percentile (based on entering college freshmen).

Assignment of Subjects. Screening tests were administered to all subjects at the Vision Testing Center. Applicants passing the screening tests were then referred to an ophthalmologist for examination. Applicants passing the ophthalmological examination were referred back to the Vision Testing Center for administration of the complete battery of visual tests, fol-

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[7]Studies in pilot selection: Lane, G. Gorham. I. The prediction of success in learning to fly light aircraft. Greene, Ronald F. II. The ability to perceive and react differentially to configurational changes as related to the piloting of light aircraft. Psychological Monographs, Vol. 61, No. 5, Whole No. 286, 1947.

[8]A complete description of this test is being prepared in a report on the Study of Organized Behavior, done under the auspices of the Committee on Selection and Training of Aircraft Pilots (now Committee on Aviation Psychology), National Research Council.

lowing which the battery of psychological tests was administered. All pertinent data were then reviewed by the Visual Study Committee on Admissions who assigned subjects to the various visual groups.

Subjects were selected, on the basis of the standards previously described, from [illegible] applicants for flight training. Of the latter 510 were disqualified or withdrew during preliminary screening activities, for reasons shown in Table 3. Another 77 withdrew during the period between the completion of the screening procedures and the first day of flight training. Reasons for these withdrawals are presented in Table 4.[9]

The design of the experiment called for a total of 200 subjects, 80 in Group A, and 40, respectively, in Groups B, C, and D. (Twice as many subjects were included in Group A as in any other single group in order that the most stable measures might be obtained on the "normal" visual group.) Because of the withdrawals noted above, the total number of subjects given flight training for purposes of the experiment was actually 194, including 80 in Group A, 38 in Group B, 40 in Group C, and 36 in Group D. These, then, were the subjects of the experiment.

<u>Flight Training</u>. Subjects were given flight training in accordance with the requirements of a controlled course of primary flight instruction approved by the CAA. The experiment was conducted over a period of six academic quarters, the subjects trained during each quarter being designated a "class." Each of the six successive classes, ranging in size from 25 to 39 subjects, included subjects in each visual group (A, B, C, and D) roughly in the ratio of 2:1:1:1, respectively. These were distributed as equitably as possible among the instructors within the limitations imposed by the available number of instructors and scheduling problems.

The number of flight instructors employed for each class varied between 6 and 7. Originally it was planned to employ the same group of instructors throughout the program. This, however, proved impossible since some turnover was unavoidable, although with one exception every subject was assigned a single instructor for the entire course of primary flight training.[10] Similarly, it was desired that each instructor be assigned subjects in each visual group, roughly in the ratio of 2:1:1:1 for Groups A, B, C, and D, respectively. Again, however, this pattern of assignments could not altogether be realized. The distribution of subjects in the experiment in terms of visual groups, classes, and instructors is presented in Table 5.

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[9] In addition, a total of 12 subjects withdrew after training had started, but within short enough period (less than 10 hours) to permit substitutions of entirely new subjects without interfering with the design of the experiment. Six of these subjects withdrew due to lack of time, 2 were drafted, 2 were subject to airsickness, 1 was emotionally unstable, and 1 proved physically handicapped. Seven of these subjects fell in Group A, 2 in Group B, 2 in Group C, and 1 in Group D.

[10] In one instance, an instructor (Serafini) left the program before completing the academic quarter. The training of his students was completed by another instructor (Hill). The combination was treated in the analyses as a single "instructor" (Serafini-Hill).

TABLE 3

REASONS FOR DISQUALIFICATION OR WITHDRAWAL DURING PRELIMINARY SCREENING ACTIVITIES
N = 510

Reason	Number
Preliminary Visual Examination (Failed)	208
Lack of Interest*	206
Lack of Time	57
College Disapproval	11
Previous Flight Time	14
Over-age	7
Physical Examination (Failed)	5
Lack of Funds	3
	510

*Including failure to return after initial interview.

TABLE 4

REASONS FOR DISQUALIFICATION OR WITHDRAWAL DURING THE PERIOD BETWEEN THE COMPLETION OF SCREENING PROCEDURES AND THE FIRST DAY OF FLIGHT TRAINING
N = 77

Reasons for not Continuing	A	B	C	D	TOTAL
Lack of Time	8	11	16	7	42
College Disapproval	1	2	2	4	9
Lack of Interest	4	7	2	11	24
Drafted	1	-	1	-	2
TOTALS	14	20	21	22	77

TABLE 5

DISTRIBUTION OF SUBJECTS BY VISUAL GROUPS, CLASSES, AND INSTRUCTORS

	Visual Group A								Visual Group B						
Instr.	Class	Fall 45 (1)	Wint. 46 (2)	Spr. 46 (3)	Sum. 46 (4)	Fall 46 (5)	Wint. 47 (6)	Total	Class	Fall 45 (1)	Wint. 46 (2)	Spr. 46 (3)	Sum. 46 (4)	Fall 46 (5)	Wint. 47 (6)
Stahle		2	1	3	-*	-	-	6		0	2	0	-	-	-
Pontius		3	2	1	3	2	-	11		1	1	0	1	-	-
Sterling		2	2	1	0	-	-	5		1	1	0	1	-	
Rasmus		3	0*	2	-	-	-	5		1	1	1	-		-
Serafini-Hill		1	-	-	-	-	-	1		1	-	-	-	-	-
McGriff		1	2	3	2	-	-	8		2	1	0	2	-	-
Willi		1	2	3	2	2	2	12		1	1	1	1	-	-
Hill			2	3	2	-	-	7		-	1	1	2		
Morris		-		-	2	3	2	7		-	-	-	2	-	
Anderson		-	-	-	3	-	-	3		-	-	-	1	-	
Shafer		-	-	-	-	2	2	4		-	-	-	-	-	-
Zimmerman		-	-	-	-	2	2	4		-		-		-	-
Buher		-	-	-	-	-	1	1		-	-	-	-	-	
Hench		-	-	-	-	2	2	4		-	-	-	-	-	
Shisler			-	-	-	-	2	2		-	-	-	-	-	-
	TOTAL	13	11	16	14	13	13	80		7	8	4	9	[illegible]	-

Total A = 80 Total B = [illegible]

*A dash indicates that the instructor was not in the program at the time.
A zero indicates that the instructor was in the program but did not have subjects in the visual group.

TABLE 5 (Continued)

DISTRIBUTION OF SUBJECTS BY VISUAL GROUPS, CLASSES, AND INSTRUCTORS

Instr.	Class	Visual Group C Fall 45 (1)	Wint. 46 (2)	Spr. 46 (3)	Sum. 46 (4)	Fall 46 (5)	Wint. 47 (6)	Total	Class	Visual Group D Fall 45 (1)	Wint. 46 (2)	Spr. 46 (3)	Sum. 46 (4)	Fall 46 (5)	Wint. 47 (6)	Total
Steele		1	1	0*	-*	-	-	2		1	0	1	-	-	-	2
Pontius		1	0	2	0	2	-	5		1	1	1	1	0	-	4
Sterling		1	0	2	-	-	-	3		2	0	1	-	-	-	3
Easeas		1	1	0	-	-	-	2		1	0	1	-	-	-	2
Seraidar Hill		1	-	-	-	-	-	1		2	-	-	-		-	2
McRiff		1	0	2	1	-	-	4		2	1	0	1	-	-	4
Willi		[illegible]	0	1	1	1	1	6		2	1	0	2	1	0	[illegible]
Hall		-	0	1	1	-	-	2		-	1	0	1	-	-	2
Morris			-	-	1	1	2	4		-	-	-	1	1	0	2
Anderson		-	-	-	0	-	-	0		-	-	-	0	-	-	0
Shafer		-	-	-	-	2	1	3		-	-	-	-	0	2	2
Zimmerman		-	-	-	-	0	2	2		-	-	-	-	1	1	2
Buher		-	-	-	-	-	1	1		-	-	-	-	-	1	1
Sezel		-	-	-	-	2	1	3		-	-	-	-	1	2	3
[illegible]		-	-	-	-	-	2	2		-	-	-	-	-	1	1
	TOTAL	[illegible]	2	8	4	8	10	40		11	4	4	6	[illegible]	[illegible]	36

Total C = 40

Total D = 36

* A dash indicates that the instructor was not in the program at the time.
A zero indicates that the instructor was in the program but did not have subjects in the visual group.

Subjects received a minimum of 35 hours of flight training and a maximum of 50, those failing the flight examination for the private pilot license, given after 35 hours of training, being given additional instruction up to the maximum number of hours if necessary.

The flight instructors and check pilots were selected according to rigorous standards and were all college graduates, with a minimum of 1,000 hours instructional experience. Many of them were also "research minded," having previously been employed at the Institute of Aviation Psychology, University of Tennessee, Knoxville, Tennessee.

None of the instructors was informed as to the visual group classification of their subjects. There can be no question, however, that the flight instructors, as well as the check pilots, flight examiners, and inspectors had considerable knowledge as to which of the subjects were visually deficient. All subjects in Group D were required, by regulation, to be administered a special "Medical Flight Test" by a CAA inspector. Even in the case of subjects in Groups C and B other cues as to visual deficiency, such as the wearing of thick lenses, were evident.

As far as could be determined, however, there was no bias against the visual deficients in so far as the instructors and check pilots were concerned, several of the instructors opining, privately, that there should be no reason why visual deficients could not learn to fly if properly trained. If any bias existed, it may well have been in favor of the visually deficient.

With reference to the check pilots, flight examiners, and inspectors, determination of bias could not be made. It might be noted, however, that several of the check pilots and flight examiners were formerly employed at the Institute of Aviation Psychology, and, being "research minded," apparently made a real effort to be objective.

Check Flights and Flight Examination. Each subject in the experiment was administered a check flight by a check pilot after the seventh, fifteenth, twenty-fifth, and thirty-fifth hour of flight training. Following the 35 hour check flight, every subject was administered the private pilot flight examination by a CAA inspector, or an approved flight examiner.[11] Subjects failing the private pilot examination at this point were given additional instruction, until their flight instructor considered them ready for another test. At this point they were given a check flight by a check pilot, followed by a readministration of the private pilot flight examination by either

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[11]In general, subjects in Groups A, B, and C were administered this test by a flight examiner. Subjects in Group D, however, were tested by an inspector, who also administered the special "Medical Flight Test," required for all applicants for the private license exhibiting visual deficiency to the degree of subjects in Group D.

a flight examiner or a CAA inspector. If this test was failed, additional training, and additional check flights and flight tests were given, up to a maximum of 50 hours of flight training.[12]

The maneuvers included in the check flights administered by the check pilots are presented in Table 6. During execution of these maneuvers a large number of detailed measures on the performance of each subject was obtained. Two airplanes and two check pilots were employed. Both the planes and the check pilots were counterbalanced with respect to visual groups in order to avoid any bias which might result from plane or check pilot differences. Since each subject received four check flights, the check pilots were alternated in the check flights so that one check pilot would have the first and third check flights, and the other check pilot would have the second and fourth check flights. Thus, if one check pilot is designated P and the other check pilot Q, the sequence of check flights would be PQPQ for half the subjects in each visual group, and QPQP for the other half.

CRITERION MEASURES

__Principal Criterion Measures__. The principal criterion measures on which the evaluation of the flight performance of subjects in the experiment was based are presented in Table 7. It will be noted that in general these criterion measures are based on evaluations or observations of performance made by the flight instructor or by the check pilot.[13]

__Photographic Records__. Photographic records were also taken of a concealed instrument panel during the execution of four maneuvers in each check flight: Take-off, Steep Turns, Straight and Level Flight, and Landings. These maneuvers were selected as representative on the basis of __a priori__ considerations; Take-off and Landings representing relatively difficult maneuvers in which visual efficiency might be considered important Steep Turns representing a relatively difficult maneuver in which visual efficiency might not be important, and Straight and Level a relatively easy maneuver possibly not calling for marked visual efficiency.

A concealed photographic installation included in both criterion planes is shown in Figure 1. It should be noted that one of the principal advantages of the type of criterion measures obtained is their objectivity, and

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[12]In addition, subjects who failed to solo following 30 hours of training were eliminated when, in the opinion of their flight instructor and the check pilots, the prospects for their completing the course within 50 hours were poor.

[13]"Time to Solo" might be considered an exception to this generalization, although this measure is actually based on a judgment by the instructor as to the subject's readiness to take-off, circle the field, and land without the instructor's assistance or the moral support of his presence.

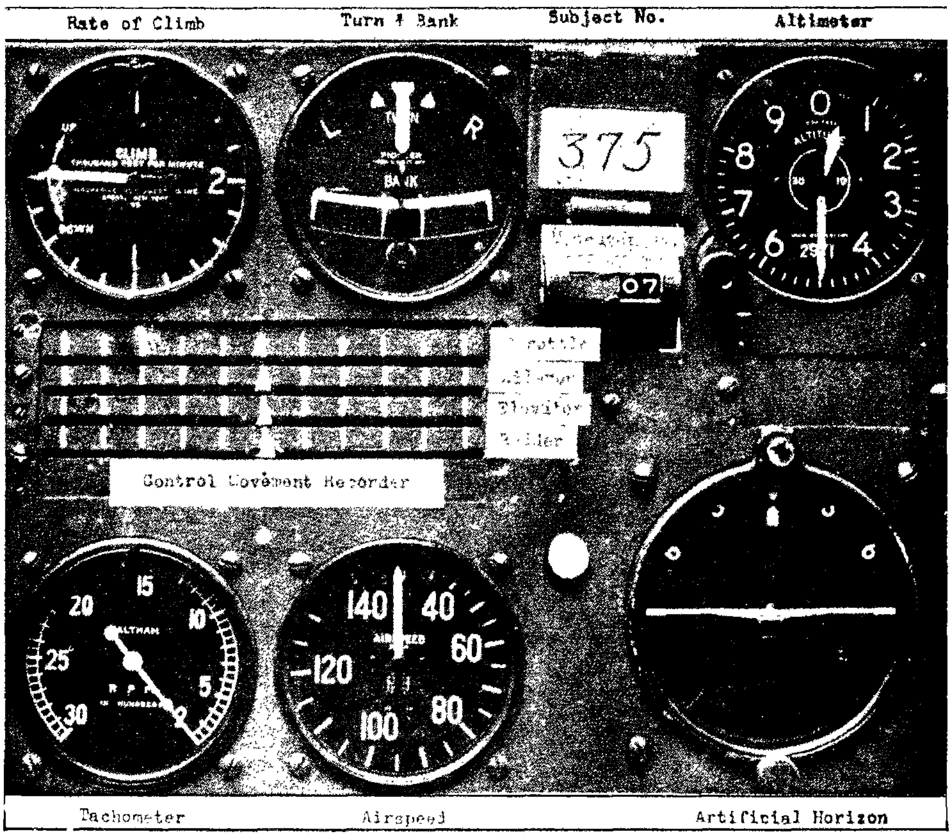

Figure 1

CAMERA FIELD -- PHOTOGRAPHIC INSTALLATION

(Model employed represented an adaptation of this basic panel)

TABLE 6

SEQUENCE OF MANEUVERS IN STANDARD FLIGHTS

No.	Maneuver	Check flt: hours:	1 7	2 15	3 25	4** 35
1.	Taxi		X	X	X	X
2.	Take-off		X	X	X	X
3.	Straight and level (1 1/2 min.)		X*	X*	X*	X*
4.	Shallow S around pylon			X		
	Medium S around pylon				X	X
5.	Straight climb (30 sec.)		X	X	X	X
6.	L. 90° climbing turn		X	X	X	X
7.	L. 90° turn, 30° bank		X	X	X	X
8.	R. 90° turn, 30° bank		X	X	X	X
9.	L. 720° steep turn			X*	X*	X*
10	R. 720° steep turn			X*	X*	X*
11.	Normal power-off stall		X	X	X	X
12.	R. 720° steep turn			X*	X*	X*
13.	L. 720° steep turn			X*	X*	X*
14.	Straight glide (30 sec.)		X	X	X	X
15.	90° Left gliding turn		X	X	X	X
16.	Forward slip (20 sec.)		X	X	X	X
17.	Traffic pattern and approach (with power)					X
18.	Strange field landing (with power)					X
19.	Straight and level flight (1 1/2 min.)		X*	X*	X*	X*
20.	Traffic pattern and approach		X	X	X	X
21.	Landing (with slip)		X	X	X	X
22.	Take-off		X*	X*	X*	X*
23	Traffic pattern and approach		X	X	X	X
24.	Landing		X*	X*	X*	X*
25.	Take-off		X*	X*	X*	X*
26.	Traffic pattern and approach		X	X	X	X
27.	Landing		X*	X*	X*	X*
28.	Take-off		X*	X*	X*	X*
29.	Traffic pattern and approach		X	X	X	X
30.	Landing		X*	X*	X*	X*

An X in the check flight column indicates that the maneuver in question is included in the given check flight.

*Denotes photographed maneuver.

**If the student fails the 35th hour check flight, the sequence for the subsequent check flights will be the same as that for the 35th hour check flight

TABLE 7

PRINCIPAL CRITERION MEASURES

Criterion Measure	Explanation
1. Weighted Over-all Grade (Instr.)	During each dual flight the instructor assigned a grade on the basis of his judgment of the over-all performance
2. Weighted Mean Maneuver Grade (CP)	To each maneuver performed by the subject the check pilot assigned a grade on the basis of his judgment. These were averaged for each check flight.
3. Weighted Over-all Grade (CP)	During each check flight the check pilot assigned a grade on the basis of his judgment of the over-all performance.
4. Weighted OSFI Score (1-I/A) (CP)	During each check flight the check pilot filled out the Ohio State Flight Inventory on the basis of his observations of the subject's performance. A = the largest possible error score that the subject could have. This is actually the error score for all items that were not omitted by the check pilot. I = the subject's total error score.
5. Weighted Mean Maneuver Grade (Instr.)	During each dual flight the instructor assigned a grade to each maneuver on the basis of his judgment. These were averaged for each lesson.
6. Mean Maneuver Grade (CP) Last CF	As 2, above, but based only on the last check flight.
7. Over-all Grade (CP) Last CF	As 3, above, but based only on the last check flight.
8. OSFI Score (1-I/A) Last CF (CP)	As 4, above, but based only on the last check flight.
9. Purdue Sum (Instr.)	Sum of item scores on the Purdue Rating Scale. As score, the higher the score, the poorer the pilot. Filled out by the instructor at the end of the training.

TABLE 7 (Continued)

PRINCIPAL CRITERION MEASURES

Criterion Measure	Explanation
10. Time to Solo (logarithm)	The logarithm of the number of minutes of dual training prior to the first solo flight. It is assumed that this measure is a good index of the instructor's judgment of the pilot's competence. The logarithm is used instead of the number of minutes because of the skewness of the distribution. Using the logarithm tends to make the data more normal. The logarithm also has greater *a priori* validity than the number itself because it gives greater weight to small differences at the low end of the scale and less weight to small differences at the high end of the scale. If the subject was never permitted to solo, the point was arbitrarily set at forty hours, or 2400 minutes.
11. Weighted Landing Maneuver Grade (CP)	As indicated under 2, above, the check pilots assigned grades to each maneuver. These are the grades on the landings.
12. Weighted Landing OSFI score (CP)	Error score on the OSFI landing sheet. Recorded by the check pilot during the check flights.
13. Weighted Mean Maneuver Grade on Practice Landings. (Instr.)	Grade based on instructor's judgment of student's performance of landings during the dual flights.

lack of susceptibility to bias, in as much as the record readers did not know the visual qualifications of the subjects whose records they read. The individual measures taken from these photographic records will be presented subsequently, in connection with the discussion of the analyses of the data from the photographic records.[14]

Additional Criterion Measures. In addition to the criteria presented above, the following measures of flight performance also were obtained.[15]

1. Grade given by the flight examiner or inspector on the private pilot flight test (generally expressed in terms of "pass" or "fail").

2. Measures of performance as indicated by specific items on the Ohio State Flight Inventory, pertaining to the maneuver "Landing," taken on the last check flight.[16] A sample page from the Ohio State Flight Inventory is presented in Exhibit 1.[17]

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[14]The development of the photographic criteria and the photographic installation, of which the installation employed in this study was an adaptation, is presented in: Viteles, Morris S., & Thompson, Albert S. An analysis of photographic records of aircraft pilot performance. Washington, D. C.: CAA Division of Research, Report No. 31, July 1944. The specific procedures employed in reading the records from this investigation are included in the files of the Visual Study.

[15]It was also planned to include a "Taxi-obstacle course," a course containing simulated obstructions through which the subject would be required to taxi the plane. Because of practical difficulties, however, use of this "Taxi-obstacle course" was abandoned.

[16]The Ohio State Flight Inventory consists of a series of check sheets, each page of the inventory, i.e., each check sheet, being devoted to a single maneuver. On each "maneuver sheet" the critical elements of the maneuver in question are indicated, and spaces are provided whereby the check pilot, who administers the flight test, records the subject's performance on each critical element. The inventory is filled out by the check pilot, while in flight, during the actual execution of the maneuvers in question. For a full discussion of this inventory and its development see: Edgerton, H. A., & Walker, R. Y. History and development of the Ohio State Flight Inventory, Part I: Early versions and basic research. Washington, D.C.: CAA Division of Research, Report No. 47, July 1945. Also: NRC Committee on Selection and Training of Aircraft Pilots. History and development of the Ohio State Flight Inventory, Part II: Recent versions and current applications. Washington, D.C.: CAA Division of Research, Report No. 51, November 1945.

[17]All individuals charged with obtaining criterion measures were thoroughly trained in the procedures to be employed in collecting such data. Training procedures and manuals employed in such indoctrination are in the files of the Committee on Aviation Psychology.

Weighting of Criterion Measures. Reference to Table 7 will indicate that certain criterion measures are designated as "weighted." These measures were based on a combination of scores from individual measures over the first four check flights or over the entire course. For each of such measures weighted averages were computed. For the check flight measures the weights 1, 2, 3, and 5 were assigned to the scores derived from the first, second, third, and fourth check flights, respectively, and the total (the sum of the weighted scores) averaged. In the case of grades assigned by the instructor during each flight lesson throughout the course, the weight of 1 was assigned to grades given during the first quarter of the course, the weight of 2 to grades assigned during the second quarter, the weight of 3 to third quarter grades, and the weight of 5 to fourth quarter grades. Again, a single score in terms of each such measure was obtained, representing the average of the weighted totals for each quarter of the course.[18]

RESULTS OF THE INVESTIGATION

Although analysis of variance was the principal statistical tool employed in this investigation, a variety of other types of analysis also was employed. Initially, determination was made of the correlations among selection tests and among criteria, and between selection tests and criteria. In the analyses of criterion measures certain of the measures were treated by chi-squared, rather than through the use of analysis of variance. In addition, for the analysis of data in terms of the Pass-Fail criterion, a partial correlation technique, by means of which the effect of the selection tests could be held constant, was used in the evaluation of the Pass-Fail data, as well as an analysis involving interaction chi-squared. Moreover, for a number of measures learning curves were drawn, as an indication of the performance of subjects in the various visual groups throughout the course; and cumulative curves were prepared by means of which the proportion of subjects in each visual group surpassing any given degree of proficiency can be determined.

Design of Analysis of Variance. Ideally, for each of the measures treated by analysis of variance, the analysis should have been conducted by a three-way classification design as shown in Figure 2. In such an analysis the three variables: Visual Groups, Instructors, and Classes would all be controlled simultaneously. However, limitations in the data prevented use of this type of analysis. Since the experiment was conducted over a period of six academic classes, there were several instances in which instructors resigned and were replaced prior to the beginning of the next class. Thus, in such a three-way classification design there would be many empty cells, making analysis inadvisable.

As an expedient under these circumstances two analyses were made for each criterion measure. In the one, presented diagrammatically in Figure 3 the variables Visual Groups and Classes were controlled; and in the other the variables Visual Groups and Instructors were controlled (see Figure 4).

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[18] These particular weights were assigned on the basis of estimates as to the relative importance of measures taken early, and later, in the course of flight training.

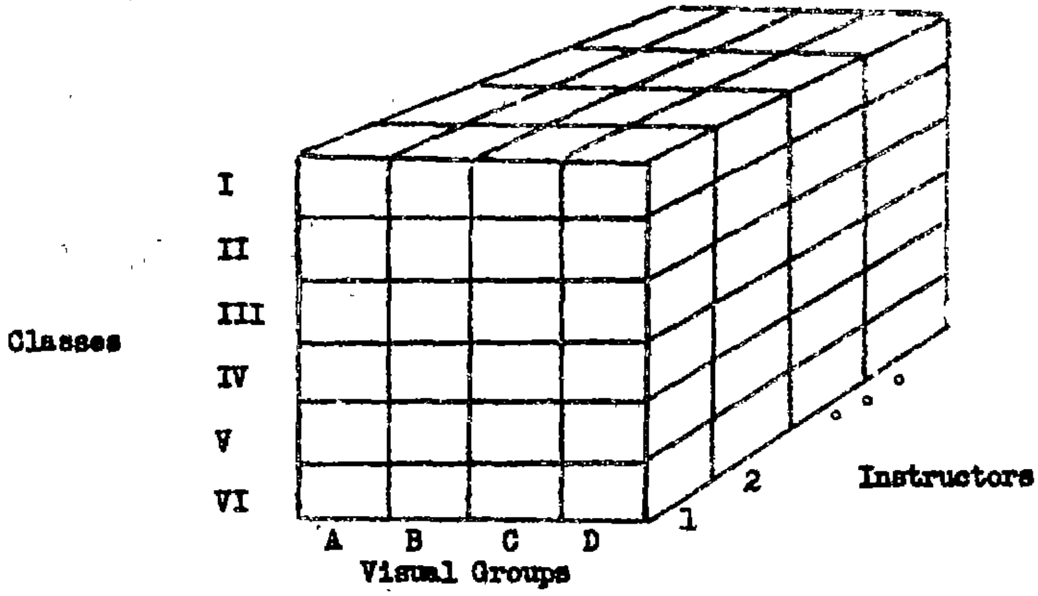

FIGURE 2

DIAGRAMMATIC REPRESENTATION OF IDEAL DESIGN

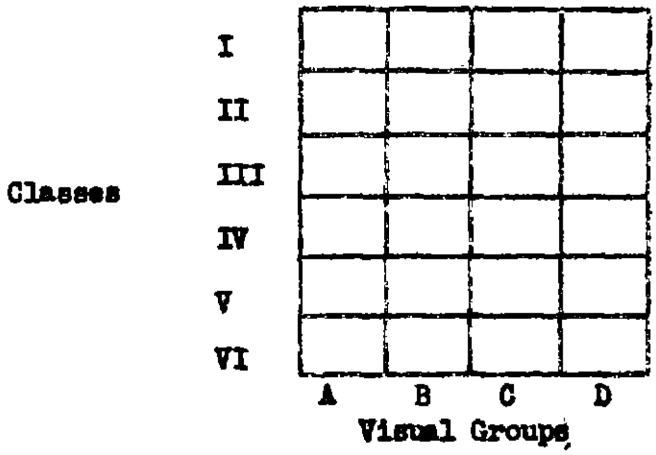

FIGURE 3

DIAGRAMMATIC REPRESENTATION OF "VISUAL GROUPS-BY-CLASSES" DESIGN

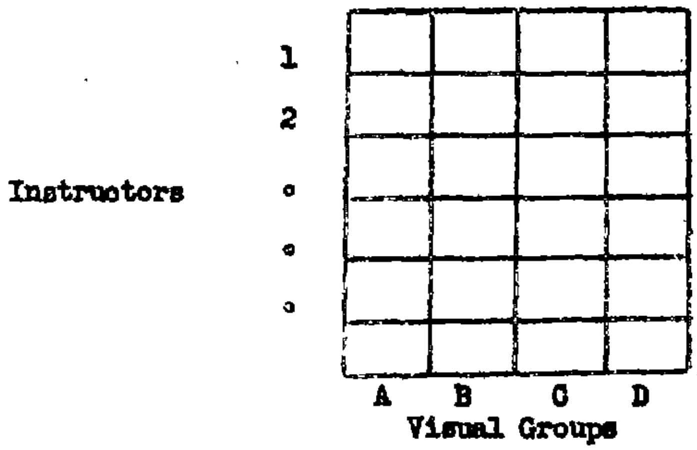

FIGURE 4

DIAGRAMMATIC REPRESENTATION OF "VISUAL GROUPS-BY-INSTRUCTORS" DESIGN

One of the major limitations of the design employed is that the tests of significance are reduced in power[19] in the Visual Groups by Classes analysis because the error term contains the variation due to instructors, and in the Visual Groups by Instructors analysis because the error term contains the variation due to Classes. An advantage of the design employed is, however, that if significant differences appear as a result of the analyses, the findings have greater generality than if the error term had the variation due to both Instructors and Classes removed. Thus, for example, a significant F for the Visual Groups in the Visual Groups by Classes analysis (F = Variance due to visual groups/error variance) may permit one to generalize to the population of instructors.

In each analysis the sums of squares and degrees of freedom were divided into four components: Visual Groups, Classes or Instructors (depending on the analysis), Interaction, and Residual. The residual, or within-cells variance, was used as the error term in the computation of each F. In presenting the results of the analyses of variance later in this report, it will be noted that the reported p-values are given as "greater than .20," "less than .20 and greater than .05," etc.

Results: Correlations Among Selection Tests and Among Criterion Measures; and Between Selection Tests and Criterion Measures

Correlations Among Selection Tests. The question may be raised as to whether the selection tests are measuring one or many factors. Table 8 gives the matrix of correlations of the selection tests. Inspection of this table indicates that there is little reason to suppose that there is any general factor, such as aptitude for flight performance, which is being measured by these tests. Aside from a few relatively high correlations such as those between the Mashburn and the Two-Hand, the Otis and the Ohio State Psychological Examination, and the Biographical Inventory and the Test of Aviation Information, the correlation coefficients are rather low.

Correlations Among Criterion Measures. A similar question may be raised in connection with the criterion measures which were developed. Is there reason to suppose that they are measuring roughly the same thing, something which may be called general flight proficiency? Some notion as to the answer to this question may be obtained by inspection of the matrix of correlation coefficients among the criterion measures. This matrix is presented in Table 9. It will be noted, first, that none of the coefficients are negative. Second, the order of magnitude of the coefficients is generally quite high. Therefore, there is good reason to believe that the criterion measures have considerable in common.

Correlations Among Components of Weighted Criterion Measures. Of the thirteen criterion measures, five are general measures referring to no specific maneuver, and consist of duplicated components, i.e., of scores on individual criterion measures assigned at successive periods during the course of flight training either by the check pilot on each check flight or

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[19] Power is defined as the probability of rejecting the null hypothesis when it is false.

TABLE 8

CORRELATIONS AMONG SELECTION TESTS*

	Washburn	Two-Hand	DF	BI	Otis	AI	MC	OSPE	Lane	Greene	Dockeray
Washburn		.52	-.03	.17	.34	.14	.41	.26	.23	-.11	-.03
Two-Hand			-.15	.12	.47	-.41	.60	.39	.30	-.15	.23
DF				.12	-.17	-.27	-.01	-.13	.09	.21	-.13
BI					-.04	.53	.25	.11	.04	.14	.17
Otis						.38	.28	.63	.33	.03	.22
AI							.38	.37	.19	-.03	.23
MC								.36	.01	-.16	.03
OSPE									.32	.09	.13
Lane										.14	.02
Greene											-.10
Dockeray											

N = 129 $r_{.05}$ = .26 $r_{.01}$ = .34

*Wherever necessary, the correlation coefficients have been reflected. Positive coefficients indicate positive relationships between proficiencies.

TABLE 9

CORRELATION COEFFICIENTS AMONG THE THIRTEEN CRITERION MEASURES*

	Wtd. Over-all (I)	Wtd. MMG (CP)	Wtd. Over-all (CP)	Wtd. OSFI	Wtd. MMG (I)	MMG (Last check)	Last Over-all (CP)	Last OSFI (CP)	Purdue Sum	TTS (log)	Wtd. Landing MG(CP)	Wtd. Landing OSFI Score	Wtd. Landing MG on Practice landings (I)
Wtd. Over-all (I)		.48	.42	.60	.91	.19	.13	.11	.56	.48	.40	.42	.84
Wtd. MMG (CP)			.91	.88	.37	.61	.58	.47	.67	.68	.77	.60	.54
Wtd. Over-all (CP)				.77	.29	.58	.63	.46	.60	.63	.81	.57	.49
Wtd. OSFI					.48	.55	.50	.38	.68	.71	.73	.70	.60
Wtd. MMG (I)						.15	.08	.12	.50	.40	.27	.35	.74
MMG (Last check)							.89	.75	.58	.49	.47	.46	.21
Last Over-all (CP)								.75	.47	.49	.55	.43	.15
Last OSFI (CP)									.38	.40	.34	.24	[illegible]
Purdue Sum										.62	.52	.51	.54
TTS (log)											.64	.56	.60
Wtd. Landing MG (CP)												.74	.48
Wtd. Landing OSFI Score													.43
Wtd. Landing MG on Practice Landings (I)													

N = 129 $r_{.05} = .26$ $r_{.01} = .34$

*Wherever necessary, the correlation coefficients have been reflected. Positive coefficients indicate positive relationships between proficiencies.

on individual criterion measures assigned at successive periods during the course of flight training (either by the check pilot on each check flight or by the instructor on each dual instructional flight). These are:

1. Over-all Grades (I)[20]
2. Mean Maneuver Grades (CP)[20]
3. Over-all Grades (CP)
4. OSFI (CP)
5. Mean Maneuver Grades (I)

The correlation coefficients among the four components of each of these criterion measures were computed in order to determine the stability of the measures during flight training.[21]

These intercorrelations are presented in Tables 10 to 14, inclusive. Examination of these tables indicates that:

1. With two exceptions (the correlation between check flights 2 and 3 for the OSFI score and for the over-all grade given by the check pilot), all of the coefficients in these tables are significant at the 5 per cent level of confidence.

2. For the instructor over-all grades, the coefficients are uniformly high, the lowest being .65 between the first and fourth quarters. It is interesting to note that the higher coefficients appear between contiguous quarters.

3. Moderately strong coefficients appear for the mean maneuver grades (CP). It will be recalled that the first and third check flights were administered by one check pilot, and the second and fourth check flights were administered by the other check pilot.

4. For the over-all grade given by the check pilot, although all but one of the correlation coefficients are significant, they are not markedly high.

5. For the OSFI score, the correlation between the first and third check flights and the second and fourth check flights are higher than all the others. This is to be expected on the basis of the arrangement of check flights and check pilots.

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[20](I) denotes that the measure was taken by the Instructor, (CP) by the check pilot.

[21]The number of cases on which these correlations are based is 129. These correlations were computed prior to the completion of the study, and hence, are based on a smaller number of cases than the total sample. For 129 cases, a correlation coefficient of .18 is required in order to be significant at the 5 per cent level of confidence.

TABLE 10

CORRELATIONS AMONG
INSTRUCTOR OVER-ALL GRADES

	Qtr.1	Qtr.2	Qtr.3	Qtr.4
Qtr.1		.87	.76	.65
Qtr.2			.91	.79
Qtr.3				.89
Qtr.4				

TABLE 11

CORRELATIONS AMONG
MEAN MANEUVER GRADES - CHECK PILOTS

	C.F.1	C.F.2	C.F.3	C.F.4
C.F.1		.52	.78	.27
C.F.2			.47	.41
C.F.3				.58
C.F.4				

TABLE 12

CORRELATIONS AMONG
OVER-ALL GRADE-CHECK PILOT

	C.F.1	C.F.2	C.F.3	C.F.4
C.F.1		.28	.49	.30
C.F.2			.16	.34
C.F.3				.47
C.F.4				

TABLE 13

CORRELATIONS AMONG
(1 - I/A) OSFI SCORE

	C.F.1	C.F.2	C.F.3	C.F.4
C.F.1		.18	.57	.23
C.F.2			.11	.47
C.F.3				.39
C.F.4				

TABLE 14

CORRELATIONS AMONG
MEAN MANEUVER GRADES - INSTRUCTOR

	Qtr.1	Qtr.2	Qtr.3	Qtr.4
Qtr. 1		.86	.74	.66
Qtr. 2			.92	.81
Qtr. 3				.92
Qtr. 4				

6. The correlations for the mean maneuver grade assigned by the instructors are uniformly high.

In general, the correlation coefficients obtained from the instructor grades are higher than those obtained for the check flight grades. There are probably two factors which account for this. First, a single instructor gave all the instructor scores to each student. Second, the instructor grades for which correlations were computed are probably more reliable than the check flight scores because of the averaging method used in the computation of the instructor quarter scores. Averaging removes a considerable amount of chance variation, since the standard error of a single score is larger than that for a mean of several scores.

In general, the implications of this analysis are that these criterion measures showed sufficient stability to warrent their use as measures of flight proficiency.

<u>Correlations Between Selection Tests and Criteria</u>. As has been indicated, the purpose of administering selection tests at the outset of the experiment was to determine the extent to which the visual groups may have differed in characteristics pertinent to flight performance. It seemed desirable to determine the correlations between selection tests and the criteria, in part to determine whether the use of analysis of covariance, which originally had been considered, would be justified. The correlations between the selection tests and the thirteen principal criterion measures were computed, based on all subjects in the first four classes on which complete data were available (N = 129). In addition, biserial correlations with the Pass-Fail criterion also were computed. Passers were represented by those subjects who passed the flight test for the private pilot's license. Conversely, failers were represented by those who failed to receive the private pilot's license. These coefficients are presented in Table 15.

With the exception of the correlation with the Pass-Fail criterion it is evident that the coefficients are, in general, low, only 6 of the 143 coefficients being significant at the 1 per cent level of confidence. There is indicated little reason to believe that these criterion measures were affected by traits measured through the selection tests, at least in sufficient degree to warrant the additional labor involved in the employment of analysis of covariance rather than analysis of variance. With reference to the Pass-Fail criterion, however, the correlations between certain tests and this criterion were sufficiently high[22] to warrant an analysis in terms of which the significance of the relationship between visual efficiency (as represented by the Visual Group to which the respective subjects belonged) and flight proficiency (as represented by passing or failing the course) could be determined, with the effect of the matching or selection tests held constant (i.e., partialed out.) The results of this analysis will be described in a later section of this report.

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[22]The relatively high correlations with the Pass-Fail criterion may indicate that the element of flight proficiency measured by Pass-Fail are not the same elements as are measured by the other criteria. Alternatively, it could be suggested that the correlations between tests and criteria other than Pass-Fail are attenuated by the unreliability of these criteria. Militating against this possibility is the fact that the Pass-Fail criterion, on the basis of substantial evidence, has been considered quite unreliable.

TABLE 15

CORRELATIONS BETWEEN THE SELECTION TESTS AND THE CRITERION MEASURES*

	Washburn	Two-Hand	D-P	ET	Otis	AI	MC	OSPE	Lens	Greene	Dockeray
Wtd. Over-all (I)	.06	.05	.03	.27	.02	.23	.16	.10	-.09	.44	.12
Wtd. MMG (CP)	.10	.23	-.05	.28	.11	.36	.35	.21	.02	.08	.11
Wtd. Over all (CP)	.01	.21	-.03	.19	.06	.33	.31	.11	.08	.09	.03
Wtd. OSFI	.08	.20	-.03	.27	.08	.31	.27	.19	.00	.20	.12
Wtd. MMG (I)	.05	.12	-.06	.22	.03	.25	.08	.13	-.08	.36	.24
MMG (Last check)	.08	.17	-.08	.09	.22	.16	.11	.12	-.02	-.10	.24
Last Over-all (CP)	-.08	.07	.04	.07	.07	.16	.07	-.02	-.04	-.10	.24
Last OSFI (CP)	.15	.09	-.12	.10	.27	.33	.14	.11	-.01	-.14	.28
Purdue Sum	.28	.34	.11	.15	.25	.19	.31	.15	.07	.19	.13
TTS (log)	.06	.04	.02	.16	.00	.24	.20	-.04	-.14	.01	.17
Wtd. Landing MG (CP)	-.14	.04	.03	[illegible]	-.04	.33	.22	.02	.08	.14	.06
Wtd. Landing OSFI	-.04	.02	-.04	.20	-.02	.03	.09	.11	.09	.02	-.02
Wtd. Landing MG on practice landings (I)	.05	.04	-.05	.17	.15	.30	.13	.13	-.13	.34	.12
Pass-Fail (r_{bis})	.19	.31	.31	.16	.06	.25	.33	-.15	.10	.40	.21
$\sigma_{r_{bis}}$	.10	.09	.09	.10	.07	.09	.09	.10	.12	.11	.12

*Wherever necessary, the correlation coefficients have been reflected. Positive coefficients indicate positive relationships between proficiencies. The N for all coefficients is 129. For all except the biserial coefficients (involving Pass-Fail) $r_{.05} = .26$; $r_{.01} = .34$. The standard errors for the individual biserial coefficients are given.

Results: Analysis of Variance of Selection Tests

With reference to determining the relationship between tests and flight proficiency it was considered desirable to determine the extent to which visual groups differed in terms of scores on the several selection tests, in addition to the determination of the correlations between tests and flight criteria. Such an analysis was carried out even though the correlations between tests and criteria were low.

The type of analysis employed has been outlined previously, and was identical to that employed in the analysis of criterion measures, to be discussed subsequently, i.e., two analyses were run; in one visual groups and classes were controlled, in the other visual groups and instructors were controlled. The residual variance was used as the error term for the computation of each F. The results of the analyses are presented in Table 16, in which are shown the p-values obtained in the evaluation of each F and the means of the groups on each test.

Examination of this table indicates that in the Visual Groups-by-Classes analysis significant variation attributable to Visual Groups was evident in scores on the following tests:

1. Desire to Fly Inventory
2. Otis Test of Mental Ability*
3. Test of Aviation Information
4. Test of Mechanical Comprehension*
5. Ohio State Psychological Examination*
6. Greene Test*

The tests followed by the asterisks were also found to be significant in the Visual Groups-by-Instructors analyses.

In addition, the following points are noteworthy:

1. With but one exception, namely, the Greene Test, the selection tests in which there was significant variation in the means, show the B and C groups to be superior to the A and D groups.

2. For the Otis Test of Mental Ability, and the Ohio State Psychological Examination, both of which presumably measure intelligence, the confidence level at which the variation in the means is significant, is less than 1 per cent in both analyses.

3. Significant variation in the means of the classes occur for four out of the eleven selection tests.

4. Significant Visual Groups-by-Classes interactions are found for two of the selection tests.

5. In no instances are there significant variances for either the instructors or the Visual Groups-by-Instructors interaction.

TABLE 16

SUMMARY OF RESULTS OF ANALYSES OF VARIANCE FOR SELECTION TESTS: P-VALUES FOR F-TESTS
MEANS FOR SELECTION TESTS FOR VISUAL GROUPS

Visual Groups-by-Classes

Analysis	Washburn	Two-Hand	D.F.	B.I.	Otis	A.I.	M.C.	O.S.P.E.	Lane	Greene	Dockeray
Visual Groups	.20-.05	.20-.05	.05-.01	.20-.05	<.001	.05-.01	.05-.01	<.001	>.20	<.001	>.20
Classes	.20-.05	>.20	.20-.05	.20-.05	.05-.01	.05-.01	>.20	>.20	>.20	<.001	.05-.01
V x C	>.20	.20-.05	.20-.05	>.20	>.20	.05-.01	.05-.01	>.20	>.20	>.20	>.20
Means of Visual Groups											
A	295.13	323.43	67.13	9.42	47.45	114.03	53.43	57.44	58.95	103.6	40.1
B	270.71	355.3	68.41.5	10.31	52.22	120.92	57.01	81.71	58.2	123.1	29.7
C	290.32	345.22	68.41.5	9.33	53.01	121.57	55.12	75.62	61.1	137.0	34.7
D	300.14	322.34	65.14	9.04	46.84	105.64	52.34	58.53	57.8	125.3	34.1

Visual Groups-by-Instructors

Analysis	Washburn	Two-Hand	D.F.	B.I.	Otis	A.I.	M.C.	O.S.P.E.	Lane	Greene	Dockeray
Visual Groups	.20-.05	.20-.05	.20-.05	.20-.05	.01-.001	.20-.05	.05-.01	<.001	>.20	.01-.001	>.20
Instructors	>.20	>.20	>.20	>.20	>.20	>.20	>.20	>.20	.20-.05	>.20	>.20
V x I	>.20	>.20	>.20	>.20	>.20	>.20	>.20	>.20	>.20	>.20	>.20
Means of Visual Groups											
A	295.13	323.43	67.13	9.42	47.53	114.93	53.33	57.64	58.93	103.13	38.34
B	270.71	355.31	68.41.5	10.33	52.22	120.92	57.01	81.71	58.24	123.13	29.73
C	290.32	345.22	68.41.5	9.33	53.01	121.53	55.12	75.62	61.14	137.04	34.73
D	300.14	322.34	65.14	9.04	46.84	105.64	52.34	58.53	57.83	125.33	34.12

For each analysis in which a significant F was found, indicating significant variation in the means of the visual groups, the differences between pairs of means were tested for significance by use of the t-test. The results of these tests are presented in Table 17. It will be noted that although a number of the differences between visual groups is statistically significant, there is no apparent direct or linear relationship between scores on the tests and degree of visual handicap. For this reason, and in view of the generally low correlations between tests and criterion measures, analysis of variance, rather than analysis of covariance, was considered justified in the case of all criterion measures except Pass-Fail.[23]

The fact of the relatively high correlations between certain tests and the criterion Pass-Fail was not considered justification for use of covariance in the analysis of all criterion measures. However, as noted previously, in the analysis involving the Pass-Fail criterion the significance of differences in passing and failing, among subjects with high and low test scores, respectively, was determined through the use of interaction chi-squared. Partial correlation technique also was employed.

Results: Disposition of Cases

Mention has previously been made of withdrawals from the course, and before proceeding to a discussion of results in terms of individual criterion measures it is desirable to present data bearing on differences between visual groups in terms of the disposition of cases. These data are presented in Table 18.

Withdrawals. As is evident from inspection of Table 18, only 14 per cent of the subjects in Group A withdrew; whereas of the B, C, and D groups, respectively, 33, 33, and 37 per cent withdrew. The variation in these percentages is significant at the 1 per cent level of confidence. When Groups A and B were pooled and compared with the pooling of Groups C and D, 21.1 per cent of the former combination of groups withdrew as compared to 35.2 per cent of the latter. This difference in percentage is also significant at the 1 per cent level of confidence.

These figures suggest the hypothesis that students with defective visual acuity are less motivated to fly than are those with unimpaired or slightly impaired visual acuity. On the other hand, on the basis of informal interviews with subjects, there is also considerable justification for the additional hypothesis that individuals in Groups C and D were subjected to

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[23] It is of some interest that in general the tests showing the largest number of correlations with the criteria which approached or exceeded the level of statistical significance are also those for which significant variations in group means, attributable to Visual Group, were evident.

TABLE 17

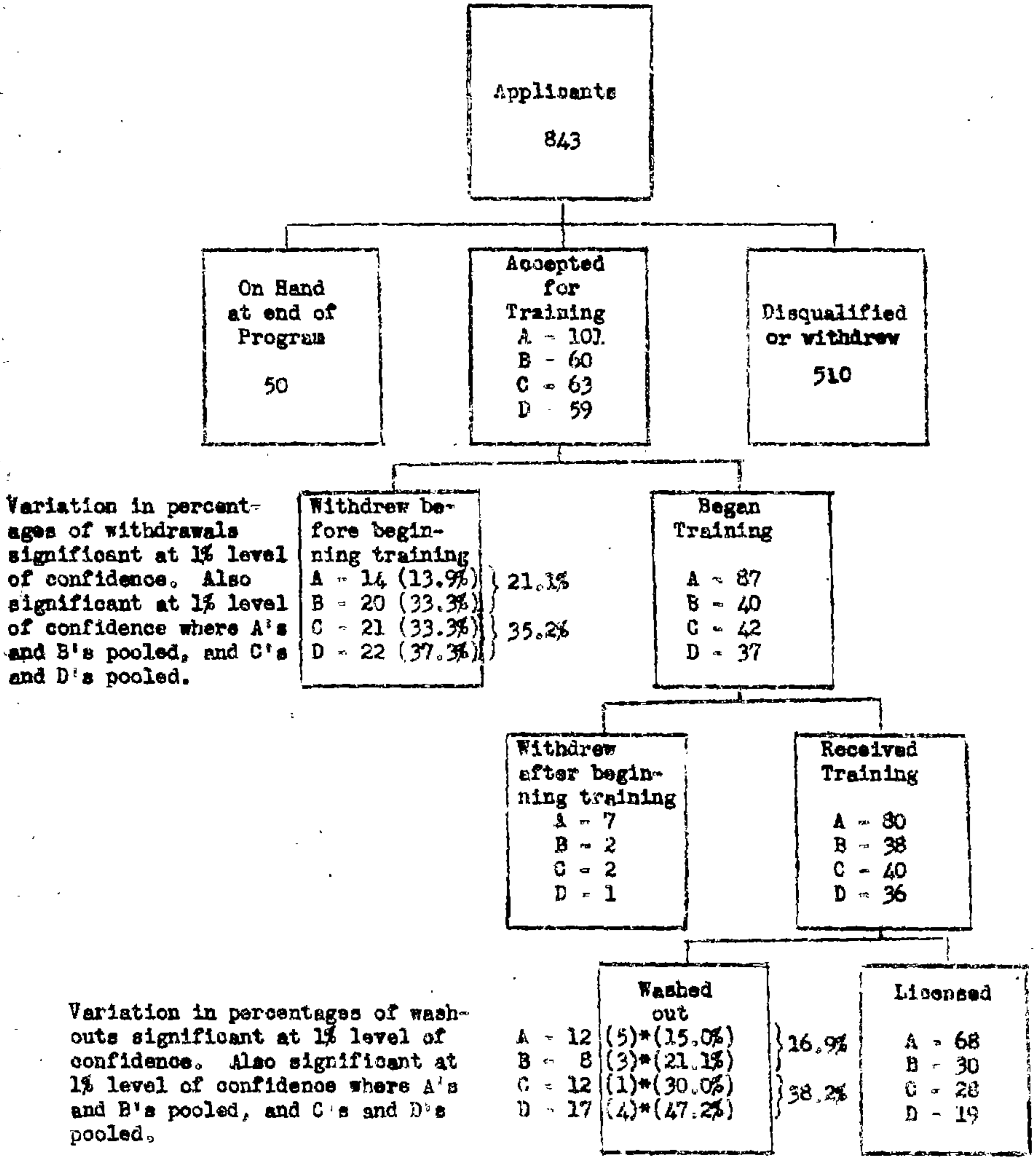
RESULTS OF t-TESTS ON PAIRS OF MEANS FOR THOSE ANALYSES OF THE SELECTION TESTS IN WHICH F WAS FOUND TO BE SIGNIFICANT AT 5% LEVEL OF CONFIDENCE

Selection Tests

Analysis	Pairs	Desire to Fly	Otis	Aviation Information	Mechanical Comprehension	O.S.P.L.	Greene
Visual Group by Classes	A – B	.30 > P > .20	.01 > P > .01	.20 > P > .10	.02 > P > .01	P < .001	.01 > P > .001
	A – C	.30 > P > .20	P < .001	.20 > P > .10	.30 > P > .20	P < .001	P < .001
	A – D	.10 > P > .05	.80 > P > .70	.20 > P > .10	.50 > P > .40	.90 > P > .80	.01 > P > .001
	B – C	P > .90	.70 > P > .60	P > .90	.30 > P > .20	.30 > P > .20	.10 > P > .05
	B – D	.02 > P > .01	.01 > P > .001	.20 > P > .01	.01 > P > .001	P < .001	[illegible]
	C – D	.02 > P > .01	.01 > P > .001	.01 > P > .001	.20 > P > .10	.01 > P > .001	[illegible]
Visual Group by Instructors	A – B		.01 > P > .001		.02 > P > .01	P < .001	[illegible]
	A – C		.01 > P > .001		.30 > P > .20	P < .001	P < .001
	A – D		.70 > P > .60		.60 > P > .50	.90 > P > .80	.02 > P > .01
	B – C		.70 > P > .60		.30 > P > .20	.30 > P > .20	.20 > [illegible]
	B – D		.01 > P > .001		.02 > P > .01	P < .001	.90 > P > .80
	C – D		.01 > P > .001		.20 > P > .20	.01 > P > .001	[illegible]

TABLE 18

DISPOSITION OF ALL CASES INVOLVED IN VISUAL STUDY



*These values are the number of subjects who washed out before taking the private pilot's examination.

more comments than were those in Groups A and B, to the effect that they were endangering themselves in undertaking flight training. However, it may be recalled that significant variation in means of the visual groups was found for the Desire to Fly Inventory, even among those subjects who did not withdraw. The D's showed less desire to fly than all other groups. The subjects showing the greatest desire to fly in terms of scores on this test were the B's and C's, with the A's intermediary. Twelve individuals withdrew after training began. The number of withdrawals in the four visual groups is, however, too small to permit statistical evaluation.

Licensing. Of the individuals who continued training, 15 per cent of the A's, 21 per cent of the B's, 30 per cent of the C's, and 47 per cent of the D's failed to receive licenses. The variation in percentages of washouts in the visual groups is significant at the 1 per cent level of confidence, although the difference in proportions of washouts when adjacent groups are compared, i.e., Group A vs. B; B vs. C; and C vs. D are not significant except with respect to the last comparison, a significantly greater proportion (at the .01 level of confidence) of Group D than Group C subjects having been eliminated before completing training. It is interesting to note, however, that the difference in percentages of washouts between the A and B groups is smaller than that between any other two groups. Furthermore, when the individuals of Groups A and B, on the one hand, and of Groups C and D, on the other, are pooled, the percentage of washouts in the former two groups is only 17 per cent as compared with 38 per cent in the latter two groups. This difference is significant at the 1 per cent level of confidence.

It appears evident that considering all subjects in each visual group, those with marked visual defect exhibited a significantly greater incidence of withdrawals from the course, and a significantly greater failure rate.

Results: Learning Curves

Learning curves were drawn, using averages of the visual groups, for the five duplicated criterion measures listed on page 24. In view of the special importance of landings in this investigation, the learning curves for the criterion measures of landing performance were also drawn.

These learning curves serve two purposes. First, they permit visual comparison of the learning rates of the four visual groups. Second, they permit visual comparison of the performance of the visual groups at various stages of training.

Figures 5 to 12 present these learning curves. Examination of these curves shows that there is a distinct tendency for the A and B groups to be superior to the C and D groups. This superiority is more marked in the final than in the early stages. Thus, it is interesting to note that for the various criterion measures administered by the check pilots (Figures 5, 6, 7, 11, and 12) on the second check flight the mean performance of Group C subjects is equal or superior to the mean performance of either Group A or Group B subjects, or as is indicated in Figures 6 and 7, superior to both. This superiority is not evident, however, by the time of the fourth check

FIGURE 5
LEARNING CURVES FOR VISUAL GROUPS
Mean Maneuver Grade (CP)

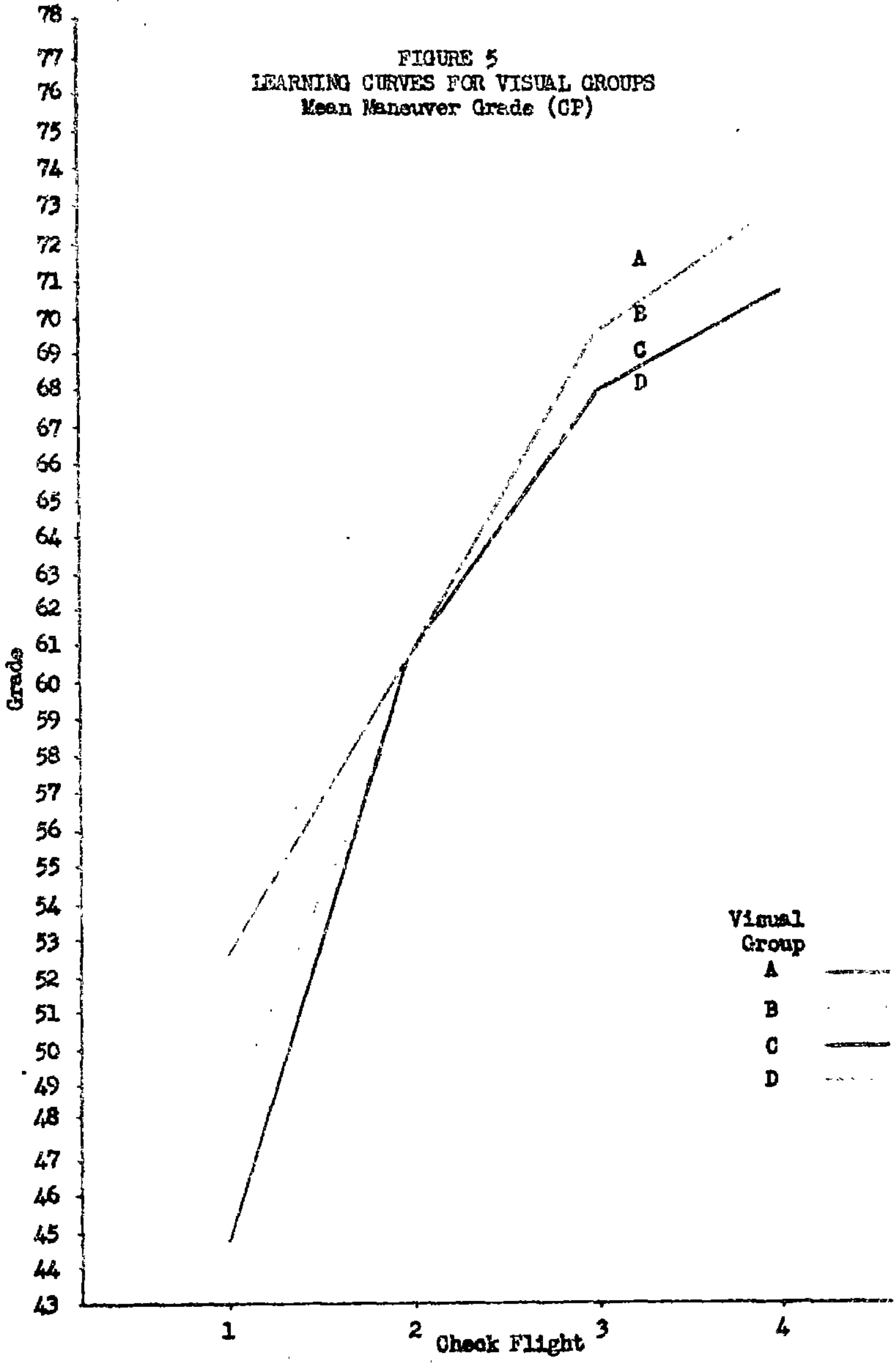


FIGURE 6
LEARNING CURVES FOR VISUAL GROUPS
Over-all Grade (CP)

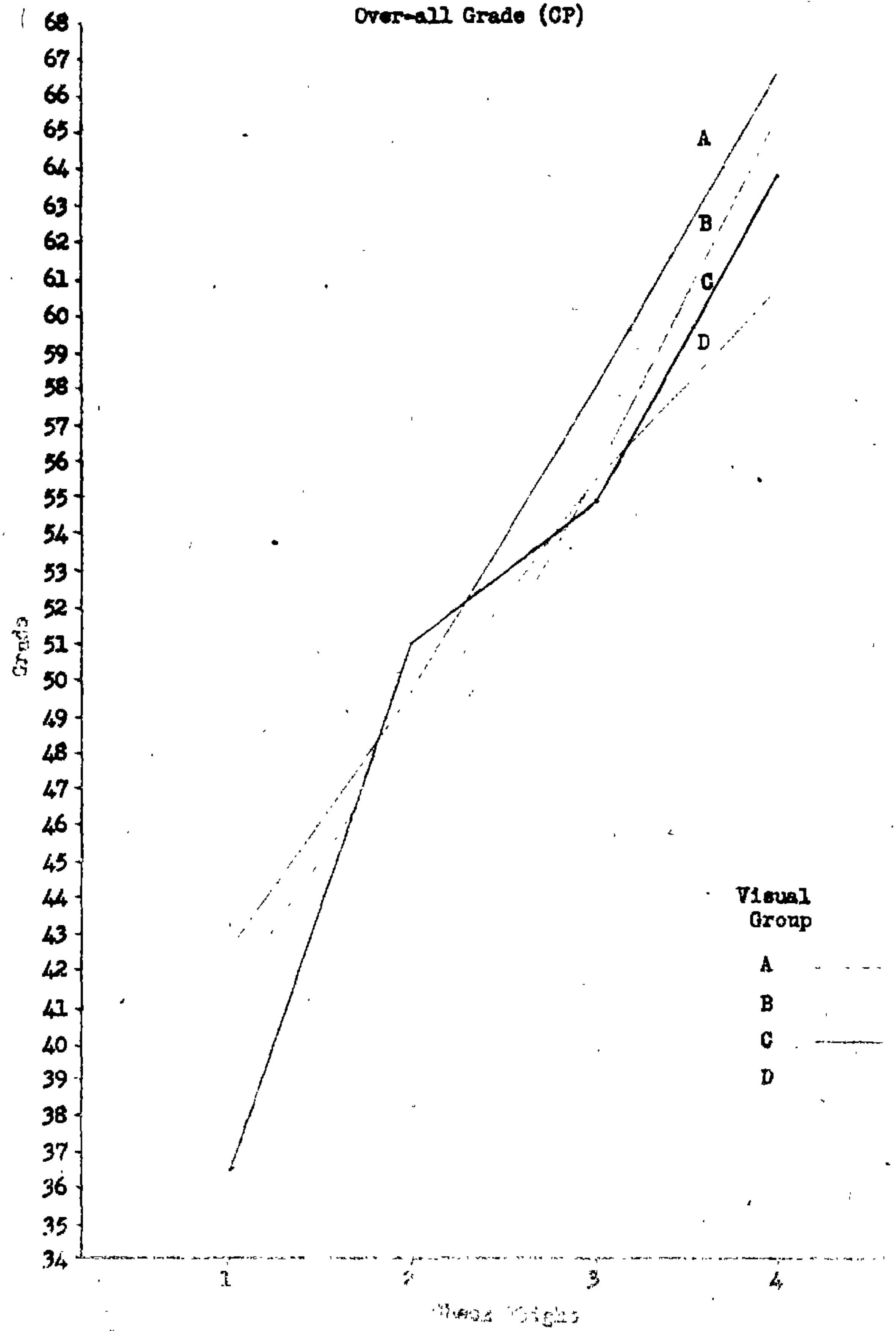
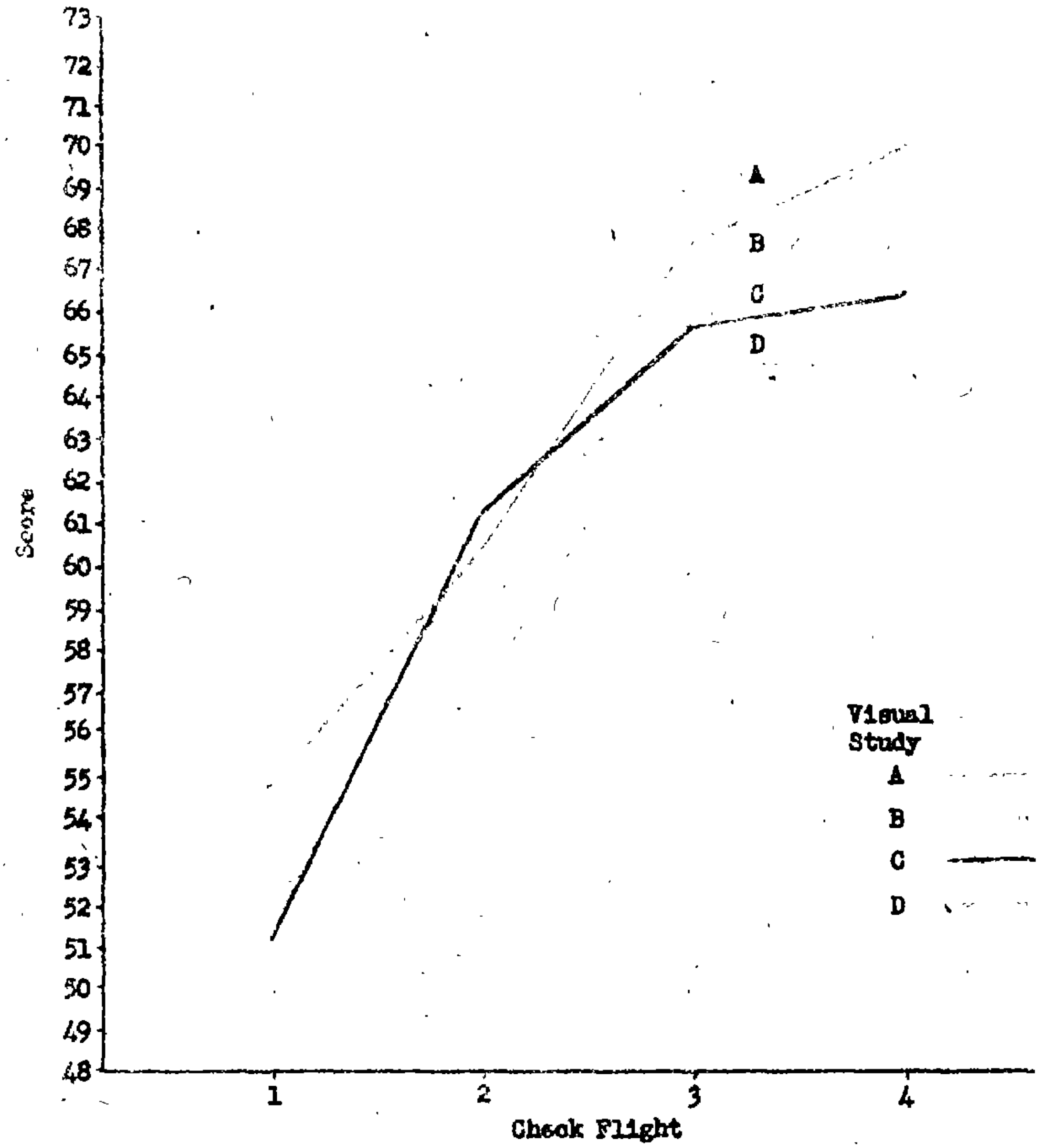


FIGURE 7
LEARNING CURVES FOR VISUAL GROUPS
OSFT Score (1-I/A) (CP)



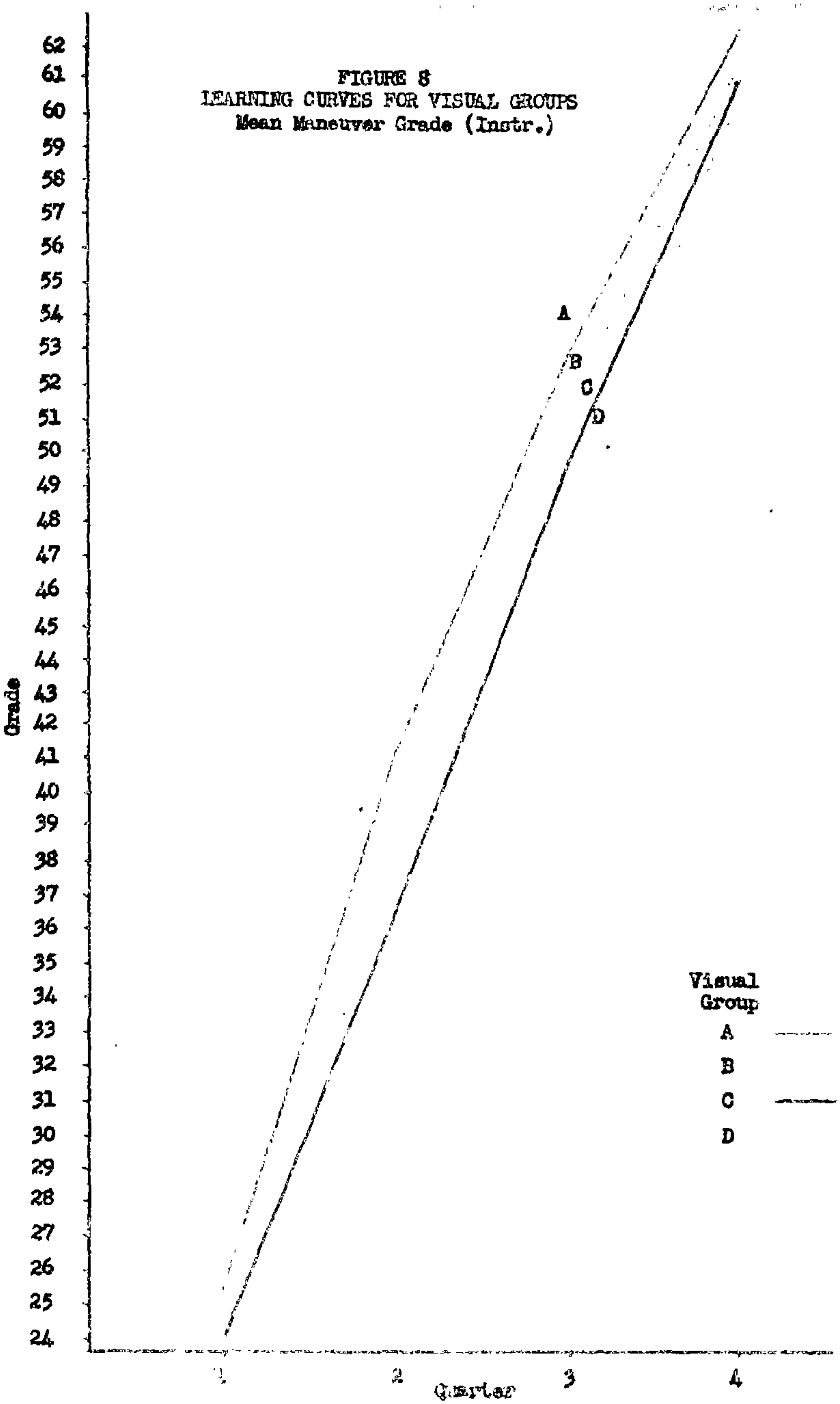


FIGURE 8
LEARNING CURVES FOR VISUAL GROUPS
Mean Maneuver Grade (Instr.)
Grade
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
A
B
C
D
Visual Group
A
B
C
D
1
2
3
4
Quarter

FIGURE 9
LEARNING CURVES FOR VISUAL GROUPS
Over-all Grade (Instr.)

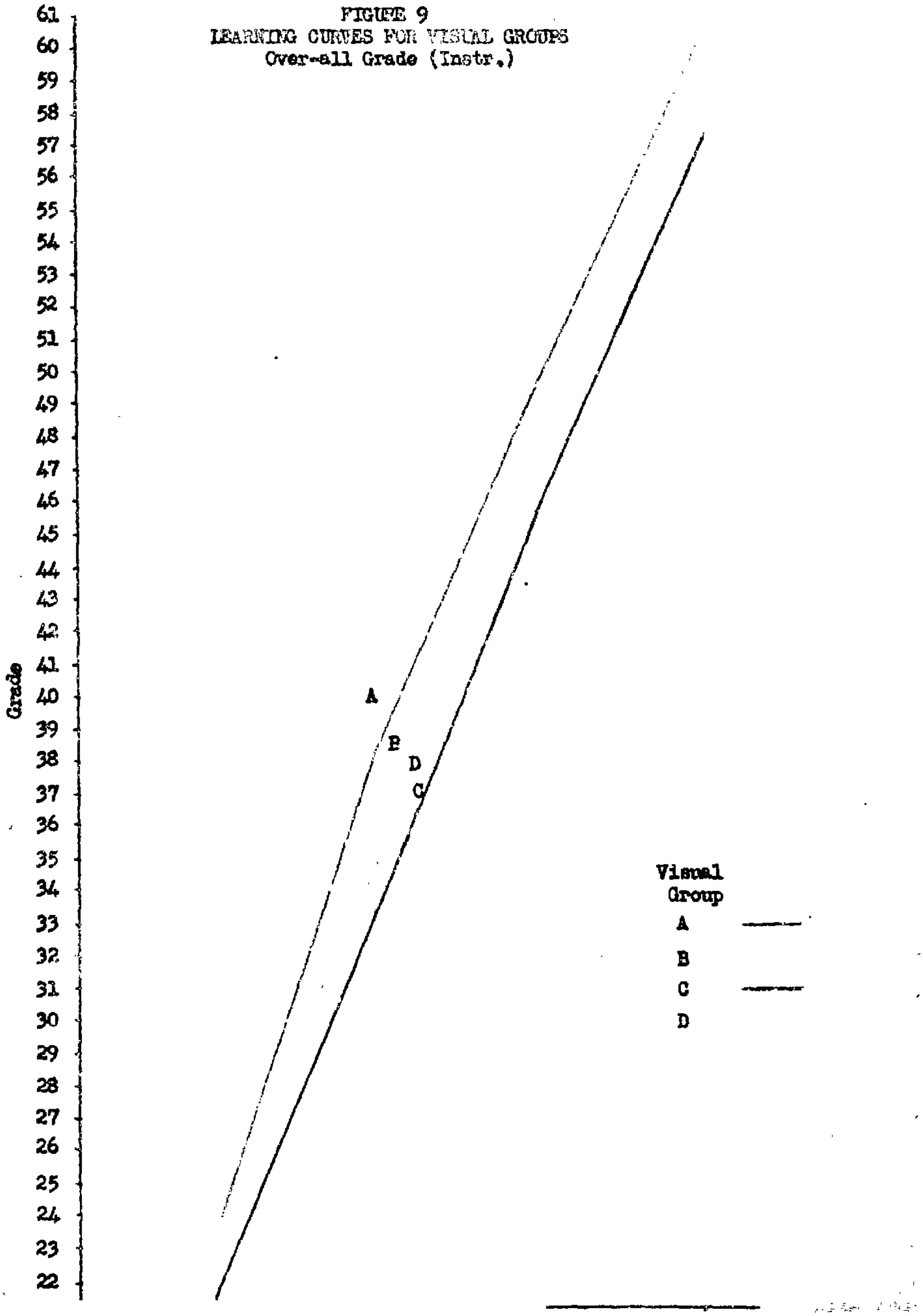


FIGURE 10
LEARNING CURVES FOR VISUAL GROUPS
Mean Maneuver Grade on Practice Landings
(Instr.)

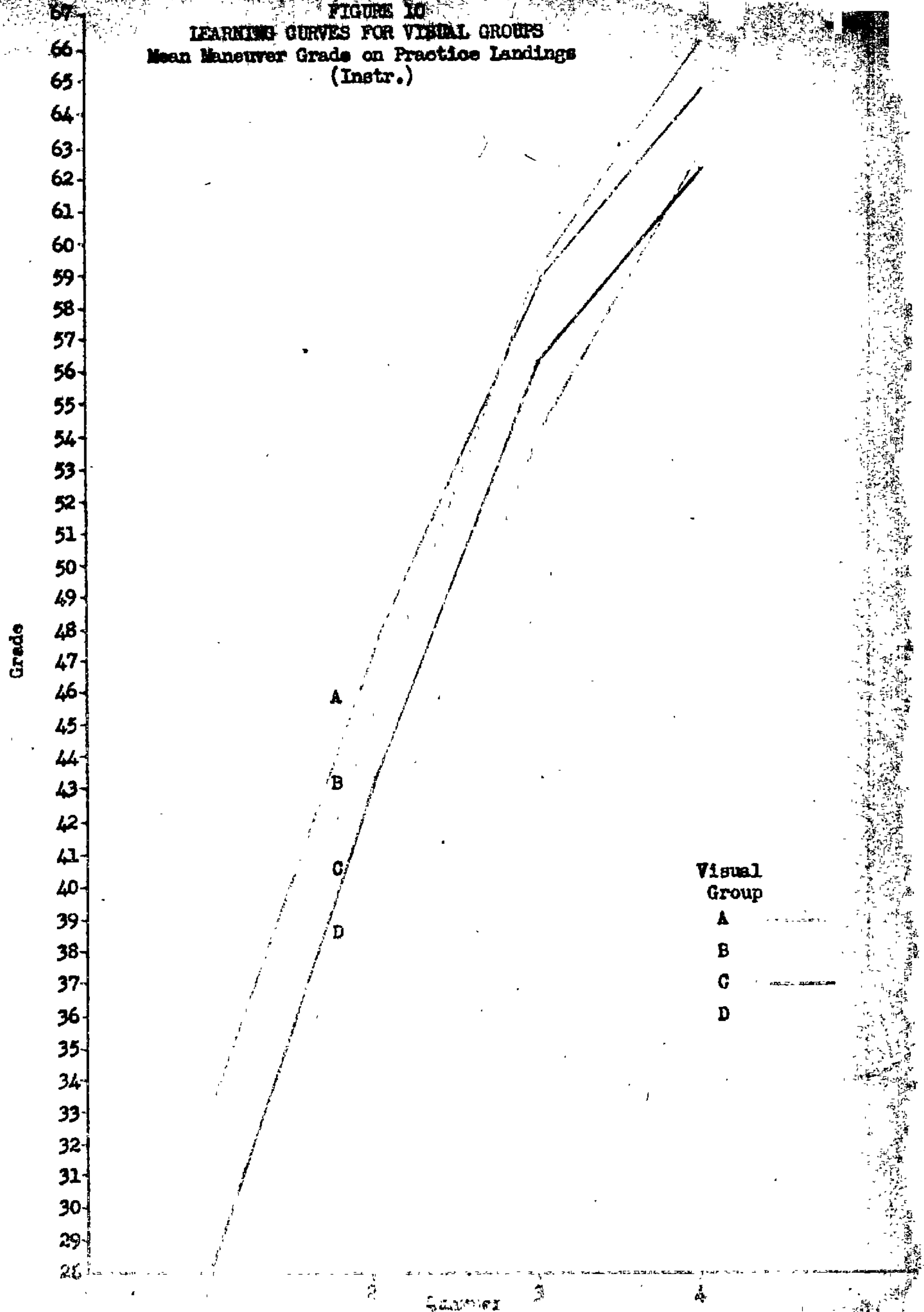


FIGURE 11
LEARNING CURVES FOR VISUAL GROUPS
Landing OSFI Score (CP)

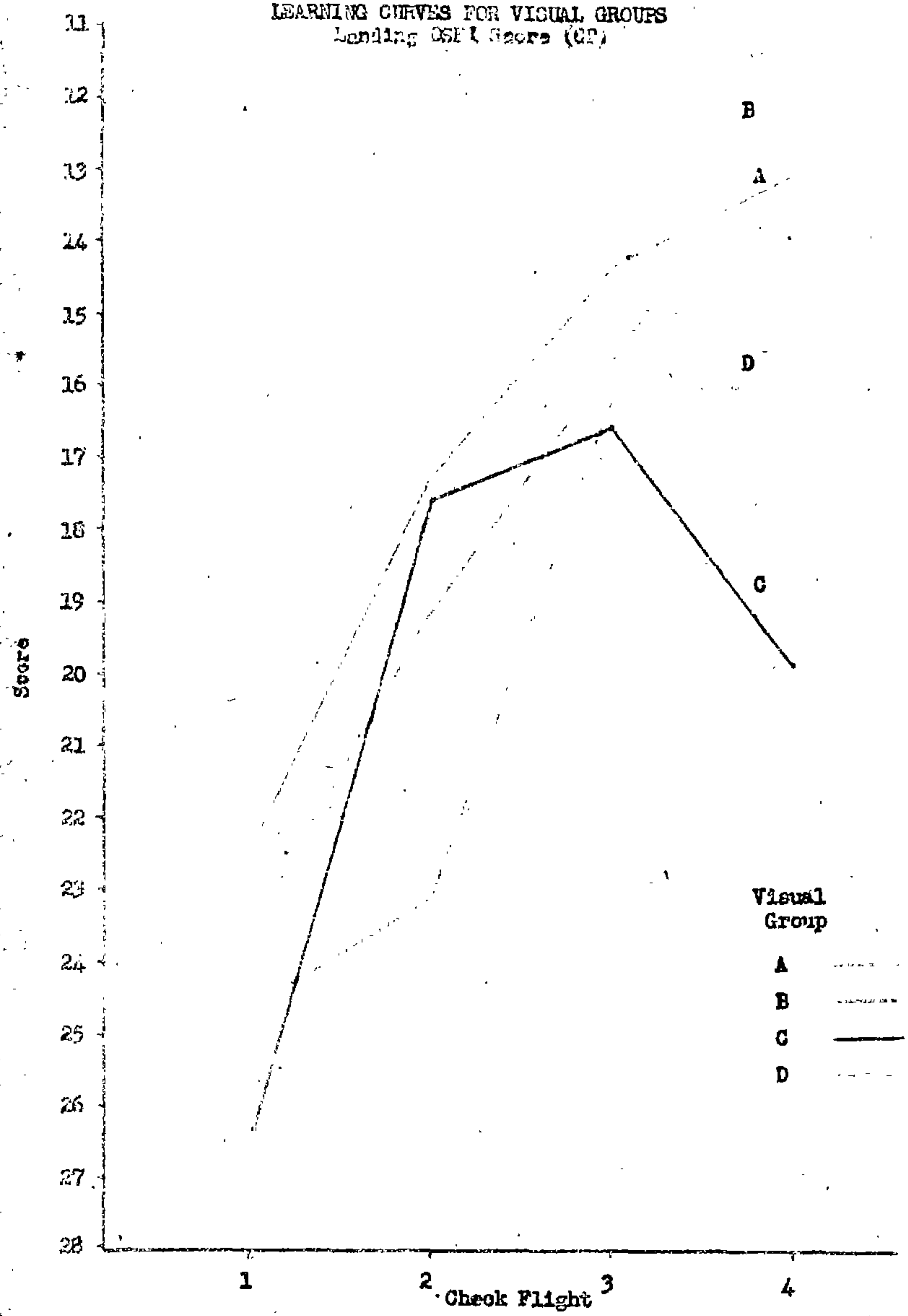
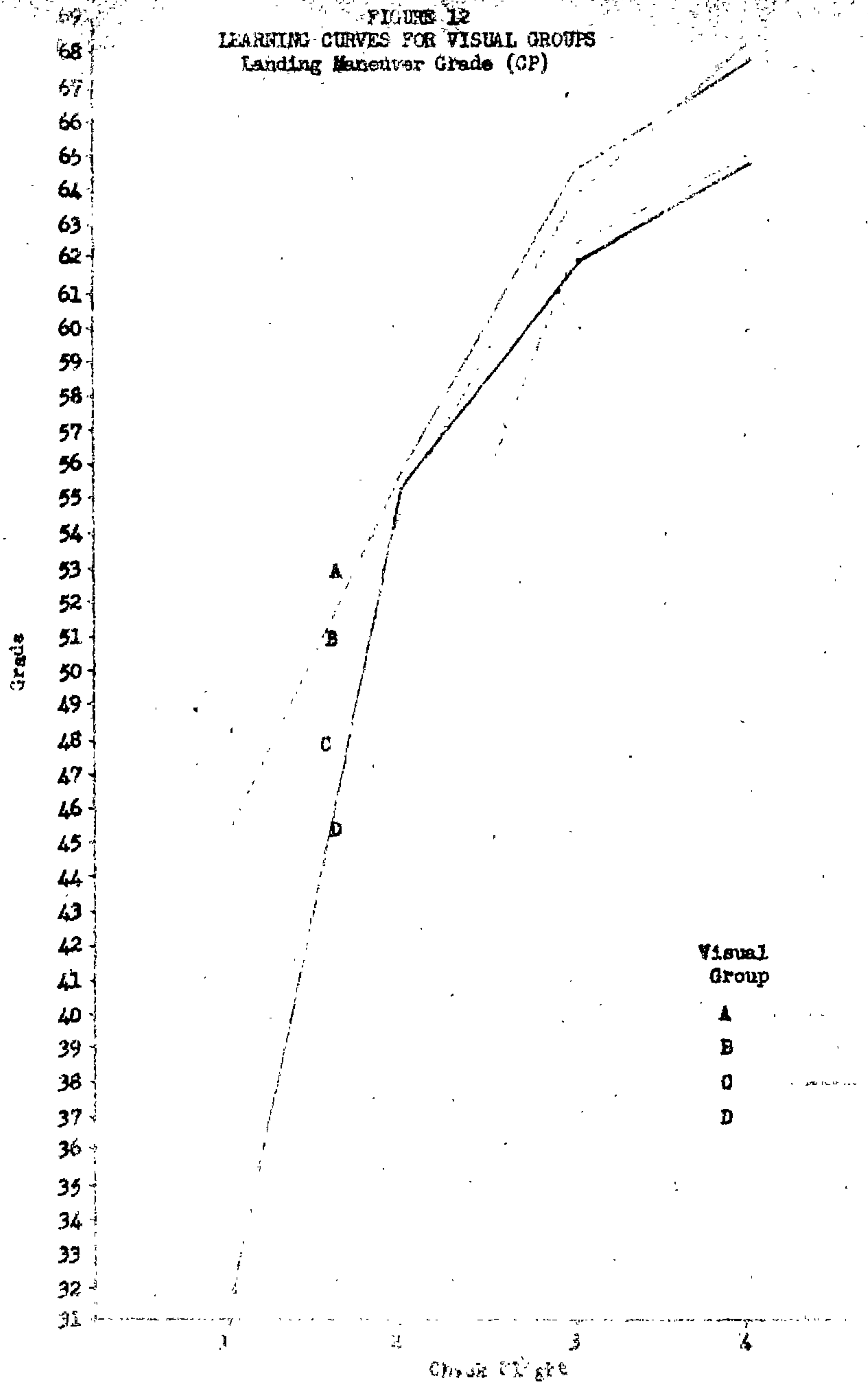


FIGURE 12
LEARNING CURVES FOR VISUAL GROUPS
Landing Maneuver Grade (CP)



flight. It should be noted that in the case of the grades administered by the instructors, the superiority of the A and B groups is maintained throughout.

As has been suggested above, the check flight grades are undoubtedly less reliable than those which represent the average of dual flight grades administered over a full quarter of training. In any case, there is little question of the superiority of the A and B groups in the fourth check flight. It should be noted finally that even in the later stages of training, there is some ambiguity in several of the criterion measures as to relative rank of Groups A and B, and also of Groups C and D. These results are in general agreement with the findings in terms of disposition of cases.

Results: Analysis of Variance of the Thirteen Criterion Measures for all Subjects Trained

The thirteen criterion measures listed in Table 7 were analyzed by the methods of analysis of variance, in terms of the design outlined previously. As noted, two analyses were run on each criterion measure: one in which Visual Groups and Classes were controlled, and one in which Visual Groups and Instructors were controlled. As a preliminary to the analyses of variance, Bartlett's test for homogeneity of variance was made.[24] The results of this test indicated that the assumption of homogeneity of variance was justified. This in itself represents a positive finding through the indication that the variability in flight performance of groups of subjects, differentiated as these groups were in terms of visual efficiency, is comparable.

Table 19 gives the results obtained from these analyses of variance. This table shows the p-values obtained for each F. The table also presents the means for the visual groups on each criterion measure. It should be pointed out that there were several instances in which an instructor did not have students in each visual group. In those instances, the data of those instructors were not included in the Visual Groups-by-Instructors analyses. The table therefore presents the means of the visual groups separately for each type of analysis. However, every class had students in each visual group.[25] It should be noted that whereas the means based on the Visual Groups-by-Classes have the advantage of being based on somewhat more cases, the means based on the Visual Groups-by-Instructors will not contain any bias due to the fact that the instructors may not be distributed equitably among the visual groups.

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[24] The assumption of homogeneity of variance is basic to the application of the procedure of analysis of variance. The results of the test for homogeneity of variance are presented in Appendix 1.

[25] In the second class, the data on the Purdue Sum were very incomplete. This was the only instance in which a class had to be dropped.

TABLE 19

SUMMARY OF RESULTS OF ANALYSES OF VARIANCE: P-VALUES FOR F-TESTS, MEANS OF CRITERION SCORES FOR VISUAL GROUPS

Visual Groups-by-Classes

Analysis	Wtd. Ov-All (I)	Wtd. MMG (CP)	Wtd. Ov-All (CP)	Wtd. OSFI (CP)	Wtd. MMG (I)	MMG Last CF(CP)	Last Ov-All (CP)	Last OSFI (CP)	Purdue Sum (I)	TTS (Log)	Wtd Landing MG (CP)	Wtd Landing OSFI(CP)	[illegible] Landing MG [illegible]
Visual Groups	.20-.05	.05-.01	.20-.05	.20-.05	> .20	.20-.05	.20-.05	> .20	> .20	> .20	.05-.01	< .001	[illegible]
Classes	< .001	.20-.05	.20-.05	< .001	< .001	> .20	> .20	< .001	> .20	> .20	.20-.05	.20-.05	[illegible]
V x C	> .20	> .20	> .20	> .20	> .20	> .20	.05-.01	> .20	> .20	.05-.01	.01-.001	> .20	[illegible]
Means of Visual Groups*													
A	49.93 1	67.85 2	59.11 1	66.29 1	52.56 1	73.35 2	69.0 1	71.0	207.9 1	2.811 2	62.77	14.94	[illegible]
B	48.86 2	67.89 1	57.85 2	65.81 2	51.02 2	73.72 1	68.2 2	70.5 2	216.8 3	2.802 1	62.65 2	15.21	56 [illegible]
C	46.54 4	65.70 3	56.55 3	63.96 3	49.92 3	71.01 4	65.2 4	68.5 3	216.6 2	2.826 3	59.29 3	18.23	55 [illegible]
D	47.14 3	65.31 4	54.60 4	62.35 4	49.68 4	71.90 3	65.8 3	67.4 4	244.0 4	2.853 4	58.91 4	17.99	[illegible]

Visual Groups-by-Instructors

Analysis	Wtd. Ov-All (I)	Wtd. MMG (CP)	Wtd. Ov-All (CP)	Wtd. OSFI (CP)	Wtd. MMG (I)	MMG Last CF(CP)	Last Ov-All (CP)	Last OSFI (CP)	Purdue Sum (I)	TTS (Log)	Wtd Landing MG (CP)	Wtd Landing OSFI(CP)	[illegible] Landing MG [illegible]
Visual Groups	.20-.05	.05-.01	.05-.01	.05-.01	> .20	.20-.05	.20-.05	.20-.05	> .20	> .20	.01-.001	< .001	[illegible]
Instructors	< .001	> .20	.20-.05	< .001	< .001	.20-.05	.20-.05	.20-.05	> .20	.05-.01	.05-.01	.20-.05	[illegible]
V x I	> .20	> .20	.20-.05	.05-.01	> .20	> .20	> .20	.20-.05	> .20	.05-.01	.05-.01	.20-.05	[illegible]
Means of Visual Groups													
A	50.26 1	68.33 1	59.78 1	66.82 1	52.95 1	73.85 1	69.7 1	72.0 1	209.4 1	2.810 2	63.42	14.60 1	57.88 1
B	48.85 2	67.92 2	57.98 2	65.88 2	51.10 2	73.76 2	68.5 2	70.7 2	211.1 2	2.802 1	62.78 2	15.05 2	56.[illegible] 2
C	46.85 4	65.98 3	56.88 3	64.34 3	50.33 3	71.38 4	65.5 4	69.1 3	216.6 3	2.826 3	59.47 3	17.89 3	54.[illegible] 3
D	47.14 3	65.31 4	54.60 4	62.35 4	49.68 4	71.90 3	65.8 3	67.4 4	244.7 4	2.853 4	58.91 4	17.99 4	53.[illegible] 4

*Numbers in red indicate rank order of means of visual groups in terms of proficiency of performance.

From this table it may be seen that:

1. In the Visual Groups-by-Classes analyses, the following criterion measures show significant variation in the means at the 5 per cent level of confidence:

a. Weighted Mean Maneuver Grade (CP) - rank order: BACD
b. Weighted Landing Maneuver Grade (CP) - rank order: ABCD
c. Weighted Landing OSFI Score (CP) - rank order: ABDC

Examination of the differences among the means shows that the A's and B's differed only slightly, and that the C's and D's differed only slightly. The largest differences prevail between the A-B pair and the C-D pair.

2. In the Visual Groups-by-Instructors analyses, the following criterion measures show significant variation in the means at the 5 per cent level of confidence:

a. Weighted Mean Maneuver Grade (CP) - rank order: ABCD
b. Weighted Over-all Grade (CP) - rank order: ABCD
c. Weighted OSFI Score (CP) - rank order: ABCD
d. Weighted Landing Maneuver Grade (CP) - rank order: ABCD
e. Weighted Landing OSFI Score (CP) - rank order: ABCD
f. Weighted Landing Maneuver Grade (I) - rank order: ABCD

In these analyses the rank orders are consistent, with A showing the best performance, B next, C next, and D last.

3. In every instance, with the exception of the Purdue Sum in the Visual Groups-by-Classes analysis, the A's and B's show better performance than the C's and the D's.

4. Significant class variances, at the .1 per cent level of confidence, are found in 5 out of the 13 criterion measures.

5. Significant instructor variances, at the 5 per cent level of confidence, are found in 6 out of the 13 criterion measures. Four of these are significant at the .1 per cent level of confidence.

6. Significant Visual Groups-by-Classes interaction, at the 5 per cent level of confidence, are found in 3 out of the 13 criterion measures.

7. Significant Visual Groups-by-Instructors interactions, significant at the 5 per cent level of confidence, are found in 4 out of 13 criterion measures.

The F-tests in Table 19 indicate whether the variation in the means of the visual groups is significant, but do not show between which specific groups the differences are significant. Therefore, in each instance, in which the F was found to be significant, t-tests between each pair of means were run. The results of these tests are shown in Table 20. It may be seen that:

1. For each test involving the A and the D groups, the difference is significant.

2. Except for the differences between A and B, and the differences between C and D, significant differences are found between means of each pair of groups in at least one analysis.

3. For the Weighted Landing OSFI (CP), all differences are significant, except those between A and B, and between C and D.

It is evident that the analyses of variance on data from all subjects indicated that significant variance in group means existed in terms of a number of criterion measures. It is also of interest to note that two landing measures yielded significant variation in both the analyses controlling Visual Groups and Classes and Visual Groups and Instructors. The t-test analysis indicates that the least significant differences are in general between Groups A and B, and between Groups C and D.

Results: Cumulative Curves

The results of the analyses so far discussed show a definite relationship between visual efficiency and certain criteria of flight performance. However, the results cannot be interpreted as showing that all subjects with visual defects characteristic of Groups C and D failed to attain acceptable flight proficiency. Even when failers are included with passers, as is the case in the data discussed up to this point, there are on all 13 criterion measures subjects in Groups C and D who made scores better than the average of those attained by subjects in Group A.

This fact is brought out graphically in Figures 13 to 18. In these figures are presented cumulative curves which indicate the proportion of each visual group exceeding various scores on each of the six criterion measures yielding significant F's in the Visual Groups-by-Instructors analysis.[26] For example, visual groups represent a significant source of variation, at the 5 per cent level of confidence, in performance as measured by

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[26] These curves can be read in two ways:

1. By choosing some point on the horizontal axis, one can read on the vertical axis the percentages of subjects in each visual group who made a score at or below the chosen score. Thus, for example, for the Weighted Mean Maneuver Grade (CP) (Figure 13), approximately 25 or 30 per cent of the subjects in the A and B groups have scores of 65 and below, and approximately 45 or 50 per cent of the subjects in the C and D groups have scores of 65 and below, indicating distinct superiority of the A and B groups.

TABLE 20

RESULTS OF t-TESTS ON PAIRS OF MEANS OF CRITERION SCORES FOR THOSE ANALYSES IN WHICH F WAS FOUND TO BE SIGNIFICANT AT 5% LEVEL OF CONFIDENCE

Analysis	Pair	Criterion Measures: Wtd. MWG (CP)	Wtd. Over-All (CP)	Wtd. OSFI (CP)	Wtd. Landing MG (CP)	Wtd. Landing OSFI (CP)	Wtd. Landing MG (I)
Visual Groups by Classes	A-B	> .20			> .20	> .20	
	A-C	.05-.02			.05-.02	.01-.001	
	A-D	.05-.02			.02-.01	.01-.001	
	B-C	.10-.05			.10-.05	.01-.001	
	B-D	.05-.02			.05-.02	.05-.02	
	C-D	> .20			> .20	> .20	
Visual Groups by Instructors	A-B	> .20	> .20	> .20	> .20	> .20	> .20
	A-C	.05-.02	.10-.05	.10-.05	.01-.001	< .001	.05-.02
	A-D	.02-.01	.01-.001	.01-.001	.01-.001	< .001	.02-.01
	B-C	.20-.10	> .20	> .20	.10-.05	.02-.01	.20-.10
	B-D	.10-.05	.10-.05	.05-.02	.05-.02	.02-.01	.20-.10
	C-D	> .20	> .20	> .20	> .20	> .20	> .20

FIGURE 13
WEIGHTED MEAN MANEUVER GRADE (CP)

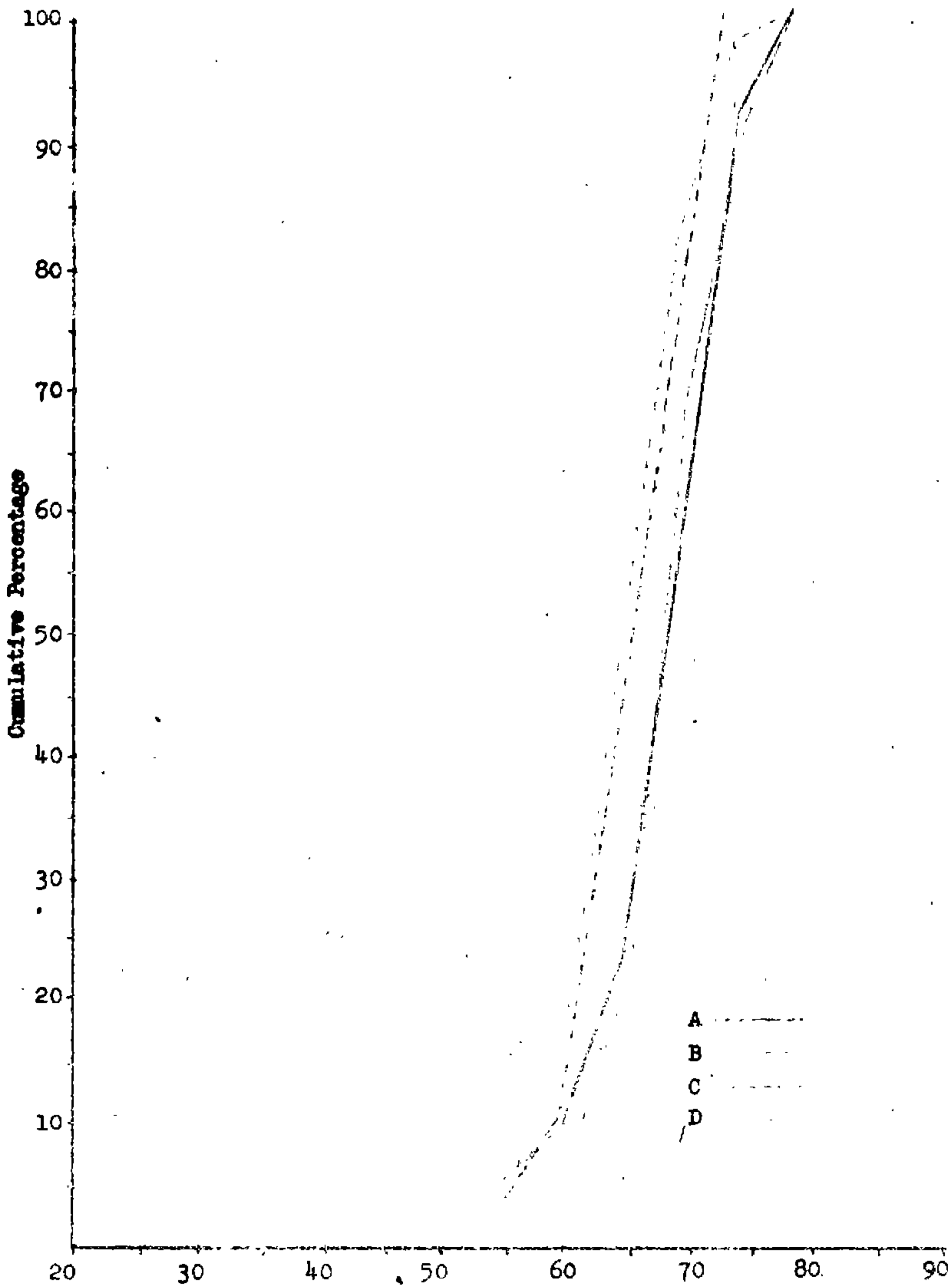


FIGURE 14
WEIGHTED LANDING MANEUVER SCORES
ON OSFI (CP)

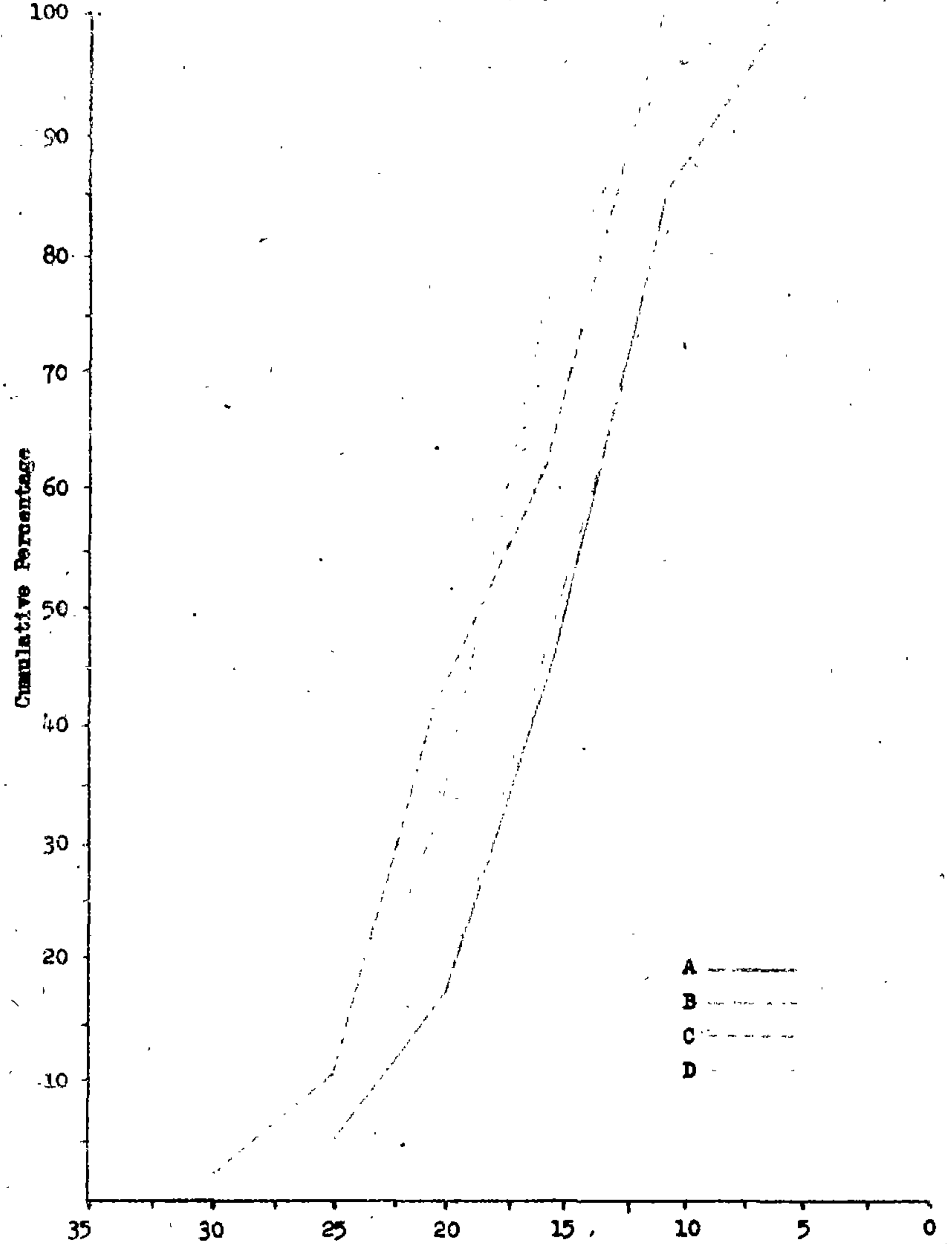


FIGURE 15
WEIGHTED OVER-ALL GRADE (CP)

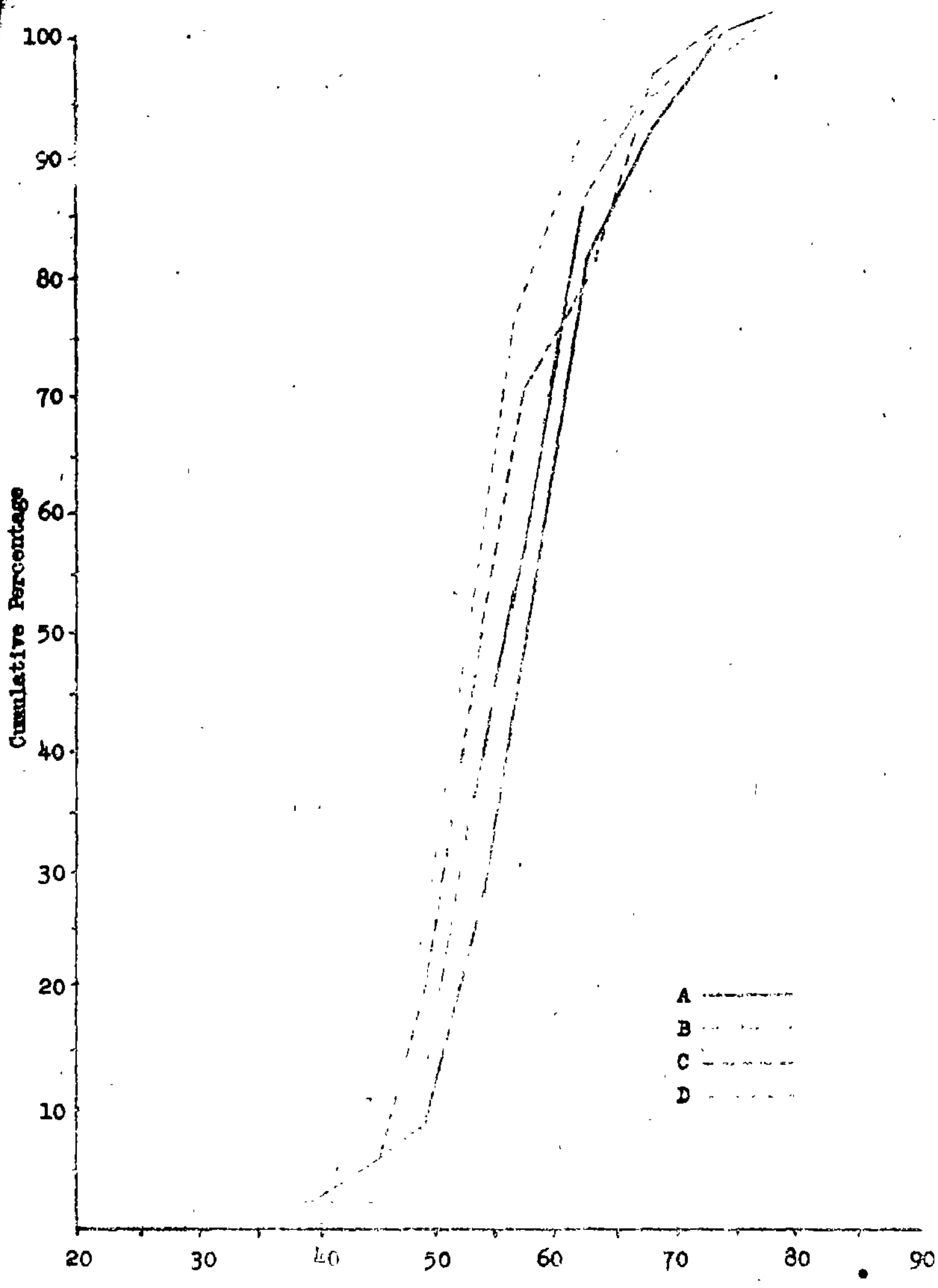


FIGURE 16
WEIGHTED OSFI SCORE (1-I/A) (CP)

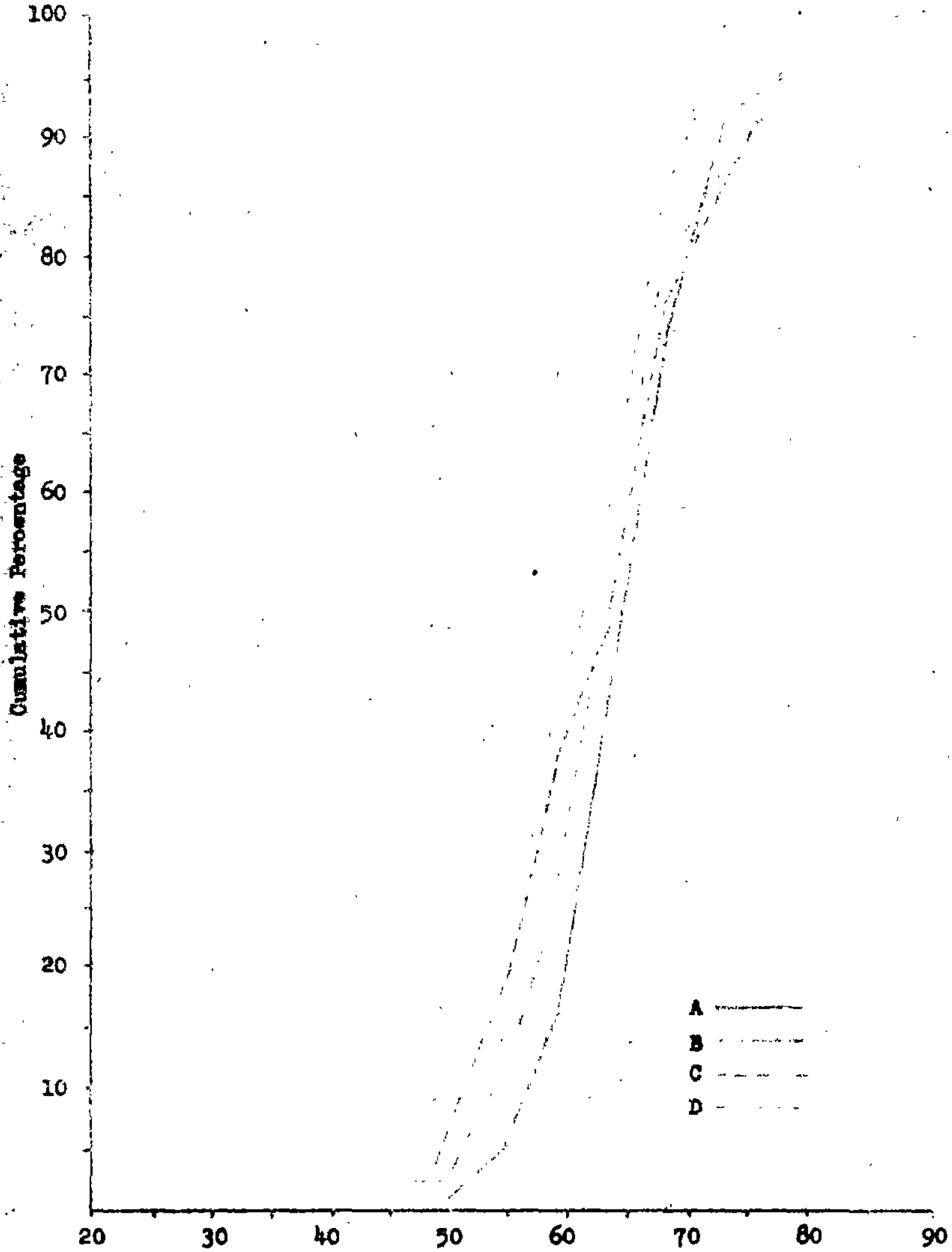


FIGURE 17
WEIGHTED LANDING MANEUVER GRADE (CP)

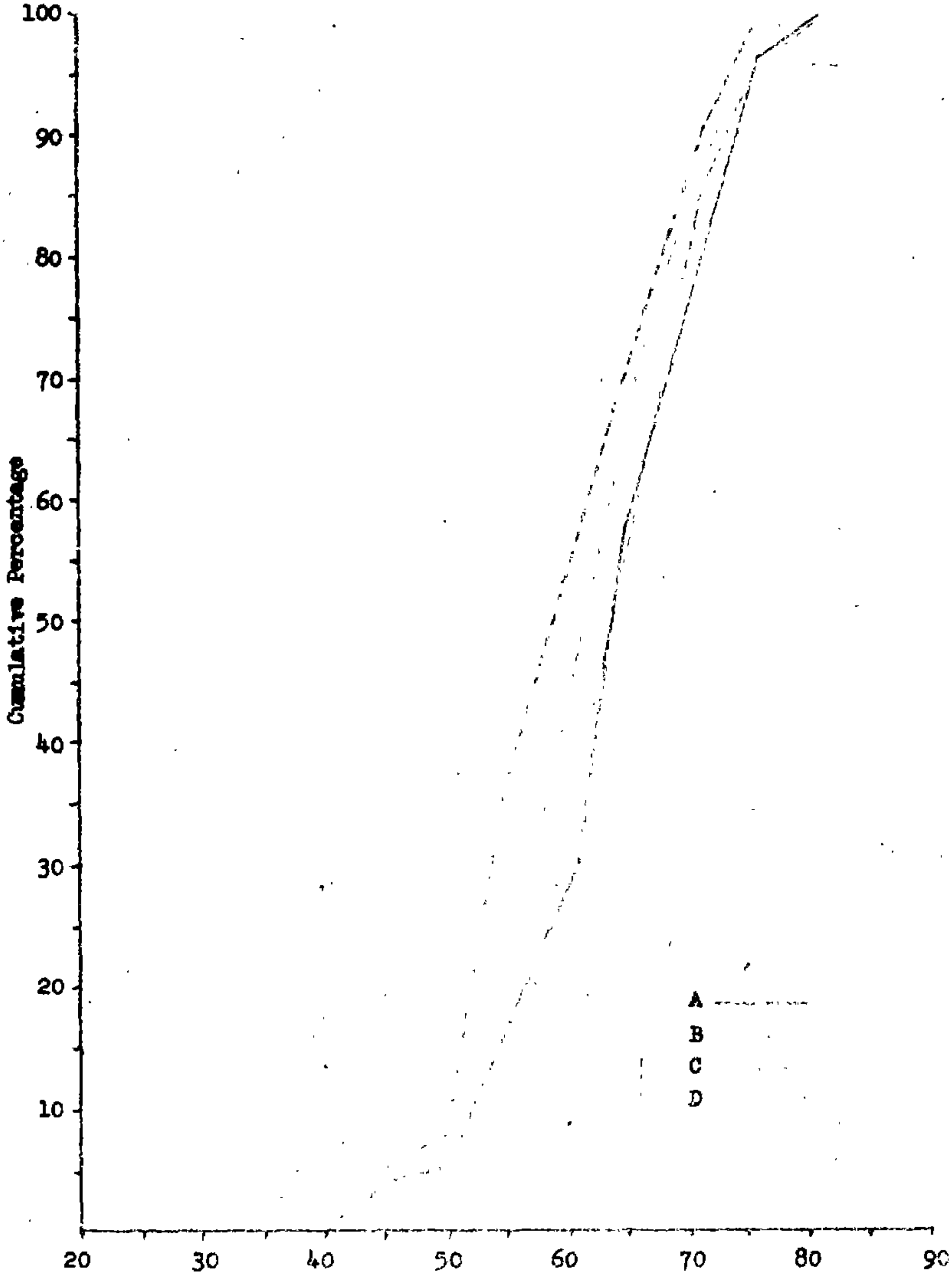
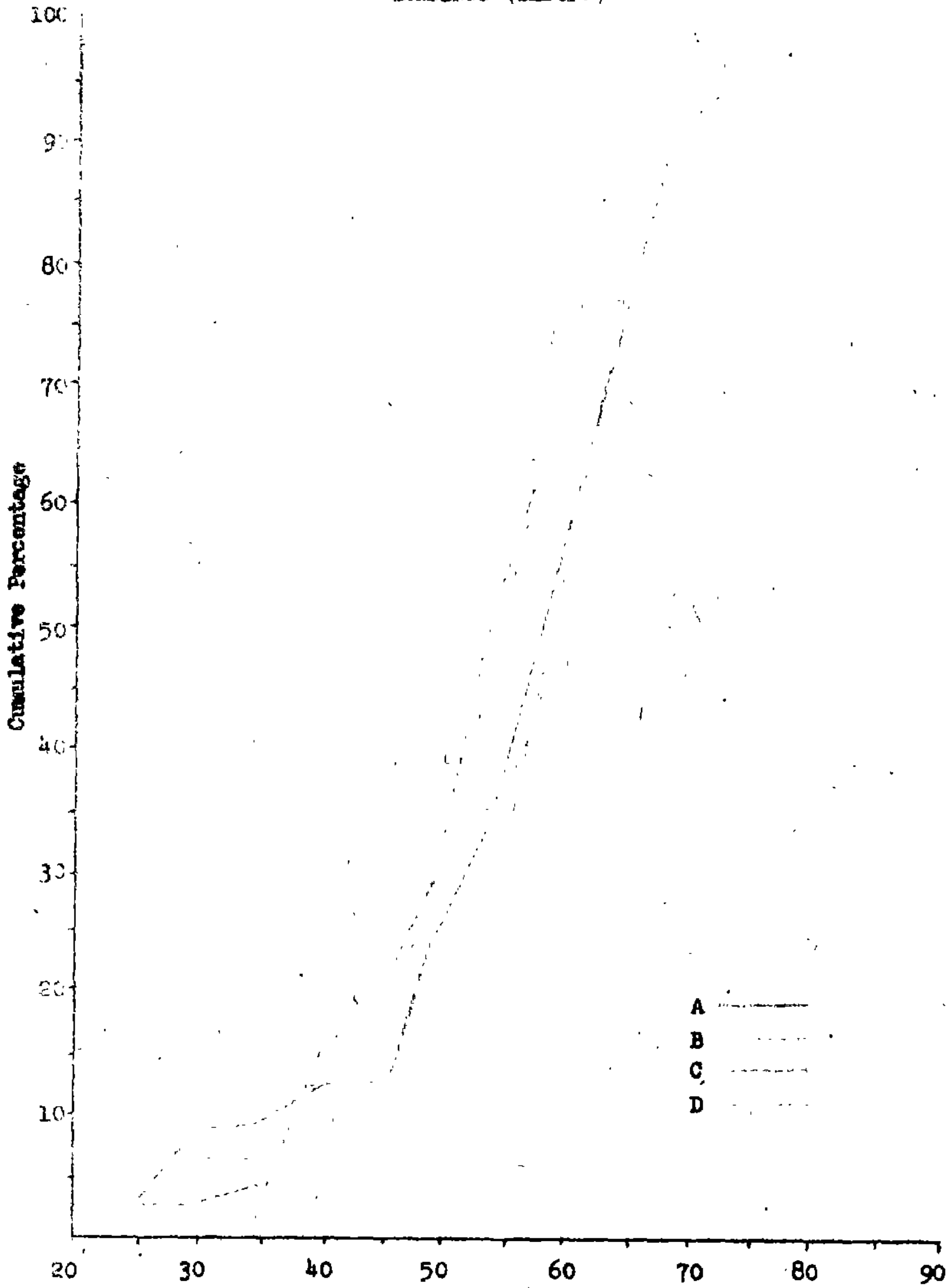


FIGURE 18
WEIGHTED MEAN MANEUVER GRADE ON PRACTICE
LANDINGS (Instr.)



the Weighted Mean Maneuver Grade (Check Pilot). Nevertheless, as is evident from Figure 13, 32 per cent of the subjects in Group C, and 27 per cent of the subjects in Group D, respectively, attained scores at or above the average of subjects in Group A. A similar situation is apparent in terms of the Weighted Landing OSFI Score (Check Pilot). Although significant variations in group means, attributable to Visual Group, were evident in terms of this measure, reference to Figure 14 indicates that 32 per cent of the subjects in Group C, and 22 per cent of the subjects in Group D make scores equal to or better than the average of subjects in Group A. Similar interpretations can be made from the remainder of these figures.

These figures are in agreement with the results of other types of analyses which indicate that the C and D groups are in general, somewhat inferior to the A and B groups. Nevertheless the graphic presentation of the amount of overlap between groups, as represented in these figures, cannot be overlooked. It was for this reason that a separate analysis was made of subjects in all Visual Groups who received their licenses.

Results: Analyses of Variance of the Thirteen Criterion Measures for Licensed Subjects Only

From the results reported in the preceding section, it may be concluded that there is a definite relationship between visual ability and flight performance. The question now arises as to whether there is any relationship between visual ability and flight performance among those subjects who were considered sufficiently competent to receive private pilot's licenses. In order to answer this question, the analyses were repeated, using only the data on subjects who were licensed. The analyses have important practical significance. From a statistical point of view, it has been demonstrated that a relationship prevails. However, since there were some subjects in the D group who showed superiority to some subjects in the A group, the question remains open as to whether the same visual ability is related to flight performance among licensed pilots as well.

The answer to this inquiry as noted above lies in an analysis of data from only those subjects who passed the flight examination. This analysis was carried out in exactly the same fashion as were the previous analyses, except that only subjects passing the flight examination were included. The results of these analyses are presented in Table 21.[27]

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26 (Continued)

2. By choosing some point on the vertical axis, one can read on the horizontal axis the corresponding score at or below which the chosen percentage of the groups falls. For example, in Figure 13, whereas 50 per cent of the A and B groups have scores approximately 68 or below, 50 per cent of the C and D groups have scores approximately 65 and below.

[27] Application of Bartlett test indicated that the assumption of homogeneity of variance was justified. See Appendix 1.

TABLE 21

SUMMARY OF RESULTS OF ANALYSES OF VARIANCE FOR SUBJECTS WHO WERE LICENSED: P-VALUES FOR F-TESTS
MEANS OF CRITERION SCORES FOR VISUAL GROUPS

Visual Groups-by-Classes

Analysis	Wtd. Ov-all (I)	Wtd. MMG (CP)	Wtd. Ov-All (CP)	Wtd. OSFI (CP)	Wtd. MMG (I)	MMG Last CF(CP)	Last Ov-All (CP)	Last OSFI (CP)	Purdue Sum (I)	TTS (Log)	Wtd. Landing MG (CP)	Wtd. Landing OSFI(CP)	Wtd. Landing MG (I)
Visual Groups	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	.20-.05	> .20
Classes	< .001	.20-.05	.05-.01	< .001	< .001	> .20	.20-.05	< .001	> .20	< .001	> .20	> .20	.01-.001
V x C	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	.05-.01	> .20	> .20
Means of Visual Groups*													
A	51.262	68.932	60.241	67.393	53.842	73.823	69.82	71.64	187.14	2.7642	63.982	14.332	58.767
B	49.893	69.101	59.462	68.171	51.793	74.602	69.03	72.13	177.12	2.7501	64.031	14.157	56.6[illegible]
C	48.464	67.484	59.123	67.982	50.764	73.264	68.74	73.2[illegible]	180.53	2.7744	61.474	16.41	55.3[illegible]
D	51.381	67.783	58.864	66.844	54.141	74.651	70.81	72.62	174.61	2.7713	63.243	15.973	57.10

Visual Groups-by-Instructors

Analysis	Wtd. Ov-all (I)	Wtd. MMG (CP)	Wtd. Ov-All (CP)	Wtd. OSFI (CP)	Wtd. MMG (I)	MMG Last CF(CP)	Last Ov-All (CP)	Last OSFI (CP)	Purdue Sum (I)	TTS (Log)	Wtd. Landing MG (CP)	Wtd. Landing OSFI(CP)	Wtd. Landing MG (I)
Visual Groups	> .20	.20-.05	> .20	> .20	> .20	> .20	> .20	> .20	> .20	.20-.05	.20-.05	.01-.001	.05-.01
Instructors	< .001	> .20	> .20	.01-.001	< .001	> .20	> .20	> .20	.05-.01	.01-.001	.20-.05	> .20	< .001
V x I	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20	> .20
Means of Visual Groups													
A	52.073	69.472	61.091	67.533	54.782	74.622	71.41	72.92	187.54	2.7612	64.832	13.281	62.201
B	52.261	69.481	60.812	67.811	54.703	74.403	70.23	71.84	172.11	2.7321	65.481	13.462	61.172
C	49.874	67.294	58.994	67.652	52.234	73.144	69.54	73.51	179.62	2.7804	61.394	16.274	57.40[illegible]
D	52.132	68.213	59.133	66.784	55.531	74.641	70.52	72.33	184.83	2.7743	63.683	15.763	58.633

*Numbers in red indicate rank order of means of visual groups in terms of proficiency of performance.

The results of this analysis indicate that, whereas in the analysis of visual groups by instructors, for the entire sample, significant variations were found in terms of six criterion measures, in the analysis of data from licensed subjects only, significant variation was found in terms of only two criterion measures. These were (1) the Weighted Ohio State Flight Inventory score on Landing (a measure obtained from the check pilots); and (2) the Weighted Landing Maneuver Grade (a measure obtained from the instructors).

Testing for the significance of differences between means of Visual Groups by the t-test indicates that differences in performance between Groups A and C, and A and D, were most significant whereas differences between Groups B and C, and B and D, were less significant. Groups A and B and Groups C and D did not differ significantly in terms of these measures. These facts are evident from Table 22.

The analyses of data from licensed subjects only indicate significant variation in group means, and significant differences for group means in markedly fewer criterion measures than was the case when data from all subjects were analyzed. However, it should be pointed out that since these analyses were based on fewer cases the power of the tests of significance was reduced. Therefore some reduction in the number of criterion measures yielding significant results might be expected.

It is also noteworthy that in spite of the fact that only licensed subjects were considered in these analyses, and despite the reduction in the power of the tests of significance, significant variances, and significant differences between group means are evident for two of the landing measures, the Group C and D subjects exhibiting less proficient performance in terms of these criteria.

TABLE 22

RESULTS OF t-TEST ON PAIRS OF MEANS OF CRITERION SCORES FOR THOSE ANALYSES IN WHICH F WAS FOUND TO BE SIGNIFICANT AT 5% LEVEL OF CONFIDENCE (PASSERS ONLY)

Analyses	Pairs	Criterion Measures: Weighted Landing OSFI SCORE (CP)	Criterion Measures: Weighted Mean Maneuver Grades on Practice Landings
Visual Group by Instructors	A-B	$.90 > P > .80$	$.60 > P > .50$
	A-C	$.01 > P > .001$	$.01 > P > .001$
	A-D	$.05 > P > .02$	$.10 > P > .05$
	B-C	$.02 > P > .01$	$.10 > P > .05$
	B-D	$.10 > P > .05$	$.30 > P > .20$
	C-D	$.70 > P > .60$	$.60 > P > .50$

In view of this evidence that the visually deficient subjects were less proficient in landing, analyses were made in terms of individual items on the Ohio State Flight Inventory which pertained to landing performance.

Results: Detailed Analysis of Items on Landings in the Ohio State Flight Inventory

In view of the fact that the previous analyses have indicated that the visual groups differ in landing proficiency, even if only the subjects who were licensed are considered, it was decided to make a detailed statistical analysis of the landing errors by the subjects in each visual group. A further reason for making such a detailed study is the *a priori* importance of good landing performance for safe flying.

The detailed analyses of the items were based on the data from the fourth check flight only. During the fourth check flight, each subject made three landings. To analyze these data, a 2 x 4 table was constructed for each landing, shown in Figure 19. The appropriate frequencies were entered in the cells and a chi-squared test of contingency was run.[28]

	A	B	C	D
Satisfactory				
Unsatisfactory				

FIGURE 19

After a separate analysis had been made for an item on each of the three landings, the data from the three landings were pooled in a single table, and chi-squared was computed. Also, the chi-squared values and degrees of freedom for each of the three landings were added.[29]

Total Sample. The results for the total sample (as opposed to licensed subjects only) are given in Table 23. The table also gives the percentages in each visual group who showed satisfactory performance on the item. Examination of the table shows that:

1. Items in which there is a relationship between visual group and percentage of satisfactory performances (p-values of 5 per cent or less) are:

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[28]This test is mathematically equivalent to a test of the significance of the variation in percentages.

[29]Both of these tests are probably biased since the requirement of independence is essential to each. The tests were made to get an over-all view of the results.

TABLE 23

RESULTS OF CHI-SQUARED TESTS OF CONTINGENCY ON ITEMS ON FINAL APPROACH AND LANDING IN OSFT FOR BOTH LICENSED AND WASHED-OUT SUBJECTS

Item	Dichotomy	Landing	Percentage Correct A	B	C	D	Chi-Squared	d.f.	p
Direction during Approach	Constant or Varies	1	37	30	31	34	0.642	3	.90-.80
		2	41	35	36	25	2.516	3	.50-.30
		3	46	27	32	39	4.572	3	.30-.20
		Pooled	41	31	33	33	5.222	3	.20-.10
		1+2+3					7.930	9	.70-.50
Wing Level during Approach	Constant or Varies	1	40	43	38	41	0.198	3	.98-.95
		2	54	38	41	34	4.914	3	.20-.10
		3	56	42	42	48	3.008	3	.50-.20
		Pooled	50	41	41	41	4.644	3	.20-.10
		1+2+3					8.120	9	.70-.50
Direction during Roll	Constant or Varies	1	47	65	41	43	5.315	3	.20-.10
		2	49	49	39	31	3.542	3	.50-.30
		3	56	57	32	52	6.178	3	.20-.10
		Pooled	51	57	38	42	10.421	3	.02-.01*
		1+2+3					15.035	9	.10-.05
Wing Level during Roll	Constant or Varies	1	77	89	76	77	2.830	3	.50-.30
		2	79	81	62	72	4.735	3	.20-.10
		3	87	86	68	81	7.058	3	.10-.05
		Pooled	81	85	68	76	10.959	3	.02-.01*
		1+2+3					14.623	9	.20-.10
Stalls	Smoothly or Abruptly	1	66	82	58	65	3.782	3	.30-.20
		2	63	72	55	83	3.399	3	.50-.30
		3	72	69	70	69	0.106	3	> .99
		Pooled	67	74	61	71	3.325	3	.50-.30
		1+2+3					7.287	9	.70-.50
Stalls	Did or Did Not	1	72	78	68	60	2.884	3	.50-.30
		2	66	78	54	41	11.916	3	.01-.001*
		3	73	78	53	55	8.735	3	.05-.02*
		Pooled	70	78	58	52	20.997	3	< .001*
		1+2+3					23.535	9	.01-.001*
Deviation from Correct Speed	Constant or Varies	1	75	83	66	74	2.700	3	.50-.30
		2	79	80	75	87	1.566	3	.70-.50
		3	80	83	80	81	0.170	3	.99-.98
		Pooled	78	82	74	81	2.477	3	.50-.30
		1+2+3					4.436	9	.90-.80

TABLE 23 (Continued)

RESULTS OF CHI-SQUARED TESTS OF CONTINGENCY ON ITEMS ON FINAL APPROACH AND LANDING IN OSFI FOR BOTH LICENSED AND WASHED-OUT SUBJECTS

Item	Dichotomy	Landing	Percentage Correct A	B	C	D	Chi-Squared	d.f.	P
Observer Assisted in Landing**	Did Not or Did	Pooled	92	94	88	89	2.705	3	.50-.30
Speed	Constant or Varies	1	30	36	37	32	0.172	3	.99-.98
		2	45	42	36	50	1.419	3	.80-.70
		3	46	36	49	48	1.521	3	.70-.50
		Pooled	42	33	41	43	0.822	3	.90-.80
		1+2+3					3.112	9	.98-.95
Correction for Drift	Did or Did Not	1	56	78	45	54	4.407	3	.30-.20
		2	62	55	38	40	4.224	3	.30-.20
		3	70	59	41	61	3.364	3	.20-.10
		Pooled	63	63	41	52	9.620	3	.05-.02*
		1+2+3					13.994	9	.20-.10
Levels off at Appropriate Height	Did or Did Not	1	62	57	46	43	4.432	3	.30-.20
		2	53	67	45	34	7.758	3	.10-.05
		3	61	59	41	33	9.346	3	.05-.02*
		Pooled	59	61	44	37	18.744	3	< .001*
		1+2+3					21.536	9	.02-.01*
Height Above Ground at Stall	Correct or Incorrect	1	61	70	42	45	8.380	3	.05-.02*
		2	53	76	37	38	14.542	3	.01-.001*
		3	62	62	42	52	5.245	3	.20-.10
		Pooled	59	69	40	45	24.769	3	< .001*
		1+2+3					28.167	9	< .001*
Landing	Satisfactory or Unsatisfactory	1	59	73	46	58	5.665	3	.20-.10
		2	64	73	37	34	17.836	3	< .001*
		3	71	70	37	55	7.822	3	.05-.02*
		Pooled	65	72	43	49	26.395	3	< .001*
		1+2+3					31.324	9	< .001*
Unsatisfactory Landing	Does or Does Not Correct	1	40	70	45	31	3.869	3	.30-.20
		2	58	50	54	57	0.211	3	.98-.95
		3	67	50	35	64	4.920	3	.20-.10
		Pooled	55	57	45	52	1.402	3	.80-.70
		1+2+3					9.000	9	.50-.30

*Significant at the 5% level of confidence.
**Cell frequencies were too small to permit separate analyses for each landing.

a. Whether the direction during roll is constant or varied.

b. Whether the wing level during roll is constant or varied.

c. Whether the subject did or did not stall the airplane in landing.

d. Whether the subject did or did not correct for drift.

e. Whether the subject did or did not level off at the appropriate height.

f. Whether the height above the ground at stall was correct or incorrect.

g. Whether the landing was satisfactory or unsatisfactory.

2. In each of the above instances in which the variation in percentages was found to be significant, the percentage of satisfactory performances for the A and B groups is higher than the percentage of satisfactory performances for the C and D groups.

Licensed Subjects Only. The data on the landings were reanalyzed using only subjects who had received their licenses. The results of these analyses are presented in Table 24. Examination of this table shows that:

1. Items in which there is a relationship between visual group and percentage of satisfactory performance (p-values of 5 per cent or less) are:[30]

a. Whether the subject did or did not stall the airplane in landing.

b. Whether the subject did or did not correct for drift.

c. Whether the height above ground at stall was correct or incorrect.

d. Whether the landing was satisfactory or unsatisfactory.

2. Again, in each instance in which the variation in percentages was found to be significant, the percentage of satisfactory performances for the A and B groups is higher than the percentage of satisfactory performances for the C and D groups.

The results of these analyses cannot be held to indicate that all visually handicapped pilots are inferior in landing to pilots with so-called "normal" or "near normal" vision. However, the results do indicate that even among pilots passing the flight examination, visually handicapped pilots such as those subjects in Groups C and D are as a group somewhat less proficient in executing landings than are pilots with more "normal" or "near normal" vision, as represented by pilots in Groups A and B.

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[30] Each of these was also significant for the total sample given.

TABLE 24

RESULTS OF CHI-SQUARED TESTS OF CONTINGENCY ON ITEMS ON FINAL APPROACH AND LANDINGS IN OSFI FOR LICENSED SUBJECTS ONLY

Item	Dichotomy	Landing	Percentage Correct A	B	C	D	Chi-Squared	d.f.	p
		1	41	30	36	42	1.248	3	.80-.70
Direction	Constant	2	44	40	39	37	0.381	3	.95-.90
during	or	3	50	30	32	50	5.085	3	.20-.10
Approach	Varies	Pooled	45	33	36	43	4.418	3	.30-.20
		1+2+3					6.714	9	.70-.50
		1	43	47	39	47	0.449	3	.95-.90
Wing Level	Constant	2	55	47	46	47	1.056	3	.80-.70
during	or	3	55	45	50	61	1.502	3	.70-.50
Approach	Varies	Pooled	51	46	45	52	1.363	3	.80-.70
		1+2+3					3.007	9	.98-.95
		1	48	77	48	56	7.608	3	.10-.05
Direction	Constant	2	50	55	50	42	0.784	3	.90-.80
during	or	3	57	60	44	65	2.205	3	.70-.50
Roll	Varies	Pooled	52	64	48	54	5.434	3	.20-.10
		1+2+3					10.595	9	.50-.30
		1	82	93	85	94	3.287	3	.50-.30
Wing Level	Constant	2	83	83	71	84	1.960	3	.70-.50
during	or	3	88	93	79	89	2.919	3	.50-.30
Roll	Varies	Pooled	84	90	78	89	5.162	3	.20-.10
		1+2+3					8.166	9	.70-.50
		1	65	82	63	69	2.303	3	.70-.50
	Smoothly	2	64	75	56	100	5.143	3	.20-.10
Stalls	or	3	71	76	65	88	1.609	3	.70-.50
	Abruptly	Pooled	67	77	62	82	6.192	3	.20-.10
		1+2+3					9.055	9	.50-.30
		1	75	77	70	78	0.431	3	.95-.90
	Did	2	69	80	57	42	8.659	3	.05-.02*
Stalls	or	3	74	83	61	50	7.733	3	.10-.05
	Did Not	Pooled	73	80	63	56	12.156	3	.01-.001*
		1+2+3					16.823	9	.10-.05
		1	74	82	68	68	1.725	3	.70-.50
Deviation	Constant	2	79	79	80	89	1.166	3	.80-.70
from	or	3	80	86	80	79	0.515	3	.95-.90
Correct Speed	Varies	Pooled	78	82	76	79	1.042	3	.80-.70
		1+2+3					3.406	9	.95-.90

TABLE 24 (Continued)

RESULTS OF CHI-SQUARED TESTS OF CONTINGENCY ON ITEMS ON FINAL APPROACH AND LANDINGS IN OSFI FOR LICENSED SUBJECTS ONLY

Item	Dichotomy	Landing	Percentage Correct A	B	C	D	Chi-Squared	d.f.	p
Observer Assisted in Landing**	Did Not or Did	Pooled	95	94	93	96	1.010	3	.80-.70
Speed	Constant or Varies	1	34	34	40	37	0.281	3	.98-.95
		2	42	34	44	61	3.279	3	.50-.30
		3	46	34	56	53	2.878	3	.50-.30
		Pooled	41	34	47	50	4.196	3	.30-.20
		1+2+3					6.438	9	.70-.50
Correction for Drift	Did or Did Not	1	62	93	47	67	7.144	3	.10-.05
		2	70	64	47	55	2.604	3	.50-.30
		3	76	62	38	64	7.412	3	.10-.05
		Pooled	70	73	43	61	11.496	3	.01-.001*
		1+2+3					17.160	9	.05-.02*
Levels off at Appropriate Height	Did or Did Not	1	68	57	52	56	2.624	3	.50-.30
		2	57	69	54	47	2.542	3	.50-.30
		3	65	67	44	47	4.943	3	.20-.10
		Pooled	63	64	50	50	6.829	3	.10-.05
		1+2+3					10.109	9	.50-.30
Height Above Ground at Stall	Correct or Incorrect	1	65	67	48	63	2.763	3	.50-.30
		2	55	80	46	47	8.643	3	.05-.02*
		3	64	70	46	50	4.507	3	.30-.20
		Pooled	61	[illegible]	[illegible]	[illegible]	12.481	3	.01-.0[illegible]
		1+2+3					15.913	9	.10-.05
Landing	Satisfactory or Unsatisfactory	1	65	70	50	79	4.712	3	.20-.10
		2	68	77	46	47	8.447	3	.05-.02*
		3	73	77	54	50	6.873	3	.10-.05
		Pooled	69	74	50	59	13.796	3	.01-.001*
		1+2+3					20.032	9	.02-.01*
Unsatisfactory Landing	Does or Does Not Correct	1	48	67	54	50	0.940	3	.90-.80
		2	70	57	67	70	0.431	3	.95-.90
		3	78	50	31	67	7.308	3	.10-.05
		Pooled	64	59	51	65	1.977	3	.70-.50
		1+2+3					8.679	9	.50-.30

*Significant at the 5% level of confidence.
**Cell frequencies were too small to permit separate analyses for each landing.

Results: Analysis of Photographic Records

In addition to the analysis of criterion measures presented thus far, data from the photographic records were also analysed. As noted previously, photographic records were taken during the following maneuvers: (1) Straight and Level, (2) 720° Steep Turns, (3) Take-offs, and (4) Landings. The films were run off in slow motion projection, and detailed records of various aspects of the subject's performance were made on special check sheets developed for this purpose.

On the basis of the information recorded on the check sheets, several measures, which will hereafter be referred to as "items" were calculated. For each item, the record was scored 1 if "correct," and 0 if "incorrect." An item was considered "correct" or "incorrect" on the basis of: (1) a priori considerations, or (2) the position of the item with respect to the median of the distribution of the items for a random sample of Group A records. The items and the criteria for scoring are given in Table 25.

During each check flight, three Straight and Levels, four Turns, three Take-offs and three Landings were photographed.

For each of these maneuvers, a score consisting of the number of correct items divided by the total number of items available was computed.

The following steps were taken in obtaining scores for each subject:

1. For each maneuver (including duplications of a maneuver in a check flight) in each check flight, the number of "1's" was divided by the sum of "1's" and "0's" giving, in effect, the percentage of correct items for that maneuver. Thus, for example, the Straight and Level score might be 8/12, or 67,[31] where 8 is the number of correct items out of a possible 12 on three performances of Straight and Level.

2. The percentages for the four maneuvers were averaged to give a Total Photographic Score.

3. The weighted average for each of these five scores was determined by assigning the weights 1, 2, 3, and 5 to the first, second, third, and fourth check flights, respectively.

These five weighted scores were then analyzed by the methods of analysis of variance in the same fashion as the other criterion measures. Thus, for each score two analyses were run. In one, visual groups and classes were controlled, and in the other visual groups and instructors were controlled.[32]

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[31] For convenience each of these values was multiplied by 100.

[32] Again, the question concerning the significance of the variation in dispersions may be asked with respect to the results on the photographic records. Bartlett's test of homogeneity of variance was used to obtain an answer to this question. Table 32 in Appendix 1 shows the results of the homogeneity tests for both the total sample and the licensed subjects, and for the Visual Groups-by-Classes and Visual Groups-by-Instructors analysis. In no instance is there sufficient reason to reject the hypothesis of homogeneity.

TABLE 25

KEY USED FOR SCORING PHOTOGRAPHIC RECORDS

Maneuver	Item	Correct
Straight and Level	Average airspeed	75-85 mph (check ship 1) 80-90 mph (check ship 2)
	Airspeed range	0-7 mph
	Altitude range	0-40 feet
	Lateral stability	Percentage of 10 second intervals in which wings were low: less than, or equal to 34%.
Turn	Altitude range	0-60 feet
	Airspeed range	0-13 mph
	Nose position	Percentage of 3 second intervals in which nose position was not 8 or 9 (artificial horizon has 16 horizontal marks): less than or equal to 41%.
	Skid	Deviation of the ball in ball bank toward side of high wing: less than 2 degrees.
	Slip	Deviation of ball in ball bank toward side of low wing: less than 2 degrees.
Take-off	Average airspeed during climb	50-70 mph (check ship 1) 55-65 mph (check ship 2)
	Ball bank	Deviation of the ball in ball bank toward either side: less than 2 degrees.
Landing	Airspeed range in glide	[illegible] mph or less
	Average airspeed at moment of landing	[illegible] mph or less
	[illegible]	Contact indicator: [illegible]

Analysis of Variance for Total Sample Table 26 presents the results of the analyses for the total sample. Out of the ten analyses which were run, only one shows significant variation in the means of the visual groups. This significant variable was the Weighted Turn Score in the Visual Groups-by-Instructors analysis. Again, the A and B groups are superior to the C and D groups.

Table 27 shows the results of t-tests of the differences between pairs of means. The differences A - C and B - C are significant at the 5 per cent level of confidence. Only the differences A - B and C - D are not significant at the 10 per cent level of confidence.

Significant class variances are found for the Weighted Take-off Score, the Weighted Landing Score, and the Weighted Total Score. A significant interaction of visual groups and classes is found for the Weighted Turn Score, indicating that the relationships among the visual groups change from class to class.

Analysis of Variance for Licensed Subjects Only. As was previously done for the other criterion measures, the analyses of these five scores on the photographic records were repeated using only the data on the subjects who were licensed. The results of these analyses are presented in Table 28. None of the analyses shows significant visual group variances. Significant class variances appear for Weighted Turn Score, Weighted Take-off Score, and Weighted Total Score. A significant interaction of visual groups and instructors appears for the Weighted Turn Score.

Results: Analysis of Variance for other Individual Maneuvers

The results of analyses reported so far indicate that visually deficient subjects, as characterized by members of Groups C and D, exhibited somewhat poorer flight performance particularly in terms of criteria associated with landings. These findings raise the question of whether significant differences in performance, would also be evident in terms of other maneuvers. Therefore, analyses of variance were run in terms of criterion measures taken, in the following maneuvers:

1. Straight and Level
2. Straight Climb
3. 720° Power Turn
4. Stall
5. Take-off

As in the case of other criterion measures two types of analyses were run, viz: analyses in which visual groups and classes were controlled, and analyses in which visual groups and instructors were controlled. The results of these analyses are presented in Table 29. Examination of Table 29 indicates that in terms of both analyses by classes and by instructors significant variation attributable to visual groups was evident for criterion measures taken during the straight climb. In terms of these criterion measures the performance of subjects in Groups C and D was poorer than was the performance of subjects in Groups A and B. Furthermore, in terms of the analyses in which visual groups and instructors were controlled significant

TABLE 26

SUMMARY OF RESULTS OF ANALYSES OF VARIANCE OF PHOTOGRAPHIC DATA FOR ALL STUDENTS: P-VALUES AND MEANS OF CRITERION SCORES FOR VISUAL GROUPS

Visual Groups-by-Classes

Analysis	Wtd. Straight & Level Score	Wtd. Turn Score	Wtd. Take-off Score	Wtd. Landing Score	Wtd. Total Score
Visual Groups	$> .20$	$.20 > P > .05$	$> .20$	$> .20$	[illegible]
Classes	$> .20$	$> .20$	$< .001$	[illegible] .001	[illegible]
V x C	$> .20$	$< .001$	$> .20$	$> .20$	$> .20$
Means of Visual Groups*					
A	[illegible]	71.[illegible]	67.[illegible]	40.8	[illegible]
B	[illegible]	71.[illegible]	64.[illegible]	46.6	[illegible]
C	54.[illegible]	66.7	61.5	45.0	[illegible]
D	52.[illegible]	66.6	63.[illegible]	[illegible]	[illegible]

Visual Groups-by-Instructors

Analysis	Wtd. Straight & Level Score	Wtd. Turn Score	Wtd. Take-off Score	Wtd. Landing Score	Wtd. Total Score
Visual Groups	$> .20$	$.05 > P > .01$	$> .20$	$> .20$	[illegible]
Instructors	$> .20$	$.20 > P > .05$	$> .20$	$> .20$	[illegible]
V x I	$.20 > P > .05$	$> .20$	$> .20$	$> .20$	$> .20$
Means of Visual Groups*					
A	54.[illegible]	71.5	65.[illegible]	[illegible]	[illegible]
B	56.[illegible]	71.9	60.[illegible]	45.[illegible]	[illegible]
C	56.5	65.6	[illegible]	[illegible]	[illegible]
D	55.6	66.4	[illegible]	39.2	[illegible]

*Numbers in red indicate rank order of means of visual groups in terms of proficiency of performance.

TABLE 27

THE VISUAL GROUPS-BY-INSTRUCTORS ANALYSIS FOR WEIGHTED TURN SCORE (TOTAL SAMPLE)

Pairs	P
A-B	.90 > P > .80
A-C	.05 > P > .02
A-D	.10 > P > .05
B-C	.05 > P > .02
B-D	.10 > P > .05
C-D	.80 > P > .70

variation attributable to visual groups was evident for one of the criterion measures taken during the stall (weighted maneuver grade given by the instructor) and in terms of one of the two criterion measures taken during the take-off (also weighted maneuver grade). Again, the performance of subjects in Groups C and D was inferior to the performance of subjects in Groups A and B.

Results discussed earlier in the report indicated that subjects in Groups C and D exhibited somewhat poorer performance in criterion measures associated with landings. These findings suggest that such somewhat inferior performance may also be evident in terms of the straight climb, and possibly in terms of elements of performance associated with the stall and the take-off. However, the evidence of significant variance attributable to instructors, as indicated in Table 29, indicates the importance of considering the instructor variable in evaluating these findings.

Results: Analyses of Variance of Criterion Measures taken on Last Check Flight

The findings reported up to this point suggest inferiority of subjects in Groups C and D in terms of certain criterion measures associated with flight performance, in particular in connection with performance on the maneuver "Landing." However, it should be noted that with three exceptions, the remaining 10 of the 13 criterion measures were based on flight performance over the first 35 hours of the training course. Although statistically significant difference in variance, attributable to Visual Groups, were evident for 6 of the 13 measures, such significant differences were not indicated for the three measures from the last check flight, viz: Mean Maneuver Grade, Last Over-all Grade, and Last CSFI score (all given by the check pilot). The question can well be raised as to whether visually deficient individuals, as represented by subjects in Groups C and D, while learning more slowly may not eventually prove as proficient as subjects with slight deficiency or no deficiency at all, although perhaps taking longer to reach this degree of proficiency.

In order to check on this possibility, analyses of additional criterion measures were run in terms of data from the final check flight only, irrespective of the hour of training at which this check flight occurred. Thus, if a subject failed to pass the private pilot flight test until after 45 hours

TABLE 28

SUMMARY OF RESULTS OF ANALYSES OF VARIANCE OF PHOTOGRAPHIC DATA FOR SUBJECTS WHO WERE LICENSED: F-VALUES FOR F-TESTS MEANS OF CRITERION SCORES FOR VISUAL GROUPS

Visual Groups-by-Classes

Analysis	Wtd. Straight & Level Score	Wtd. Turn Score	Wtd. Take-off Score	Wtd. Landing Score	Wtd. Total Score
Visual Groups	> .20	> .20	> .20	> .20	> .20
Classes	> .20	.05 > P > .01	< .001	> .20	.05 > P > .01
V x C	> .20	> .20	> .20	> .20	> .20
Means of Visual Groups*					
A	54.02 [illegible]	71.7[illegible]	66.04	39.73	57.7[illegible]
B	57.[illegible]	69.5[illegible]	69.52	44.41	60.3[illegible]
C	53.2[illegible]	69.9[illegible]	66.23	40.82	57.6[illegible]
D	54.02 [illegible]	68.9[illegible]	72.61	38.94	58.52

Visual Groups-by-Instructors

Analysis	Wtd. Straight & Level Score	Wtd. Turn Score	Wtd. Take-off Score	Wtd. Landing Score	Wtd. Total Score
Visual Groups	> .20	> .20	> .20	> .20	> .20
Instructors	> .20	> .20	> .20	> .20	> .20
V x I	> .20	.05 > P > .01	> .20	> .20	> .20
Means of Visual Groups*					
A	[illegible]	[illegible]	65.9[illegible]	39.2[illegible]	58.0[illegible]
B	[illegible]	[illegible]	62.1[illegible]	46.7[illegible]	60.[illegible]
C	57.1[illegible]	68.8[illegible]	65.8[illegible]	38.2[illegible]	57.[illegible]
D	53.2[illegible]	67.8[illegible]	67.11	39.42	56.84

*Numbers in red indicate rank order of means of visual groups in terms of proficiency of performance.

TABLE 29

SUMMARY OF RESULTS OF ANALYSES OF VARIANCE ON MANEUVERS: P-VALUES FOR F-TESTS.
MEANS OF CRITERION SCORES FOR VISUAL GROUPS

Visual Groups-by-Classes

Analysis	Wtd. Strt. & lvl. MG	Wtd. Strt. & lvl. OSFI	Wtd. Climb MG	Wtd. Climb OSFI	Wtd. Turn MG	Wtd. Turn OSFI	Wtd. Stall MG	Wtd. Stall OSFI	Wtd. Take-off MG	Wtd. Take-off OSFI
Visual Groups	.20-.05	> .20	.05-.01	.01-.001	> .20	> .20	.20-.05	> .20	.20-.05	.20-.05
Classes	< .001	> .20	< .001	> .20	> .20	< .001	.20-.05	< .001	< .001	.01-.001
V x C	> .20	.20-.05	> .20	.20-.05	.20-.05	.20-.05	> .20	> .20	.20-.05	.05-.01
Means of Visual Groups*										
A	74.52	55.73	74.22	44.41	70.32.5	96.43	66.37	10.71	72.11	69.1
B	75.41	59.74	74.31	47.03	70.51	96.83	63.52	11.31	72.3	[illegible]
C	73.14	59.23	71.24	56.14	70.32.5	96.73	63.13	11.33	69.8	[illegible]
D	73.93	58.32	72.42	54.93	69.44	101.74	63.04	12.84	69.8	80.6

Visual Groups-by-Instructors

Analysis	Wtd. Strt. & lvl. MG	Wtd. Strt. & lvl. OSFI	Wtd. Climb MG	Wtd. Climb OSFI	Wtd. Turn MG	Wtd. Turn OSFI	Wtd. Stall MG	Wtd. Stall OSFI	Wtd. Take-off MG	Wtd. Take-off OSFI
Visual Groups	> .20	> .20	.05-.01	.01-.001	> .20	> .20	p = .05	.20-.05	.05-.01	.20-.05
Instructors	.01-.001	> .20	< .001	> .20	> .20	< .001	.05-.01	< .001	< .001	.05-.01
V x I	> .20	.05-.01	.20-.05	> .20	.20-.05	> .20	> .20	> .20	.05-.01	.01-.001
Means of Visual Groups										
A	74.92	54.61	74.61	43.42	70.61	96.21	66.91	10.51	72.61	67.8
B	75.41	60.24	74.42	47.12	70.42.5	97.43	64.02	11.23	72.52	69.42
C	73.14	58.63	71.84	55.84	70.42.5	97.12	63.63	11.12	70.3	77.03
D	73.93	58.32	72.43	54.93	69.44	101.74	63.04	12.64	69.8	80.64

*Numbers in red indicate rank order of means of visual groups in terms of proficiency of performance.

of flight training, his performance on the final check flight at 45 hours was compared in these analyses with the performance of subjects who passed their flight test at 35 hours and whose final check flight performance was recorded after only 35 hours of training. Such analyses of criterion measures taken on the last check flight, irrespective of the hour at which it occurred, were run in terms of the two criterion measures concerned with performance on landing. These criterion measures were selected because of the fact that subjects in Groups C and D had proved inferior on them, and because of their crucial nature. The results of these analyses are presented in Table 30. In addition, analyses were conducted in terms of two criterion measures covering performance on strange field landings.[33] The results of these analyses are also presented in Table 30.

Examination of Table 30 indicates that these analyses failed to yield significant variances attributable to visual groups. In evaluating these results, however, it should be recognized that the power of the statistical tests of significance was reduced by the fact that the criterion measures were based on data from a single check flight and are, thus, less reliable than are criterion measures employed in previous analyses which were based on a combination of data from several check flights.

Results: Analysis of Pass-Fail Criterion, with Control in Terms of Selection Test Data

Because of the nature of the correlations between selection tests and Pass-Fail, it was considered desirable to determine whether the differences in incidence of passing (or failing), evident among subjects in various visual groups could be attributed to factors represented by the test scores. Therefore two types of analyses of these data were made, one involving computation of the interaction chi-squared, and the other involving the computation of a partial correlation coefficient.

In the computation of the interaction chi-squared, the subjects were divided into two groups in terms of their scores on each selection test, viz: one group comprising subjects falling above the median in the test in question, the other group comprising subjects whose test scores fell below the median. On the basis of this categorization an analysis leading to the computation of the interaction chi-squared was run, in terms of each selection test.[34]

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[33] On the check flight conducted following 35 hours of training, subjects were required to execute an approach and landing at an unfamiliar airport. The criterion measures in terms of which performance on this maneuver was recorded were an over-all maneuver grade given by the check pilot and score on a specially designed check sheet included in the Ohio State Flight Inventory.

[34] This analysis proceeded as follows: Chi-squared analyses, categorical by Pass-Fail and Visual Groups, were run separately for subjects scoring above and below the median, respectively, in each test. The chis-squared thus determined were summated yielding a "total chi-squared" with an associated number of degrees of freedom equal to the sum of the number of the degrees of freedom for the individual chis-squared. A "pooled chi-squared" was also

TABLE 30

SUMMARY OF RESULTS OF ANALYSES OF VARIANCE FOR ALL SUBJECTS. P-VALUES FOR F-TESTS. MEANS OF CRITERION SCORES FOR VISUAL GROUPS ON LAST CHECK FLIGHT

Visual Groups-by-Classes

Analysis	Last Landing MG	Last Landing OSFI Score	Last Strange Field Landing MG	Last Strange -Field Landing OSFI
Visual Groups	> .20	.20-.05	> .20	> .20
Classes	.20-.05	.05-.01	.01-.001	.20-.05
V x C	.01-.001	> .20	.01-.001	> .20
Means of Visual Groups*				
A	207.02	39.42	54.42	19.92
B	201.12	38.71	56.11	18.43
C	198.73	49.44	48.04	22.42
D	197.14	42.63	53.83	18.72

Visual Groups-by-Instructors

Analysis	Last Landing MG	Last Landing OSFI Score	Last Strange Field Landing MG	Last Strange -Field Landing OSFI
Visual Groups	.20-.05	.20-.05	> .20	> .20
Instructors	.20-.05	.20-.05	> .20	> .20
V x I	.20-.05	> .20	.20-.05	> .20
Means of Visual Groups				
A	209.41	38.22	55.52	19.62
B	201.92	37.61	56.01	18.12
C	199.23	48.34	47.24	22.34
D	197.14	42.63	53.83	18.72

*Numbers in red indicate rank order of means of visual groups in terms of proficiency of performance.

The results of this analysis are presented in Table 31. Inspection of this table indicates that, with the exception of the "Desire to Fly" test (D-F) none of the interaction chis-squared is statistically significant at the .05 level of confidence. In the case of the "Desire to Fly" test the interaction chi-squared is significant at between the .02 and .05 level of confidence. In terms of these findings, with the exception of the "Desire to Fly" test, there is no evidence suggesting significant differences in incidence of failure among men, in the four visual groups, who have high test scores, and low test scores, respectively.

One criticism of this type of analysis is that each test is considered individually. Therefore, another approach was made to the problem through computation of the partial correlation coefficient between "Visual Efficiency" and "Flight Proficiency," partialling out the effects of selection or matching tests which, on the basis of their correlations with the criterion and among themselves, appeared to represent the best battery of tests for predicting success in learning to fly. The three tests employed in the battery were the Two-Hand Coordination test, the Greene test, and the Mechanical Comprehension test.[35] In terms of "Flight Proficiency" a score of 0 was assigned as representative of the flight performance of subjects who failed the course, a score of 1 being assigned to Passers. In terms of Visual Efficiency a score of 0 was assigned to members of Groups C and D; a score of 1 to members of Groups A and B. In the determination of the partial correlation (between Visual Efficiency and Flight Proficiency, with the effects of test scores held constant) product-moment coefficients were employed even though two of the variables were dichotomous, as indicated above.

The zero-order coefficient thus computed between "Visual Efficiency" and "Flight Proficiency" was .22, which may be considered significant at the .01 level of confidence. However, when the effects attributable to the matching tests are held constant, the partial coefficient is reduced to .05. Thus the results of this analysis by partial correlation technique do not indicate the existence of a relationship between Pass-Fail and visual efficiency scores of 0 and 1 (where 0 and 1 have the meanings indicated above) when the effects of the selection tests are partialled out.

The results of these two types of analysis (interaction chi-squared and partial correlation, respectively) appear superficially to be contradictory.

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34 (Continued) computed, represented by the distributions of all subjects, categorical by Pass-Fail and Visual Groups. To obtain the interaction chi-squared the pooled chi-squared was subtracted from the total chi-squared, the number of degrees of freedom for the interaction chi-squared being equal to the difference between the number of degrees of freedom for the "total" and for the "pooled" chis-squared, respectively. The interaction chi-squared indicates whether, among subjects above the median in test score, the incidence of failure in the various visual groups is significantly different from that among subjects below the median in test score. See: Snedecor, George W. Statistical methods. (Fourth Edition). Ames, Iowa: The Iowa State College Press, 1946, pp. 191-192.

35 The decision to employ a three test battery was purely arbitrary, but was dictated by the consideration that the correlations between the other tests and the criterion were so low that inclusion of more than three tests would have added little to the predictive efficiency of the battery.

TABLE 31

RESULTS OF THE CHI-SQUARED ANALYSIS OF THE PASS-FAIL CRITERION
TAKING ACCOUNT OF THE SELECTION TEST SCORES

Selection Tests

	Washburn	Two-Hand	D.F.	B.I.
Group Below Dichotomy Point	$.01 > p > .001$	$.20 > p > .10$	$.05 > p > .02$	$.20 > p > .10$
Group Above Dichotomy Point	$.70 > p > .50$	$.02 > p > .01$	$.01 > p > .001$	$.01 > p > .001$
Total	$.01 > p > .001$	$.02 > p > .01$	$p < .001$	$.01 > p > .001$
Pooled	$.01 > p > .001$	$.01 > p > .001$	$.01 > p > .001$	$.01 > p > .001$
Interaction	$.20 > p > .10$	$.50 > p > .30$	$.05 > p > .02$	$.20 > p > .10$

	V.G.	Washburn Pass	Washburn Fail	Two-Hand Pass	Two-Hand Fail	D.F. Pass	D.F. Fail	B.I. Pass	B.I. Fail
Group Below Dichotomy Point	A	35 (85%)	6	32 (76%)	10	32 (74%)	11	27 (75%)	9
	B	7 (58%)	5	7 (58%)	5	14 (88%)	2	13 (81%)	3
	C	16 (70%)	7	12 (57%)	9	9 (50%)	9	9 (53%)	8
	D	7 (35%)	13	10 (50%)	10	9 (53%)	8	12 (57%)	9
	Total	65 ([illegible])	31	61 (64%)	[illegible]	64 (68%)	30	61 (68%)	29
Group Above Dichotomy Point	A	29 (81%)	[illegible]	34 (92%)	[illegible]	34 (94%)	2	38 (90%)	4
	B	22 (85%)	3	22 (88%)	3	16 (73%)	6	17 (77%)	5
	C	12 (71%)	5	16 (84%)	3	19 (86%)	3	19 (83%)	4
	D	12 (75%)	4	9 (56%)	[illegible]	10 (53%)	9	7 (47%)	8
	Total	75 (80%)	19	81 ([illegible])	16	79 (80%)	20	81 (79%)	22
Pooled	A	64 (83%)	13	66 (84%)	13	66 (84%)	13	65 (83%)	13
	B	29 (78%)	8	29 (78%)	8	30 (79%)	8	30 (79%)	8
	C	28 (70%)	12	28 (70%)	12	28 (70%)	12	28 (70%)	12
	D	19 (53%)	17	19 (53%)	17	19 (53%)	17	19 (53%)	17
	Total	140 ([illegible])	50	142 (74%)	50	143 (74%)	50	142 (74%)	50

TABLE 31 (Cont.)

RESULTS OF THE CHI-SQUARED ANALYSIS OF THE PASS-FAIL CRITERION
TAKING ACCOUNT OF THE SELECTION TEST SCORES

		Selection Tests							
		Otis		A.I.		M.C.		G.S.P.E.	
Group Below Dichotomy Point		p < .001		.05 > p > .02		.05 > p > .02		.05 > p > .02	
Group Above Dichotomy Point		.90 > p > .80		.50 > p > .30		.20 > p > .10		.20 > p > .10	
Total		.01 > p > .001		.10 > p > .05		.05 > p > .02		.05 > p > .02	
Pooled		.01 > p > .001		.01 > p > .001		.01 > p > .001		.01 > p > .001	
Interaction		.30 > p > .20		.99 > p > .98		.99 > p > .98		.80 > p > .70	
	V.G.	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
Group Below Dichotomy Point	A	38 (8[illegible]%)	8	34 (79%)	9	34 (77%)	10	40 (88%)	6
	B	13 (8[illegible]%)	3	11 (69%)	5	12 (75%)	4	[illegible] (89%)	1
	C	9 (60%)	6	11 (61%)	7	12 (63%)	7	11 (69%)	5
	D	8 (36%)	14	9 (43%)	12	9 (43%)	12	11 (58%)	8
	Total	68 (6[illegible]%)	31	65 (66%)	33	67 (67%)	33	75 (79%)	20
Group Above Dichotomy Point	A	28 (85%)	5	32 (89%)	4	32 (91%)	3	20 (77%)	6
	B	17 (77%)	5	19 (86%)	3	18 (82%)	4	21 (75%)	7
	C	19 (76%)	6	17 (77%)	5	16 (76%)	5	17 (71%)	7
	D	11 (79%)	3	10 (71%)	4	10 (67%)	5	7 (47%)	8
	Total	75 (80%)	19	78 (83%)	16	76 (82%)	17	65 (70%)	28
Pooled	A	66 (84%)	13	68 (84%)	13	66 (84%)	13	65 (84%)	12
	B	30 (79%)	8	30 (79%)	8	30 (79%)	8	29 (78%)	8
	C	28 ([illegible]%)	12	28 (70%)	12	28 (70%)	12	28 (70%)	12
	D	19 (5[illegible]%)	17	19 (54%)	16	19 (53%)	17	18 (53%)	16
	Total	143 (7[illegible]%)	50	143 (74%)	49	143 (74%)	50	140 (74%)	48

TABLE 31 (Cont.)

RESULTS OF THE CHI-SQUARED ANALYSIS OF THE PASS-FAIL CRITERION TAKING ACCOUNT OF THE SELECTION TEST SCORES

	Selection Tests: Lane	Selection Tests: Greene	Selection Tests: Dockeray
Group Below Dichotomy Point	$.05 > p > .02$	$.01 > p > .001$	$.01 > p > .001$
Group Above Dichotomy Point	$.10 > p > .05$	$.20 > p > .10$	$.20 > p > .10$
Total	$.05 > p > .02$	$.01 > p > .001$	$.01 > p > .001$
Pooled	$.01 > p > .001$	$p < .001$	$p < .001$
Interaction	$.50 > p > .30$	$.95 > p > .90$	$.70 > p > .50$

	V.G.	Lane Pass	Lane Fail	Greene Pass	Greene Fail	Dockeray Pass	Dockeray Fail
Group Below Dichotomy Point	A	23 (88%)	3	20 (87%)	3	22 (92%)	2
	B	8 (80%)	2	11 (85%)	2	9 (75%)	3
	C	8 (62%)	5	9 (60%)	6	3 (38%)	5
	D	4 (44%)	5	6 (40%)	9	6 (43%)	8
	Total	43 (74%)	15	46 (70%)	20	40 (69%)	18
Group Above Dichotomy Point	A	23 (88%)	3	30 (88%)	4	23 (88%)	3
	B	12 (75%)	4	11 (85%)	2	11 (92%)	1
	C	3 (43%)	4	3 (50%)	3	9 (69%)	4
	D	9 (69%)	4	7 (70%)	3	7 (64%)	4
	Total	47 (76%)	15	51 (81%)	12	50 (81%)	12
Pooled	A	46 (88%)	6	50 (88%)	7	45 (90%)	5
	B	20 (77%)	6	22 (85%)	4	20 (83%)	4
	C	11 (55%)	9	12 (57%)	9	12 (57%)	9
	D	13 (59%)	9	13 (52%)	12	13 (52%)	12
	Total	90 (75%)	30	97 (75%)	32	90 (75%)	30

Referring to the interaction chi-squared analysis, the hypothesis that there is no difference in incidence of failure among high and low test scorers cannot be rejected; referring to the partial correlation analysis, the hypothesis that there is no relationship between "Visual Efficiency" and "Flight Performance" (when the effects associated with test score are held constant) cannot be rejected.[36] However, since while a null hypothesis can be rejected, but can, in general, not be proved, the results of these two analyses are not necessarily contradictory. Rather, both merely are inconclusive.

These findings do not permit a definitive statement regarding the relative importance of factors associated with "Visual Efficiency" and with "Test Scores" in connection with passing or failing the flight training course. Neither the hypothesis that there is no difference in incidence of failure among "high" and "low" test scores in the four visual groups; nor the hypothesis that there is no relationship between Visual Efficiency and Pass-Fail when factors associated with test score are partialled out, can unequivocally be rejected. The evidence with reference to other criterion measures indicated differentiation, attributable to Visual Group, in the case of certain criteria. It cannot confidently be stated that for the Pass-Fail criterion this conclusion should be altered, i.e., that in this case differences in incidence of failure can be attributed to factors associated with Test Scores, rather than with Visual Efficiency, per se. However, because of the inconclusive nature of the results of the two analyses, involving, respectively, interaction chi-squared and partial correlation techniques, differences in incidence of failure cannot confidently be attributed to visual proficiency, independent of test score. It may well be that differences in incidence of failure, among members of the four visual groups, can be attributed both to visual deficiency and to related factors associated with the test scores.

SUMMARY OF FINDINGS

The major findings of this investigation may be summarized as follows:

1. There is significant variation in the percentages of subjects in the various groups (characterized by difference in visual efficiency) who failed to receive licenses. Of the subjects in Group A, 15 per cent washed out; of the Group B subjects, 21 per cent; of the Group C, 30 per cent; and of the Group D, 47 per cent. Of the Group A and B subjects combined, 16.9 per cent washed out, as compared to 38.2 per cent of the Group C and D subjects combined, this difference in proportions being statistically significant at below the .01 level of confidence. The difference in proportions

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[36] The latter interpretation cannot, however, be considered completely unequivocal. Because of the dichotomous nature of two of the variables, the coefficient of .22 may not represent the "true" correlation between "Visual Efficiency" and "Flight Proficiency." Furthermore, it may be unrealistic to partial out the effect of test scores from the variable "Visual Efficiency," since there is some indication that "Test Score" and "Visual Efficiency" may be inherently related.

of washouts when adjacent groups are compared, i.e., Group A vs. B; B vs. C; and C vs. D are not significant except with respect to the last comparison, a significantly greater proportion of Group D than Group C subjects having been eliminated before completing training.

2. Learning curves representing the mean performance of members of each Visual Group in terms of several criterion measures at successive points during the training course indicate that the performance of Groups A and B is in general superior at each stage of learning, in terms of these measures, to the performance of Groups C and D. The general rank order of the groups, in terms of performance, is A, B, C, D, although the relative position of A with respect to B, and C with respect to D, is somewhat ambiguous.

3. Application of analysis of variance to data from 13 specific criterion measures of flight proficiency indicates that, in the case of 6 of these measures, the means of the four visual groups vary significantly in terms of the "Visual Groups-by-Instructors" analyses. For the "Visual Groups-by-Classes" analyses significant differences in variance were evident for three of the measures. Significant variance attributable to visual groups is evident for all three "Landing" measures in terms of the analyses of "Visual Groups-by-Instructors" and for two of the landing measures in terms of the "Visual Groups-by-Classes" analyses. Again the general rank order of performance (even for criteria for which significant variation attributable to Visual Group was not evident) is A, B, C, D, although the relative position of Group A with respect to B, and of Group C with respect to D, is somewhat ambiguous. There is little ambiguity, however, in the finding that the mean performances of Groups A and B are superior to the mean performances of Groups C and D.

4. Cumulative percentage curves, indicating the proportion of subjects in each group exceeding successive scores on the various criterion measures, demonstrate, however, that there is considerable overlap in the distributions of criterion scores. Some members of the C and D groups exceed the mean performance of subjects in Groups A and B. In general, however, Groups A and B are superior to Groups C and D.

5. Because of the evidence of overlap in the distributions of criterion scores for members of the four visual groups, it was desirable to determine whether differences among visual groups were evident when only subjects who successfully completed the course were considered. Therefore, the analyses of variance in terms of the 13 criterion measures were repeated in terms only of those subjects who were licensed. The results of these analyses indicate that when only licensed subjects are considered, the number of criterion measures evidencing significant variation in the means of visual groups is reduced from six to two. However, the two measures yielding significance are both measures of landing performance. It should also be noted that due to the reduction in the number of subjects available for these analyses, the power of the statistical test of significance is reduced, and, therefore, some reduction in the number of criterion measures yielding significant variation could be expected.

6. An analysis was made of specific items on the Ohio State Flight Inventory pertaining to landing, to determine the specific aspects of performance in this maneuver in terms of which members of the various visual groups differed. The results indicate that statistically significant differences are evident with respect to seven of the fourteen items when data from the entire group are considered, and for four of the fourteen items when only subjects who eventually were licensed are considered, the performance of subjects in Groups A and B being superior to the performance of subjects in Groups C and D. In the case of all subjects, and licensed subjects only, significant differences were evident in terms of the item referring to the pilot's judgment as to the "satisfactory" or "unsatisfactory" nature of the landing.

7. Treatment by analysis of variance of data from five measures of flight performance derived from the photographic records taken during the check flight, indicates that in the case of one measure, indicative of performance during Turns, significant variation in mean scores for visual groups is evident. This finding, however, applied only to the Visual Groups-by-Instructors analyses in the treatment of data from all subjects. When only subjects who eventually were licensed are considered, there is no evidence of significant variation in visual group means, in terms of the photographic data.

8. Analyses of 10 criterion measures of performance in other individual maneuvers indicated that significant variance, attributable to visual groups, was evident for four measures (two measures of performance in the straight climb, one measure pertaining to "Stalls," and one measure pertaining to "Take-off") in the Visual Groups-by-Instructors analyses, and for the two stall measures in the Visual Groups-by-Classes analyses. In these maneuvers the performance of subjects in Groups C and D was inferior to the performance of subjects in Groups A and B.

9. Analysis of data from the <u>last</u> check flight, irrespective of the hour at which it occurred, yielded no evidence of statistically significant variation, for the means of the four visual groups, in terms of four measures of flight performance pertaining to Landings, and in terms of the 3 major criterion variables which were based on performance during the last check flight. The criterion measures available for this analysis, being based on a single check flight, are less reliable than those measures based on performance throughout the course, and the finding cannot be considered completely unequivocal. However, the possibility cannot be rejected that the performance of visually deficient subjects, if given sufficient training, was relatively comparable to the performance of visual "normals" or "near normals."

10. Two types of analyses of the Pass-Fail criterion data were made in an effort to determine whether differences in incidence of failure, among the four visual groups, might be attributed to factors associated with the matching tests rather than, or in addition to, visual efficiency <u>per se</u>. The results of these analyses, involving, respectively, use of the interaction chi-squared, and a partial correlation technique, were inconclusive. In other words, it could not be said that factors associated with

test scores account for the Pass-Fail differences among visual groups. On the other hand the hypothesis that differences in incidence of failure are functions of factors associated with test scores (rather than of visual efficiency) cannot unequivocably be rejected.

CONCLUSIONS AND RECOMMENDATIONS

This investigation gives evidence of a relationship between visual efficiency and proficiency in learning to fly a light aircraft. In terms of a number of criterion measures pertaining to various aspects of proficiency during flight training, particularly in relation to performance in landing the plane, subjects with visual deficiency as severe as that characteristic of Groups C and D proved inferior to a statistically significant degree to subjects in Groups A and B, representing men with normal vision in both eyes, or with relatively slight defects corrected to normal in both eyes. Such statistically significant inferiority was evident in terms of two measures pertaining to landing even when only subjects who passed the training course were considered. Moreover, a significantly greater proportion of subjects with normal vision, or with slight defects corrected to normal in both eyes (subjects in Groups A and B) completed the course and received the private pilot's license than was the case for men in Groups C and D, representing subjects with relatively severe visual defects (e.g., uncorrected acuity worse than 20/50).

Interpreted broadly, these findings suggest that a man representative of the subjects in this study and with visual defects as marked as those characterizing subjects of Groups C and D has only about 5 chances in 10 of successfully completing a course in training for the private pilot certificate (at least with reference to the general type of plane employed in this study). A man with normal visual efficiency has approximately 8.5 chances in 10 of completing such a training course within a period of 50 hours of flight training. When a visual defective enrolls for a flight training course he is making an investment under conditions where the probabilities for a return are much less than are those applying to the individual with normal, or near normal, vision. Visual defectives who do not eliminate themselves by lack of interest, or for other reasons, appear to have a "good chance" of being eliminated because of failure to meet proficiency standards.

However, the fact that many of the marked visual defectives were sufficiently proficient to be granted licenses, i.e., that less than half of the Group D subjects, and less than one-third of the Group C subjects, actually failed the course, should not be overlooked. It is also significant in this regard that in terms of the various criterion measures appreciable proportions of subjects in the C and D groups exceeded the average performance of subjects in Groups A and B; and that none of the members of Group D failed the medical flight test administered, in accordance with CAA administrative policy then current, to all applicants having the degree of visual defect characteristic of this group. Of additional importance is the fact that there were no accidents in any of the four visual groups during flight training which totalled over 8,000 hours for the entire experimental program.

Furthermore, on a number of measures, performance of subjects with marked visual defects (members of Groups C and D) on the last check flight (irrespective of when it occurred) was not significantly poorer than the performance of subjects in Groups A and B with normal or near normal vision. This finding, which suggests that visual defectives eventually attain a degree of proficiency comparable to visual normals, cannot however, be compared directly with the findings previously discussed, since the last check flight measures are based on performance during a single check flight, and therefore must be considered less reliable. It may well be that the issue concerning individual, civilian flight training for student pilots with visual defects of the types represented in Groups C and D cannot be settled definitively without a follow-up to determine the flight performance of the subjects in each visual group over a period of years subsequent to licensing.[37]

The results of this study also have implications for flight training research. The indications of specific areas in which the visually deficient experience difficulty (e.g., with respect to particular aspects of the landing performance, as well as possibly with climbs, take-offs, and stalls) suggest the desirability of research in the development of instructional procedures particularly adapted to the training of visually handicapped students.

This study was directed primarily at the problem of individual civilian flight training. The results, however, also have implications for problems associated with the mass-training of large numbers of pilots at government expense. The definite relationship evident for the group as a whole, between visual efficiency and performance during the flight training course, suggests the importance of visual efficiency as a factor to be considered in selecting pilots for a large-scale mass flight training program.[38] It should be emphasized, however, that these analyses have little bearing on the specific point at which eliminations should be made in terms of visual efficiency. It is of particular importance that nothing in this study would support the rejection of all subjects with less than normal vision. It will be remembered that for no criterion measure were the somewhat visually deficient subjects characteristic of Group B, significantly poorer in terms of flight performance than were Group A subjects.

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[37]Such a follow-up has been initiated, under the auspices of the Committee on Aviation Psychology. Although insufficient time has elapsed to warrant definitive conclusions to be drawn, preliminary results indicate, for example, a higher percentage of licensed pilots in Groups C and D as not having had flight experience subsequent to licensing than is found for subjects in Groups A and B.

[38]It should be noted that the results of this study do not necessarily negate the findings of earlier studies (see, for example, (2) and (9)) which indicated no significant relationships between measures of flight proficiency and visual efficiency. The apparent disagreement may be explained by the fact that in the present investigation the range of visual efficiency was large; in many of the previous studies the range of visual efficiency of subjects treated has been markedly restricted.

From the findings and analysis presented in this report it seems possible to recommend that persons with such visual defects as characterize subjects in Groups C and D, seeking training at their own expense, be accepted as student pilots for the private flight certificate under two conditions:

1. That they be informed that the probability of obtaining a license is lower than for persons with better visual efficiency.

2. That in flight testing such applicants for certification as private pilots, particular emphasis be given to performance on landings. Consideration might well be given to developing an improved test for administration to visual defectives.[39]

The recommendation also appears warranted that consideration be given to the development of specialized training procedures, directed at those areas in which visual defectives appeared significantly less proficient.

[39] Items from the Ohio State Flight Inventory might well supply a sound basis for the development of such a test. In its administration the test should be repeated several times in order that a stable sample of the subject's landing performance could be obtained.

APPENDIX 1

NOTE ON HOMOGENEITY OF VARIANCE

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In much of the analysis the means of the visual groups have been the subject of statistical analysis. It may also be asked whether the groups varied significantly in their dispersions. In order to obtain an answer to this question, the data on the thirteen criterion measures were tested for homogeneity of variance. Bartlett's[40] test of homogeneity of variance was used for this purpose.

The tests of homogeneity of variance were run four times for each criterion measure, as follows:

1. For the Visual Groups-by-Classes analysis for the total group.

2. For the Visual Groups-by-Instructors analysis for the total group.

3. For the Visual Groups-by-Classes analysis for those subjects who were licensed.

4. For the Visual Groups-by-Instructors analysis for those subjects who were licensed.

The nature of the tests which were run can be made clear by referring to Figures 3 or 4. The sums of squares and degrees of freedom, within cells, were computed, and added for each column. The column variances so computed were tested for homogeneity of variance by Bartlett's test. In effect, it is the average within cells variance for a column that is tested for homogeneity.

These tests have two purposes. First, since homogeneity of variance is a prerequisite for the validity of the analyses of variance previously presented, they will indicate whether this prerequisite has been fulfilled.[41] Second, the question of whether the visual groups differ significantly in their dispersions is of interest in itself.

Table 32 presents the results of the tests of homogeneity for the various analyses which have been run on the thirteen criterion measures. The upper portion of the table shows the p-values obtained for all cases for which the analyses of variance were run, for both the Visual Groups-by-Instructors analyses and the Visual Groups-by-Classes analyses. The lower portion of the table shows the results of corresponding analyses for only

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[40] Snedecor, G. W. Statistical methods (4th Edition). Ames, Iowa: Iowa State College Press, 1946, pp. 249-252.

[41] It will be noted that this method of testing for homogeneity of variance assumes that there is homogeneity of variance among the cells within a column.

those cases who received licenses. Examination of this table shows that in every instance there is insufficient reason to reject the hypothesis of equal variances among the visual groups.

Similarly, with reference to the data from the photographic records which were subjected to analysis of variance, the hypothesis of equal variability between groups could not be rejected. The results of the application of Bartlett's test on these data, both for all subjects and for licensed subjects only, are presented in Table 23.

TABLE 32

RESULTS OF TESTS OF HOMOGENEITY OF VARIANCE OF VISUAL GROUPS ON CRITERION MEASURES

Corresponding to Analysis	Wtd. Ov-All (I)	Wtd. MMG (CP)	Wtd. Ov-All (CP)	Wtd. OSFI (CP)	Wtd. MMG (I)	MMG Last CF(CP)	Last Ov-All (CP)	Last OSFI (CP)	Purdue Sum (I)	TTS (log)	Wtd. Landing MG (CP)	Wtd Landing OSFI(CP)	Wtd Landing MG(I)
Total Sample													
Visual Groups by Instructors	.50-.30	.50-.30	.70-.50	.50-.30	.30-.20	.50-.30	.70-.50	.30-.20	.80-.70	.30-.20	.20-.10	.70-.50	.70-.50
Visual Groups by Classes	.30-.20	.80-.70	.80-.70	.90-.80	.50-.30	.50-.30	.90-.80	.70-.50	.30-.20	.20-.10	.20-.20	.95-.90	.80-.70
Licensed Subjects													
Visual Groups by Instructors	.95-.90	.90-.80	.90-.80	.50-.30	.20-.10	.95-.90	.70-.50	.90-.80	.10-.05	.10-.05	.70-.50	.70-.50	.90-.80
Visual Groups by Classes	.80-.70	.90-.80	.90-.80	.70-.50	.30-.20	.80-.70	.95-.90	.70-.50	.99-.98	.20-.10	.70-.50	.95-.90	.50-.30

TABLE 33

RESULTS OF TESTS OF HOMOGENEITY OF VARIANCE OF VISUAL GROUPS ON PHOTOGRAPHIC DATA

Corresponding to Analysis	Wtd. Straight & Level Score	Wtd. Turn Score	Wtd. Take-off Score	Wtd. Landing Score	Wtd. Total Score
			Total Sample		
Visual Groups-by-Instructors	.80 > P > .70	.50 > P > .30	.70 > P > .50	.70 > P > .50	.90 > P > .80
Visual Groups-by-Classes	.50 > P > .30	.90 > P > .80	.95 > P > .90	.95 > P > .90	.80 > P > .70
			Licensed Subjects		
Visual Groups-by-Instructors	.80 > P > .70	.95 > P > .90	.70 > P > .50	.90 > P > .80	.70 > P > .50
Visual Groups-by-Classes	.30 > P > .20	.90 > P > .80	.80 > P > .70	.95 > P > .90	.80 > P > .70

APPENDIX 2

SELECTED BIBLIOGRAPHY

APPENDIX 2

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APPENDIX 3

MANUAL OF VISUAL TESTS FOR QUALIFICATION AND CLASSIFICATION OF CANDIDATES FOR THE VISUAL STUDY

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MANUAL OF VISUAL TESTS FOR QUALIFICATION AND CLASSIFICATION OF CANDIDATES FOR THE VISUAL STUDY

SECTION I - INTRODUCTION

The tests are designed to select and classify six types of candidates referred to as A, B, C, D_1, D_2, and D_3 types who have certain specific and general visual qualifications.

Specific Qualifications of the A, B, C, D_1, D_2, and D_3 types

Group A. Unaided vision of 20/20 or better in each eye with high acuity of stereopsis and a refractive error under cycloplegia of less than 0.50 D. of myopia in any meridian, 1.50 D. of hyperopia in any meridian and 1.00 D. of astigmatism.

Group B. Unaided vision of 20/50 or worse in each eye corrected with forward glasses to 20/20 or better in each eye, with a high acuity of stereopsis corrected (3 cm. at 6 meters) and a refractive error under cycloplegia of less than 3.00 D. in any meridian, less than 2.00 D. of astigmatism and less than 2.00 D. of difference between any parallel meridians in the two eyes.

Group C. Unaided vision of 20/100 or worse in each eye, corrected with forward glasses to 20/50 or better in each eye, with a corresponding acuity of stereopsis (10 cm. at 6 meters) and a refractive error under cycloplegia exceeding 4.00 D. in any meridian.

Group D_1. One eye correctible to 20/20 with a refractive error less than 3.00 D. in any meridian and less than 2.00 D. of astigmatism; the other eye uncorrected 20/100 or worse not correctible to 20/50, or having been removed at least 5 years prior to application for flight training.

Group D_2. Same as D_1 except that the candidate must also be a squinter

Group D_3. A 10° or greater horizontal tropia with less than 10° of vertical tropia and with each eye correctible to 20/20 with a refractive error less than 3.00 D. in any meridian and less than 2.00 D. of astigmatism.

General Visual Requirements for Types A, B, and C

1. Phorias at 6 meters not exceeding 7 prism diopters of esophoria, 7 prism diopters of exophoria, and 1.5 prism diopters of hyperphoria.

2. Prism divergence at 6 meters equalling or exceeding the existing amount of esophoria.

3. Phorias at 33 centimeters, not exceeding 7 prism diopters of esophoria, 14 prism diopters of exophoria, and 1.5 prism diopters of hyperphoria.

4. Prism divergence at 33 centimeters of at least 14 prism diopters.

5. Prism convergence at 33 centimeters equaling or exceeding the existing exophoria.

6. Absence of any paralytic motor disturbance in the six cardinal positions of gaze.

7. The ability to read fluently at 50 centimeters, without additional lenses, type representing 20/40 of the Snellen system.

8. Satisfactory interpretation (not more than 3 mistakes) of the American Optical Company's compilation of pseudo-isochromatic plates (abridged edition, 19 plates). (In case of failure, re-examine with SAM Color Threshold Lantern.) (A score of 35 is required.)

9. Superior or satisfactory night visual efficiency as tested with the AAF School of Aviation Medicine Portable Night Vision Tester; and Aero Medical Laboratory Night Vision Tester.

10. Absence of any ocular disease, active or likely to be activated or to become progressive during the period of flight training.

11. Absence of significant (greater than 15 degrees of arc) contraction of the isopter for a 3/300 white target.

12. Absence of any pathologic scotoma within 25° of the point of fixation, and of any scotoma greater than 10° (in any direction) and absolute for 3/300 white target which is situated outside the 25° circle.

General Visual Requirements for Types D_1 and D_2

Applicants in Group D_1 are required to meet only 6, 7, 8, 9, 10, 11, and 12. Requirements 6, 11, and 12 apply only to the good eye; 10 applies to both eyes; and 7, 8, and 9 are administered without occuding one eye although the performance is dependent on one eye.

General Visual Requirements for Type D_3

Applicants in Group D_3 are required to meet only 6, 7, 8, 9, 10, 11, and 12. Requirements 6, 10, 11, and 12 apply to each eye; 7, 8, and 9 are administered without occluding one eye although the performance is dependent on one eye, i.e., either eye, whichever happens to be fixing at the moment.

Organization of Testing Procedure

The tests are organized into four separate batteries referred to as:

1. Preliminary Classification Tests.
2. Ophthalmological Examination.
3. Visual Acuity Test.
4. Special Qualification Tests.

The tests have been arranged so that as soon as a person definitely fails to qualify for one of the four major groups, he is dismissed, but in every case the notice of dismissal is given by the Director of the Flight Training Project, and the persons conducting the tests simply submit reports to the Director.

The Referral for the Preliminary Tests

The Director of the Flight Training Project authorizes a given applicant as ready for the visual tests, and refers him to the person in charge of the Preliminary Tests. He records on Form I the name of the applicant and the date on which he refers him for the Preliminary Tests. He retains Form I in his office. If it is obvious to the Director that the applicant has only one eye, he may question the applicant as to the date of removal, and if the period since removal is less than five years, he may dismiss the applicant without submitting him to any actual tests.

SECTION II

PRELIMINARY CLASSIFICATION TESTS

The tests are to be conducted by an assistant under Dr. Fry's supervision in Room 202, Mendenhall Laboratory.

If the person conducting the tests discovers that one eye is removed, before making any tests he must determine if the eye was removed more than five years prior to the date of the test. If the one eye has been removed less than five years, the applicant is immediately referred back to the

FORM I

Date of Referral for:

Preliminary Tests ______

Ophthalmological Examination ______

Visual Acuity ______

Special Tests ______

		CLASSIFICATION TESTS			
		Angle of Squint	Unaided Vision	Acuity with Rx	Skia-scope
NON-SQUINTER	Disqualified				
	Possible A				
	Possible B				
	Possible C				
	Possible D_1				
SQUINTER	Possible D_2				
	Possible D_3				
	Disqualified				

Approved as ______ Type.

______

______
Director

If disqualified, indicate by stamping here the word "disqualified."

______

Date ______ ______
Director

Reasons for disqualification:

Director, and the finding is recorded on Form II which is signed and sent to the Director. If one eye has been removed more than five years, this fact is recorded on Form II and he goes ahead with the measurement of unaided vision in the good eye. The examiner should obtain whatever substantiating evidence that he can that the eye was removed more than five years previous to the application.

A preliminary classification test which is a measure of unaided vision is made with the apparatus described in Attachment I on each eye or on the good eye if one has been removed more than five years. First the right eye is tested for unaided vision with the left eye occluded and a similar procedure is followed for the left eye. The results are recorded on Form II.

If it is not obvious by casual observation that one eye has been removed and if the first indication that one eye has been removed is that the acuity in one eye cannot be measured, the person in charge of the test must determine by direct questioning if and when the one eye was removed and this information must be recorded on Form II.

If he finds that the one eye has been removed less than five years, he stops the test and records this fact on Form II and refers the applicant back to the Director and submits Form II to the Director. If he finds that the one eye was removed prior to five years before the test, he proceeds with the measurement of unaided vision in the good eye if this has not already been completed.

A test of squint is given and if a squint is found, the objective angle of squint is measured. The results are recorded on Form II.

The candidate is then referred back to the Director of the Flight Training Project, to whom Form II is also submitted.

SECTION III

EVALUATION OF DATA OBTAINED IN THE PRELIMINARY CLASSIFICATION AND QUALIFICATION TESTS

If one eye has been removed less than five years prior to the date of evaluation, the Director of the Flight Training Project immediately disqualifies the candidate, and records this fact and the reason for it on Form I. He also notifies the candidate.

If the applicant has a manifest squint of 10° or over in horizontal direction and less than 10° in the vertical direction, he is classified either as a possible D_3 or a possible D_2 type. If the squint is less than 10° in both directions, he is classified as a possible D_2 type only.

If the candidate is not a squinter, the Director analyzes the unaided vision data and classifies the candidate either as disqualified or as a

FORM [illegible]

PRELIMINARY CLASSIFICATION TEST

Name ______________________________ Date ______________

One eye Removed

Right ________ Left ________ Date ______________

Substantiating Evidence of date of removal ________

____

Unaided Vision O. D. ________

O. S. ________

Tropia NO ________ YES ________

Objective angle of squint ______________________

____

Administrator of Tests

possible candidate for one or more of the groups to be used in the project. He records the results of his analysis on Form I by using check marks to indicate the various possible classifications in the column marked "Unaided Vision."

The classification may be made on the following basis:

The candidate is disqualified if his unaided vision for one eye is better than 20/50 and the rating for the other lies between 20/20 and 20/100.

The candidate is a possible A type if he shows an unaided vision of 20/20 or better in each eye.

The candidate is a possible B type if he gets 20/50 or worse in each eye.

He is a possible C type if he gets 20/100 or worse in each eye.

He is a possible D_1 type if he gets 20/100 or worse in one eye or has one eye removed regardless of what he gets in the other.

These classifications are illustrated graphically in Figure 1 which may be used for making the classification. The point representing the scores immediately determines the possible classification.

If the candidate is a squinter, the unaided vision test cannot disqualify any candidate for the D_3 group, but he must meet the requirements for vision uncorrected for the D_1 group to be classified as a possible D_2 type.

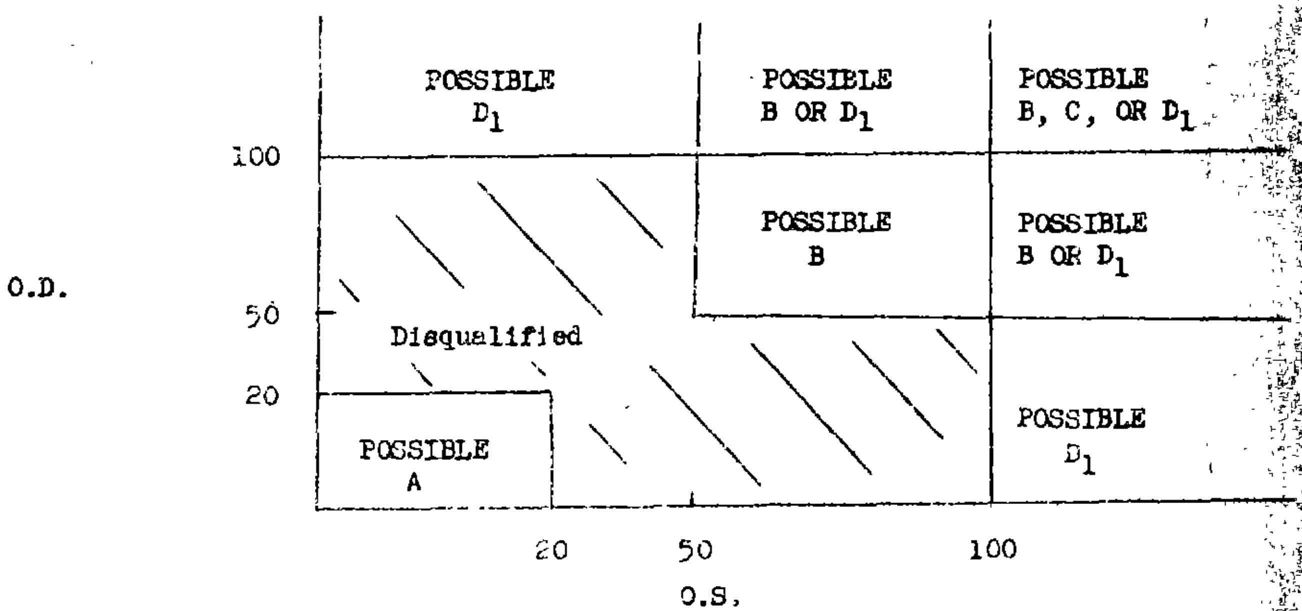


FIGURE 1

PRELIMINARY CLASSIFICATION OF NON-SQUINTERS BASED ON VISUAL ACUITY UNCORRECTED. THE NUMBERS REPRESENT THE DENOMINATORS OF THE SNELLEN FRACTION.

The Director dismisses the candidate if he is a non-squinter and is disqualified on the basis of unaided vision and indicates the dismissal and the reason for it on the bottom of Form I.

The Director also dismisses the candidate if he is a squinter of less than 10° in a vertical or a horizontal direction and if he fails to meet the unaided vision specifications for Group D_2.

If the candidate on the basis of the tests for squint and unaided vision can be classified as a usable type for the project, the Director refers him for the ophthalmological examination and records on Form I the date on which the referral is made. He also writes the preliminary classification in the box in the upper right hand corner of Form III and sends Form III to the ophthalmologist.

SECTION IV

OPHTHALMOLOGICAL EXAMINATION

This examination is to be conducted by an ophthalmologist for the purpose of:

1. Determining the unaided visual acuity of each eye of the applicant.

2. Measuring the refractive error in each eye under cycloplegia. The cycloplegia should be induced by at least two installations of 4 per cent homatropine hydrobromide, 10 minutes apart.

3. Determining, by cycloplegic and post-cycloplegic test, the correcting forward lenses for applicants whose unaided vision is less than 20/20 in one or each eye and who have worn correcting lenses for at least six months prior to application for flight training.

4. Approving, in the case of such applicants, the glasses worn by them or prescribing new ones, if a change seems indicated and the difference between the two Rx is not too great.

5. Determining, with a set-up to be decided by the Committee (see Attachment III), the visual acuity of each eye obtained through the the new and old corrections.

6. Determining the presence or absence of the following:

   a. Ocular disease, active or likely to be activated or to become progressive during the period of flight training.

   b. Paralytic motor disturbance.

Name ______________________

Date ______________________

Preliminary Classification
Director of Flight Training Project

		Refractive Error	Acuity	Degree
Cycloplegic Findings: (Skiascopic)	O. D.		20/	
	O. S.		20/	
Post Cycloplegic Findings:- (Subjective)	O. D.		20/	
	O. S.		20/	

Old Rx O. D. ____________

O. S. ____________

Period of use prior to test:

PRESCRIPTION:		Sphere	Cylinder	Axis
	O. D.			
	O. S.			

Visual Acuity with the Old Correction: O. D. __________ O. S. __________

Visual Acuity with the New Correction: O. D. __________ O. S. __________

Visual Acuity without Correction: O. D. __________ O. S. __________

Indications of ocular disease active or likely to become active during the period of flight training:

O. D.

O. S.

SUMMARY OF FINDINGS

	RIGHT EYE		LEFT EYE	
	Qual	Disqual.	Qual.	Disqual.
Ocular Pathology				
Paralytic Motor Disturbance				
Contraction of Visual Field				
Scotoma				

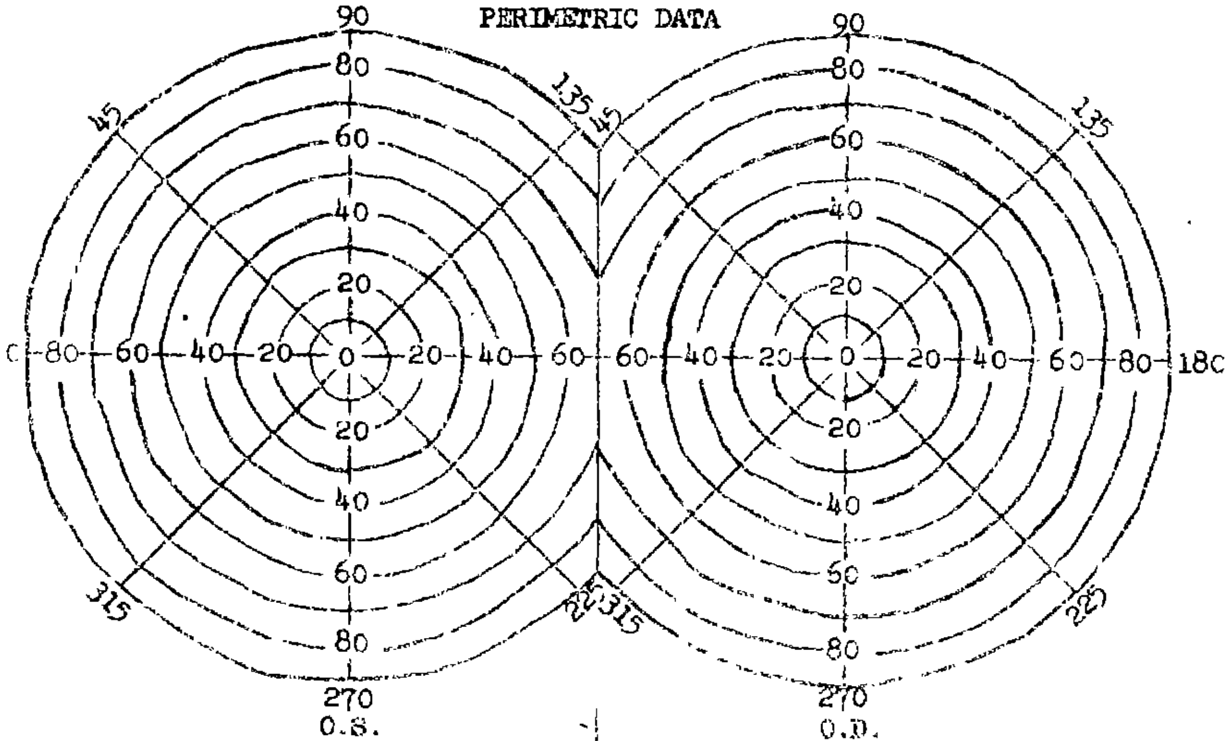
Length of time previous Rx worn nd similarity to new Rx. Satisfactory ☐ Unsatisfactory ☐

Signed: ____________________

FORM III (Continued)

Name: ____

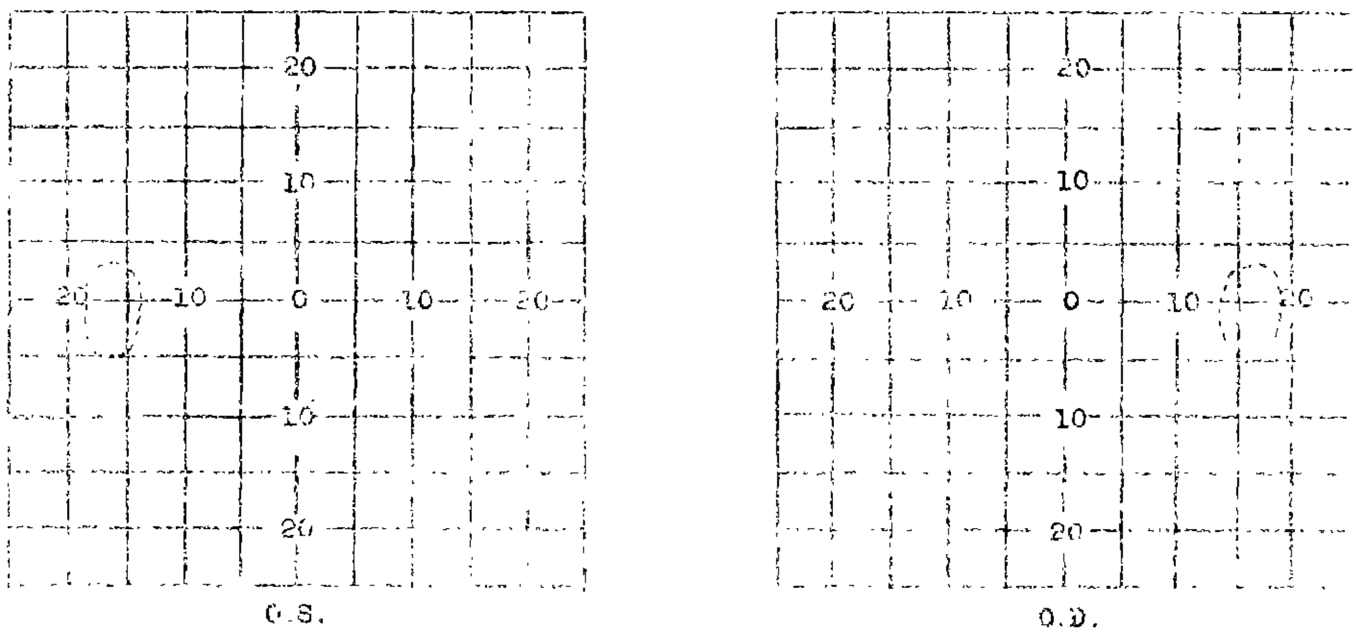
PERIMETRIC DATA



Remarks:

Remarks:

SCOTOMETRIC DATA



Remarks:

Remarks:

Date: ____________________

Examiner: ____________________

c. Contraction, greater than 15° of arc of the isopter, for a 3/330 white target.

d. A pathological scotoma within 25° of the point of fixation and any scotoma greater than 10° in any direction and absolute for a 3/330 white target situated outside the 25° (radius) circle.

It is proposed that an ophthalmologist do the testing at Mendenhall Laboratory. A booth will be assigned for this purpose. There will be available practically any type of skiascope, also practically any type of hand ophthalmoscope, a B & L Binocular ophthalmoscope, a hand slip lamp, a Ferree-Rand Perimeter, and a B & L tangent screen and a projector.

It is proposed that the ophthalmologist see each candidate twice. The skiascope test and examination of the fundus under cycloplegia are made on the first day. The cycloplegia should be induced by at least two installations of 4 per cent homatropine hydrobromide 10 minutes apart. A post cycloplegic examination can be made on the second day for errors of refraction and a final determination of the new correction, and measurements of the acuity for the separate eyes with no correction and with the new and old corrections. The remaining tests and observations may be made on either of the two days at the convenience and discretion of the ophthalmologist.

Candidates in Class A do not need to be submitted to the post cycloplegic examination, and one visit to the ophthalmologist should suffice.

The test for paralytic motor disturbance should be conducted in the following manner:

The examiner is seated one meter from a screen on which suitable fixation targets have been placed in the six cardinal positions of gaze, 50 centimeters eccentrically. By means of a chin-rest, the examinee's head is fixed in a straight position, opposite the center of the screen. While the examinee looks intently first at the center of the screen and then at the eccentric targets (one after the other) the examiner observes and neutralizes with a rotary prism the recovery movement which occurs upon removal of a suitable occluder held first over the right and then the left eye. Recovery movements exceeding significantly the phorias or their physiological variations within the field of fixation are to be considered as evidence of a paralytic motor disturbance.

The procedure for measuring visual acuity is described in Attachment I.

Form III (a supply of which may be kept on hand by the ophthalmologist) may be used for recording the ophthalmological findings. Perimetric and scotometric graphs are provided on the back side of this form for recording and analyzing the perimetric and scotometric data.

In recording the skiascope findings, the plus cylinder form of spherocylinder should be used to facilitate the subsequent analysis of the data.

If the old Rx is satisfactory, a statement to this effect may be written in the space provided for the new Rx.

If the old Rx was not worn for six months prior to the examination or if the change in the Rx required is large, the ophthalmologist may at his own discretion disqualify the candidate and indicate this fact in the appropriate square at the bottom of Form III. The reverse applies to A type applicants If such applicants have been wearing glasses during the six months period prior to the examination, the ophthalmologist may at his own discretion disqualify the candidate.

If and as soon as the ophthalmologist discovers ocular disease, active or likely to be activated or become progressive during the period of flight training, he certifies this fact by placing a check mark in the appropriate square or squares in the summary of findings at the bottom of page 1 of Form III and dispenses with the rest of the examination. Form III is signed and sent to the Director of Flight Training Project, and the candidate is referred back to the Director of the Flight Training Project for further instruction.

If the ophthalmologist discovers no evidence of pathology which is active or likely to be activated or become progressive during the period of flight training, he follows through with the complete examination and records the findings on Form III which he signs and submits to the Director of the Flight Training Project. He also refers the candidate back to the Director of the Flight Training Project for further instruction.

He also writes and signs the prescription on Form IV which he submits to the Director along with Form III. If the old glasses are satisfactory, he writes a statement to this effect in the space provided for the old Rx on Form IV. If the examinee shows 20/20 or better in each eye without glasses (A and some D_3 candidates), the ophthalmologist writes "Glasses not to be used" in the space provided for the Rx on Form IV. The same applies to D_1 and D_2 candidates if vision cannot be improved in the poor eye with glasses, or if the one eye is blind or removed.

SECTION V

EVALUATION OF THE OPHTHALMOLOGICAL DATA

Form I is used by the Director of the Flight Training Program in evaluating the ophthalmological data.

Figure 2 may be used in analyzing the skiascopic findings for the right and left eyes. The finding for each eye will be recorded as a combination of a plus or a minus sphere and a plus cylinder. Hence, the findings for each eye can be plotted on the graph. The graph may be used, therefore, to determine the degree (I, II, III, or IV) of refractive error in each eye.

FORM IV

THE OHIO STATE UNIVERSITY

VISUAL TESTING CENTER FOR FLIGHT TRAINING

Name ______________________________

Date: ______________

	Sphere	Cylinder	Axis
O. D.			
O. S.			

FOR DISTANCE VISION ONLY

Date: ______________ ______________________
Ophthalmologist

- -

This Rx is not to be filled until the candidate is certified below as approved for flight training.

This Rx may be filled in any suitable frame or mounting at the OSU Optical Dispensary or by any dispensing optician but must be checked and approved by the OSU Optical Dispensary. If the old Rx is pronounced satisfactory by the ophthalmologist, the glasses do not have to be checked and approved by the OSU Optical Dispensary.

APPROVAL OF CANDIDATE:

The above named candidate has been approved for flight training.

____
Director of Flight Training

Date: ______________

APPROVAL OF GLASSES:

The glasses submitted by the above named candidate conform to the above Rx and are properly designed, constructed and adjusted.

____
OSU Optical Dispensary

Date: ______________

This form is to be kept by the candidate and shown on demand as evidence that he is fulfilling the requirements relative to the wearing of glasses.

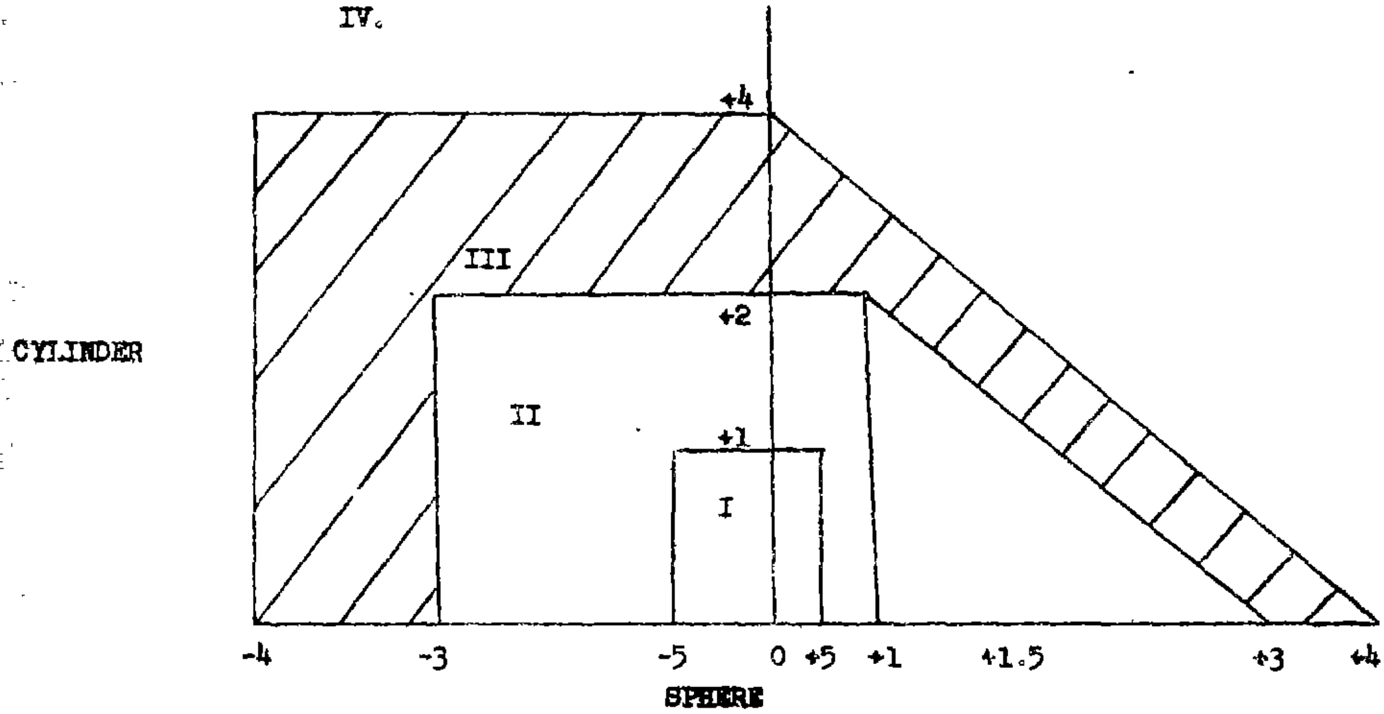


FIGURE 2

THE FOUR DEGREES OF REFRACTIVE ERROR

The degree of refractive error under cycloplegia is recorded in the space provided on Form III.

One can then determine the possible classifications for each candidate from the graph in Figure 3 or the one in Figure 4.

The possibility of a B classification is eliminated if there is a greater than 2.00 D. difference between the refractive errors in any parallel pair of meridians in the two eyes.

The possible classifications arrived at on the basis of the cycloplegic findings are indicated on Form I in the column marked "Skiascope."

The candidate may be disqualified not only on the basis of the retinoscopic findings, but also if he fails to qualify consistently as a given type on the basis of both the skiascope findings and the unaided vision.

On the basis of the other ophthalmological data, the candidate may be disqualified for any of the following reasons:

1. Presence of disease in either eye.

2. Contraction of field or scotoma in either eye if A, B, C, or D_3 type; or in better eye, if in Class D_1 or Class D_2.

3. Glasses worn during the period prior to tests do not conform to requirements.

4. Paralytic motor disturbance.

If the candidate has to be disqualified on the basis of the ophthalmological data, the candidate is notified to this effect. The word "Disqualified" is marked in the appropriate space on Form I and the reason for the disqualification is indicated at the bottom of Form I.

If the candidate remains qualified for one of the usable groups, and if the ophthalmologist has prescribed that glasses must be worn for the flight training, he is referred for the Double Broken Ring Visual Acuity Test which is to be taken with the prescribed lenses. The date of referral is recorded in Form I.

In the meantime, Form IV is sent to the person in charge of the acuity test. Form V is also sent along, and the preliminary classification is noted in the space provided at the upper right hand corner.

If the ophthalmologist has prescribed that glasses are not to be worn during the flight training, it is not necessary for the visual acuity to be retested and the data obtained without a Rx are used as a substitute for acuity data with Rx.

DEGREE OF REFRACTIVE ERROR IN RIGHT EYE				
IV	POSSIBLE D_1	POSSIBLE D_1	DISQUALIFIED	POSSIBLE C
III	POSSIBLE D_1	POSSIBLE D_1	DISQUALIFIED	DISQUALIFIED
II	POSSIBLE D_1	POSSIBLE B OR D_1	POSSIBLE D_1	POSSIBLE D_1
I	A OR D_1	POSSIBLE D_1	POSSIBLE D_1	POSSIBLE D_1
	I	II	III	IV

DEGREE OF REFRACTIVE ERROR IN LEFT EYE

FIGURE 3

CLASSIFICATION OF NON-SQUINTERS ON THE BASIS OF THE CYCLOPLEGIC FINDINGS

DEGREE OF REFRACTIVE ERROR IN RIGHT EYE	I	II	III	IV
IV	POSSIBLE D_2	POSSIBLE D_2	DISQUALIFIED	DISQUALIFIED
III	POSSIBLE D_2	POSSIBLE D_2	DISQUALIFIED	DISQUALIFIED
[illegible]	POSSIBLE D_2 OR D_3	POSSIBLE D_2 OR D_3	POSSIBLE D_2	POSSIBLE D_2
II	POSSIBLE D_2 OR D_3	POSSIBLE D_2 OR D_3	POSSIBLE D_2	POSSIBLE D_2

DEGREE OF REFRACTIVE ERROR IN LEFT EYE

FIGURE 4

CLASSIFICATION OF SQUINTERS ON THE BASIS OF THE CYCLOPLEGIC FINDINGS

SECTION VI

DOUBLE BROKEN RING TEST FOR VISUAL ACUITY WITH Rx

The Rx is copied from Form IV to Form V. Form IV will have been sent to the examiner by the Director of the Flight Training Project. The test is carried out in a dark room with the apparatus described in Attachment I.

The old habitually used glasses are worn if these are approved by the ophthalmologist for B, C, D_1, D_2, D_3 types. When a new Rx has been prescribed, trial lenses are used.

The results are recorded on Form V which, when completed, is signed and sent to the Director of the Flight Training Project. The candidate is also sent to the Director for further instructions. Form IV is also returned to the Director of the Flight Training Project.

SECTION VII

EVALUATION OF DATA OBTAINED IN THE DOUBLE BROKEN RING TEST FOR VISUAL ACUITY WITH Rx[41]

Figure 5 shows the basis for classification in the case of non-squinters.

1. The candidate is disqualified if his acuity with the Rx is worse than 20/50 in either eye or has had either eye removed, and if the acuity with the Rx in the other is worse than 20/20.

2. He is a possible D_1 type if his acuity corrected is worse than 20/50 in either eye (or is blind in one eye or has either eye removed) and if the acuity is 20/20 or better in the other.

3. He is a possible C type if his acuity corrected is 20/50 or better in each eye.

4. He is a possible A, B, or C type if his acuity is 20/20 or better in each eye.

Figure 6 shows the basis for classification of squinter.

1. The candidate is a possible D_3 type if he obtains 20/20 with Rx in each eye.

---

[41] "Visual acuity corrected" represents the acuity obtained with the glasses which are to be worn during flight training or the equivalent in the form of trial lenses. In the case of A, D_1, D_2, and D_3 type candidates who are not required to wear glasses, "visual acuity corrected" literally means visual acuity without glasses.

FORM V

[illegible] BROKEN RING TEST FOR VISUAL ACUITY

Name ______________________________ Date ______________________

Rx.
O D ______________________________ P.D ______________________

O. S. ______________________________ Candidate For ____________ type

O. D.					
	Size of Optotype				
	10 Trials				
Final Score					
	No. Correct				

O. S.					
	Size of Optotype				
	10 Trials				
Final Score					
	No. Correct				

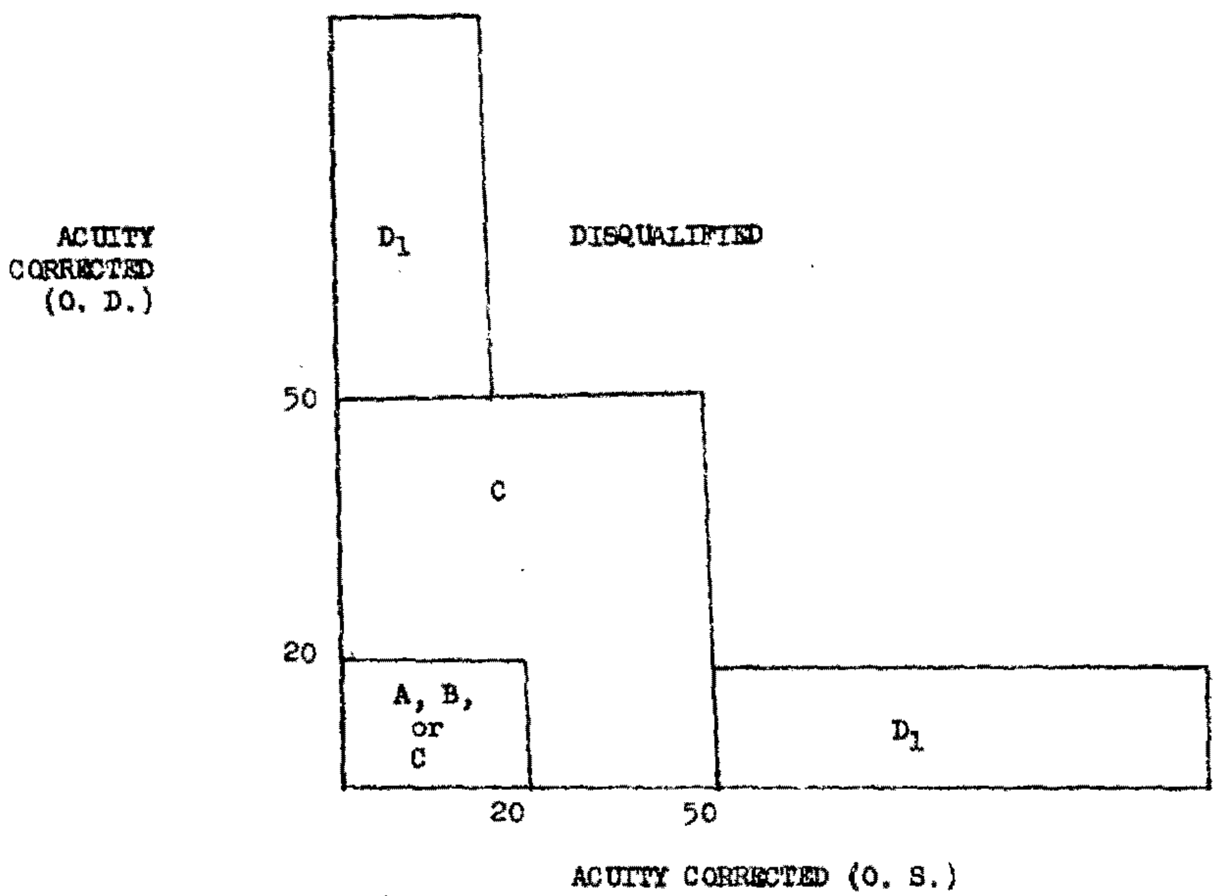


FIGURE 5

CLASSIFICATION OF NON-SQUINTERS. THE NUMBERS REPRESENT DENOMINATORS OF THE SNELLEN FRACTION.

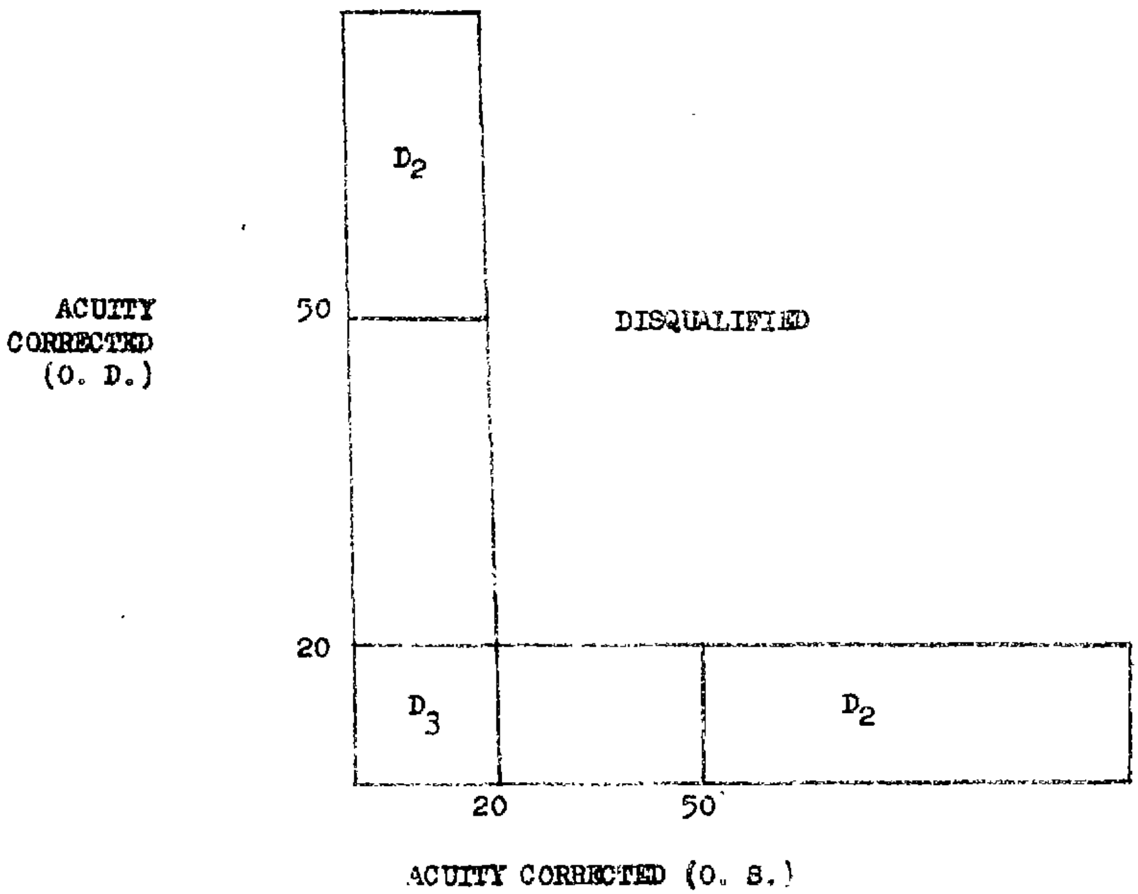


FIGURE 6

CLASSIFICATION OF SQUINTERS. THE NUMBERS REPRESENT DENOMINATORS OF THE SNELLEN FRACTION.

2. The candidate is a possible D_2 type if his acuity corrected is worse than 20/50 in either eye, and if the acuity corrected is 20/20 or better in the other eye.

3. Otherwise, he is disqualified.

The Director of the Flight Training Project refers to Form I and records the classification in the column marked "Acuity with Rx."

He may be disqualified on the basis of the "Acuity with Rx" score alone or if he fails to classify consistently as a given type on the basis of acuity corrected, acuity uncorrected, and the skiascope findings.

He may classify as a D_1 type, but still may be disqualified if he does not have the following combinations of characteristics for the good and the poor eye. The good eye which is correctible to 20/20, must have a refractive error less than 3.00 in any meridian, and less than 2.00 of astigmatism. The other eye must be removed or show 20/100 or worse uncorrected and must not be correctible to 20/50.

If the Director has to disqualify the candidate, he marked the word "Disqualified" in the space provided on Form I and, also, he checks the reason for the disqualification at the bottom of Form I.

If the candidate remains qualified for one of the usable groups, he is referred for the special qualifying tests. The date of referral is recorded on Form I. In the meantime, Form IV is sent to the person in charge and Form VI is also sent along with the final classification noted in the space provided at the upper right hand corner.

SECTION VIII

BATTERY OF SPECIAL QUALIFICATION TESTS

This battery includes a number of special "pass or fail" qualifying tests which apply alike to all groups, and a test for stereopsis in which the standards differ for the different groups. These tests include the following:

1. Night vision

2. Lateral Phoria at Distance

3. Vertical Phoria at Distance

4. Prism Divergence at Distance

5. Lateral Phoria at Near

FORM VI

BATTERY OF SPECIAL VISUAL QUALIFYING TESTS

Name ______________________________ Date ______________

Rx: O. D. ______________

O. S. ______________

P. D. ______________ Candidate for __________ type

		Score	Evaluation Pass - V Fail - X
1. Night vision			
2. Lateral Phoria at 6 Meters			
3. Vertical Phoria at 6 Meters			
4. Prism Divergence at 6 Meters			
5. Lateral Phoria at 33 Cm.			
6. Vertical Phoria at 33 Cm.			
7. Prism Convergence at 33 Cm.			
8. Prism Divergence at 33 Cm.			
9. Near Point Acuity			
10. Central Color Vision	A. O. Co. Plates		
	SAM Color Threshold Tests		
11. Stereopsis			

6. Vertical Phoria at Near

7. Prism Convergence at Near

8. Prism Divergence at Near

9. Near Point Acuity

10. Color Blindness

11. Stereopsis

The Rx is copied from Form IV to Form VI. Form IV will have been sent to the examiner by the Director of the Flight Training Project.

The tests are carried out as described below by an assistant under Dr. Fry's direction. The results are recorded on Form VI, which when completed is signed and sent along with Form IV to the Director of the Flight Training Project. The candidate is also sent to the Director for further instructions.

In each test the old habitually used glasses are to be worn if they have been approved as satisfactory by the ophthalmologist for B, C, D_1, D_2, and D_3 types.

When a new Rx has been prescribed, trial lenses are used.

No glasses at all are worn if the candidate is in the A classification and may not be necessary in the D_1, D_2, and D_3 classifications if this is judged to be the case by the ophthalmologist.

D_1, D_2, and D_3 type candidates are not required to take the special tests from 2 through 8, and are not required to take the stereo test.

(1) Night Vision

The test is made with the Radium Plaque Night Vision Tester in a totally dark room.

The examinee must be dark adapted before taking the test. This may be accomplished either by having him sit in complete darkness or wear red goggles for thirty minutes. A short discussion of the nature of night vision and an explanation of scanning and other techniques of seeing at night should be given before the test. The necessity of looking "off center," i.e., either above, below or to the sides in order to see at night must be emphasized over and over. Allow some practice in these methods before the actual test begins.

The test is given at five, seven, nine, and eleven feet, respectively. These distances are conveniently measured by a cord looped at one end to go around the examinee's neck and knotted at appropriate distances.

A presentation consists of exposing the plaque to the subject with the break in the circle in one of four positions (left, right, up or down) for no longer than ten seconds. If the position of the break is not called by the subject in this time, the trial is counted as an error. A random order of orientations should be used. A subject must name four out of the first four positions correctly to be considered as seeing the plaque at any given distance. If one or more of the first four presentations is missed, it is necessary to give ten presentations at that distance. The examinee then passes only if he can see eight out of ten.

The greatest distance at which the character is correctly judged four out of four or eight out of ten is recorded as the score.

(2 and 3) <u>The Maddox Rod Screen Test at 6 Meters for Lateral and Vertical Phoria</u>

a. Apparatus - A phorometer trial frame equipped with a pair of multiple white Maddox rods and a pair of Risley Rotary prisms, a blank card about 6 x 9 cm., which serves as a screen, and a blank card about 13 x 20 cm., with a 3 cm. hole in its center, and a spotlight 1 cm. in diameter, 6 m. from the spectacle plane.

b. Procedure - Before beginning the test, the examinee's fixing eye is determined. For this purpose, the 13 x 20 cm. card is employed. The examinee seated, facing the spotlight 6 meters away, grasps the card by the long sides with both hands. While looking intently at the light, he slowly raises the card at arm's length and locates the light through the hole without closing either eye. Only one eye can see the light through the hole, and the eye selected for this purpose is the one used habitually for sighting or fixing.

The phorometer trial frame is now properly leveled and adjusted closely in front of the examinee's eyes. One of the multiple Maddox rods is swung into position before the non-fixing eye. A rotary prism is placed before the same eye. The sighting or fixing eye must have an unobstructed view of the spotlight. For the measurement of esophoria or exophoria, the Maddox rod is adjusted before the non-sighting eye to give a vertical line of light. The rotary prism is adjusted also before the non-sighting eye for the measurement of lateral deviation and set 4 or 5 prism diopters off the zero mark. This gives enough deflection at the reading to detect an examinee who has been coached to say the line passes through the light.

The 6 x 9 cm. card is moved from one eye to the other a few times to ascertain if the examinee sees both the line and the light. If the line is not seen readily, the Maddox rod is readjusted by centering it carefully in front of the pupil.

When the examinee sees the line with one eye and the light with the other, the examiner holds the card or screen in front of the non-fixing eye to shut out the image of the line. The examinee now sees only the light. After he has fixed it for several seconds, the screen is removed for an instant and quickly replaced. In that brief interval, the examinee will be able to see the line and locate it in reference to the light. After one or two such exposures, he will say that the line is to the right or left of the light or possibly through it. He is instructed to grasp the milled head that rotates the prism and turn it to bring the line directly into the light. To enable him to do this, the screen is removed from the eye at intervals and quickly replaced. Finally the examinee will have rotated the prism enough to cause the line to pass through the light every time the screen is removed. The number of prism diopters necessary to do this is read from the scale of the rotary prism. This is entered on the record as esophoria if the prism is base out, and exophoria if the prism is base in. For the measurement of hyperphoria, the Maddox rod before the non-fixing eye is readjusted to give a horizontal line of light. The rotary prism is also readjusted before the same eye to measure vertical deviation. The screen is used exactly as before to give an occasional glimpse of the line. The number of prism diopters read from the scale is recorded as right hyperphoria if the prism is base down before the right eye, or base up before the left. It is recorded as left hyperphoria if the prism is base up before the right eye or base down before the left. In testing for hyperphoria, the Stevens' frame, which is normally a part of the phorometer mechanism, should be used instead of the large prisms. The Stevens' frame attachment is composed of weaker prisms which are calibrated in tenths of a diopter and, therefore, permit more accurate readings for hyperphoria.

c. Precautions - Maddox rod and the measuring prism are used always together before the non-fixing eye and never before the fixing eye. The test gives an inaccurate result if the examinee is permitted to see the line for a longer time than is allowed by the momentary flash exposures described above.

(4) Prism Divergence at 6 Meters

Prism divergence is to be measured under the same conditions as the central acuity. For the prism divergence at 6 meters, an optotype slightly larger than the smallest recognized by the examinee, is projected onto the screen. The phenomenon of diplopia is demonstrated to the examinee by putting 25 prism diopters base in over one of his eyes. The latter prism is then replaced by a rotary prism in horizontal position and the amount of prism base in is increased at a rate of 2 prism diopters per second until diplopia occurs. This break point is considered as a measure of prism divergence.

(5 and 6) Phorias at 33 cm.

The phoria target consists of a black card 12 x 12 inches with a pin-point opening at the center which has a bright light behind it.

The inter-ocular adjustment of the phorometer trial frame is adjusted for convergence at 33 cm. from the spectacle plane.

The same procedure is followed as in the case of the distance phoria test for measuring the lateral and vertical phorias.

(7 and 8) Prism Convergence and Divergence at 33 cm.

The same apparatus is used for these tests as for the phoria at 33 cm. except that a target with a Snellen E at the center subtending a visual arc of 10 minutes at the center of the entrance pupil is substituted for the phoria target. The two rotary prisms are adjusted into position with the base apex lines horizontal and starting from the zero setting of each prism, base out power is increased simultaneously in each of the two prisms at a rate of one prism diopter per second till diplopia occurs, and the combined powers of the two rotary prisms represent the prism convergence.

The same procedure is followed with prism base in to measure prism divergence.

(9) Acuity at 50 cm.

A target is mounted at 50 cm. with a row of optotype (Snellen letters) subtending an angle of 10 minutes at the entrance pupils (Magnification of correcting lenses ignored).

If the subject reads all letters, he passes; otherwise, he fails.

(10) Color Vision

The American Optical Company's Pseudo-isochromatic Plates (abridged Edition - 19 plates) are mounted 50 cm. from the eyes, perpendicular to the median line, under illumination provided by a 60 watt daylight lamp 100 cm. away and above with the light incident at an angle of approximately 45° at the center of the plates.

The plates are exposed two at a time in order.

The same arrangement is used as for testing acuity at near.

The number of misses is recorded and if more than three, the subject must be examined through the use of the AAF School of Aviation Medicine Color Threshold Lantern. A score of less than 35 on this test is regarded as a failure.

(11) O.S.U. Three-Bar Stereo Test

The target consists of a pair of ½" vertical bars, 2½" high and separated by a distance of 2½" (from center to center), mounted at the center of a white screen 22" in diameter, which is located at a distance of 5 meters.

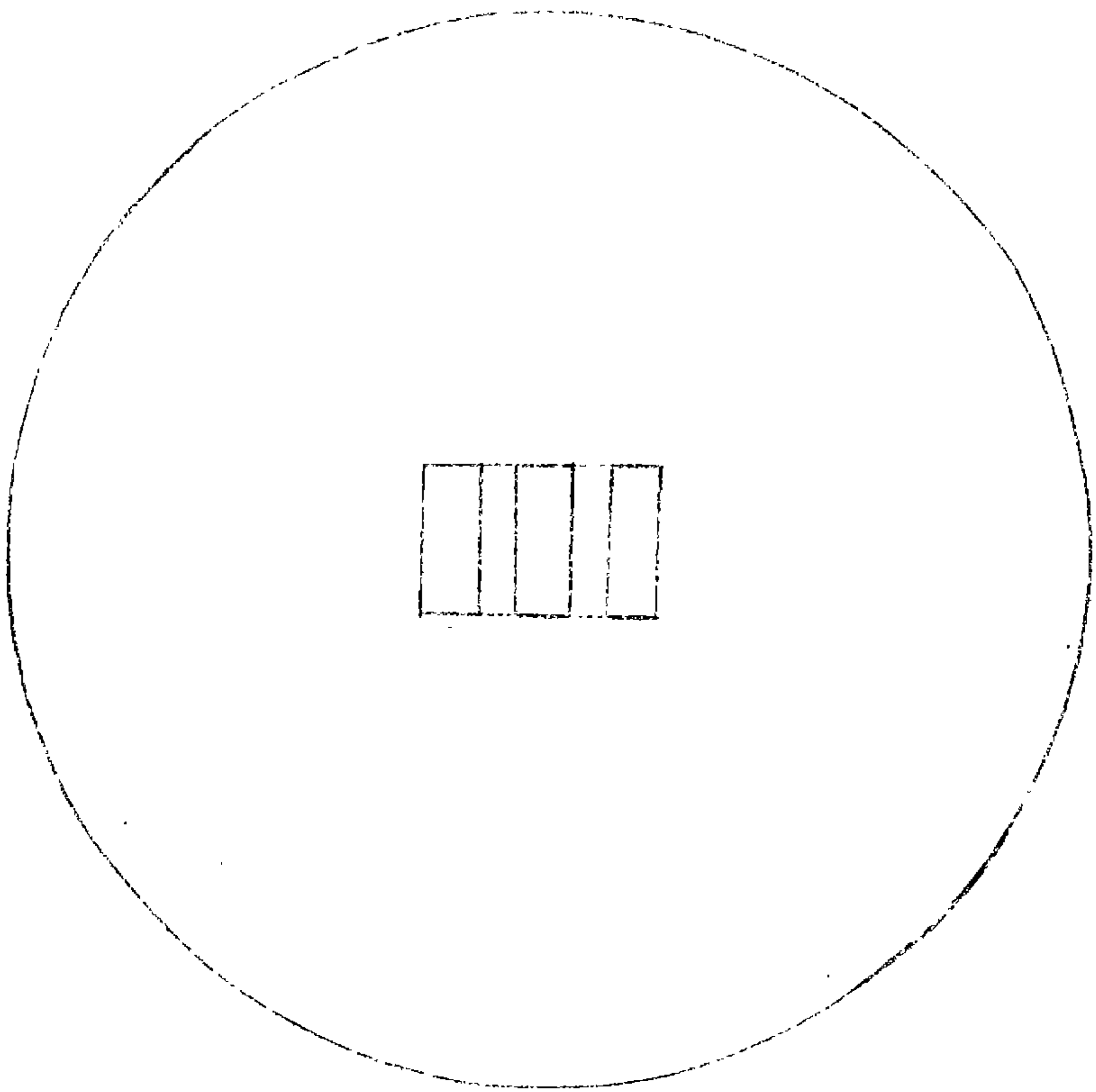


FIGURE 7

STIMULUS PATTERN FOR STEREO TEST

The space between the bars is cut out as shown by the dotted lines in Figure 7. The opening is illuminated with white light the same brightness as the screen and appears continuous with it above and below, the border being invisible or at most, barely visible.

A third bar of the same size which is an aerial optical image is seen between the two bars on the screen and is capable of being moved in a fore and aft direction along the median line, without suffering a change in angular size at the entrance pupils. This fore and aft movement is produced by the subject who turns a knob which gives no clue as to the actual position of the image.

In making a setting the middle bar is set at a considerable distance behind the screen, 20 to 50 cm., and the subject takes hold of the knob and turns it till the three bars appear in the same plane. He is instructed to "bracket" the middle bar back and forth and then make a final setting with the final movement forward. He then takes his hand off the knob and the operator sets the middle bar 20 to 50 cm. in front of the screen and the subject uses a similar procedure to make the bars appear aligned except that the final movement is backward. Five such pairs of readings are made and the ten errors are averaged. An average error greater than 30 mm. disqualifies an A or B candidate and an average error greater than 100 mm. disqualifies a C type candidate.

SECTION VIII

EVALUATION OF DATA FROM THE SPECIAL QUALIFYING TESTS

1.	Night Vision:	If the target is "not visible at 5 ft." the subject fails; if the task can be performed at 5 ft. or at a greater distance, the subject passes.
2 and 3.	Phoria at Distance:	An eso or exo greater than 7 or a hyperphoria greater than 1.5 prism diopters disqualifies.
4.	Prism Divergence at 6M.:	If esophoria is present, the prism divergence must equal or exceed it for the subject to pass.
5 and 6.	Phoria at 33 cm.:	An eso greater than 7 or an exo greater than 14 or hyperphoria greater than 1.5 disqualifies the subject.
7.	Prism convergence at 33 cm.:	Less than existing exophoria disqualifies.
8.	Prism Divergence at 33 cm.:	Less than 14 disqualifies.
9.	Visual Acuity at Near:	Failure to read 10 minute letters at 50 cm. disqualifies.

10. <u>Central Color Vision:</u> A score less than 35 on the SAM Color Threshold Lantern Test disqualifies. If the subject misses fewer than three of the American Optical Company plates, he qualifies and does not have to take the SAM Test.

11. <u>Stereopsis:</u> If the subject is an A or B type, he must make an average error smaller than 30 mm. to pass. If the subject is a C type candidate, he must have an average error smaller than 100 mm. to pass.

If the candidate fails any of the special qualifying tests which he is required to take, he is disqualified and the Director notifies the candidate to this effect. He also marks the word "disqualified" in the space provided on Form I and indicates the reason for the disqualification at the bottom of Form I

If the candidate falls into a given usable classification on the basis of visual acuity corrected as well as on the basis of unaided vision and cycloplegic findings, and passes all of the special qualifying tests that he is required to take, the Director notifies the candidate to this effect and certifies qualification and classification in the appropriate space on Form 1

When the candidate has been approved for flight training, the Director has to certify the classification on Form IV.

If he is in Class A, the Director signs the certification of classification on Form IV and gives Form IV to the candidate. If he is in Class B, C, or D_1, the Director certifies the classification on Form IV and gives this form to the candidate and instructs him on how to get the Rx filled.

Form IV is to be kept by the candidate to be shown on demand as evidence that he is fulfilling the requirements relative to the wearing of glasses.

ATTACHMENT I

APPARATUS FOR TESTING VISUAL ACUITY

The test is carried out in a dark room with the target consisting of a double broken ring at the center of a white field 5° in diameter surrounded by a dark field.

The candidate is seated with his head held steadily by means of a chin and forehead rest. Lens holders are provided for mounting and centering the correcting lenses before his eyes (when lenses are necessary).

The shutter device for exposing the target is such that the central 1° portion of the field may be presented as a uniform white field continuous with the peripheral portion, or as a white field also continuous with the periphery but containing at its center the double broken ring target with the breaks arranged up and right, or right and down, or down and left, or left and up as set by the operator prior to the exposure, and also with the size of the broken ring set for any of several sizes by the operator prior to the exposure.

The scale used in setting the size of the target is calibrated in terms of the distance at which the outside diameter of the ring would subtend five minutes of arc. The width of the ring and the size of the gaps is 1/5 of the outside diameter of the ring.

The subject is given a preliminary view of a diagram of the optotype which is large enough for any but a blind eye to see and the four orientations of the target are explained.

He is then placed in position for observation and the operator starts off with continuous exposure and with the optotype set for minimum size. The size is increased until the subject (who has been so instructed) reports that he can see the breaks.

The operator terminates the exposure, sets the optotype at the nearest even 5 on the size scale, explains the next procedure to the subject, and starts a series of 10 exposures of 5 seconds each with intervals between exposures long enough to check the answer and reset the optotype at random to another orientation. The exposures are made by hand and are timed by counting slowly 1001, 1002, 1003, 1004, 1005. At the end of 10 exposures, the number of correct answers is counted and recorded on Form V. If the number of correct answers was less than 6 out of 10, the size of the target is increased 5 ft. and the procedure repeated; if more than 6 out of 10, the size of the target is decreased 5 ft. This procedure is continued until two points are found on the scale 5 ft. apart which will yield the one more than 6 and the other less than 6, or the one exactly 6 and the other more or less than 6. The final acuity rating is arrived at by interpolation, to determine the approximate point at which six answers out of 10 would be correct.