SIMULATED NIGHT AND DAY DRIVING VISUAL ACUITY AS MEASURED BY THE TITMUS VISION TESTER AND THE SNELLEN ACUITY CHART

Thesis for the Degree of M. A.

MICHIGAN STATE UNIVERSITY

JACK VINCENT FERRARA

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By

Jack Vincent Ferrara

AN ABSTRACT OF A THESIS

Submitted to

Michigan State University

in partial fulfillment of the requirements

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MASTER OF ARTS

Department of Psychology

1970

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ABSTRACT

SIMULATED NIGHT AND DAY DRIVING VISUAL ACUITY AS MEASURED BY THE TITMUS VISION TESTER AND THE SNELLEN ACUITY CHART

By

Jack Vincent Ferrara

Night visual acuity represents a special problem to the automobile driver. Not only do lower lighting levels cut down on viewing distances, but lowered contrast makes detail detection all the more difficult. In addition, research in the area has suggested that specific eye disorders of the individual driver may produce even greater reduced acuity. Disorders such as night myopia and night hyperopia get progressively worse as lighting levels lower. A night myopic individual will get more and more nearsighted as lighting levels lower. A night hyperopic individual is analogous with respect to farsightedness. Detection of such individuals would be of value since many of these individuals' abnormal night acuity losses can be rectified with a lens correction specifically for night driving.

Through the use of the Titmus Vision Tester near and far acuity tests at mesopic and photopic illumination, detection of unusual cases of mesopic acuity loss (at simulated night driving illumination levels) was attempted. Scores on the Titmus far acuity test, which simulated a 20 foot testing distance, were compared with scores of the Snellen eye chart at an actual 20 foot distance. Performance on a variable low contrast test as opposed to the higher contrast acuity tests was also undertaken to look for possible relationship to night myopia.

The experimental group was given the Titmus near acuity test, the Titmus far acuity test, the Snellen far acuity test, and the Titmus low contrast test, in mesopic, and then again in photopic, lighting. Thus each subject set his own norms in the photopic condition. A control group was given the same tests in mesopic light both times. The purpose of the control group was to detect improvements in performance due to either improved dark adaptation or increasing familiarization with the tests. Subjects were drawn from the Michigan State University (MSU) student population and ranged in age from 18 to 25.

The results showed the Titmus near and far acuity tests were useful for detecting unusual cases of mesopic acuity loss when poor performance on one test was considered in relation to the subjects' performance on the others. Three cases of mesopic acuity loss great enough to cause potential concern for night driving were discovered, but further testing on more sophisticated apparatus is needed to classify the loss as night myopia, hyperopia, etc. The fact that the Titmus did detect such losses indicated its usefulness towards this aim.

The Titmus far acuity scores correlated well (.70) with the Snellen scores, but there were significant differences between the means. It was concluded that inaccurate Titmus simulation of visual conditions for 20 feet and differences in test targets accounted for the difference.

The experimental sample performed well on the low contrast test in both mesopic and photopic conditions with no potential problems for the night driving situation occurring.

The control group showed relatively high reliability (.55-.86) between mesopic treatments of the same tests indicating no significant learning or increase of adaptation. Only the Snellen test showed a small, but significant difference between the means in this group.

Approved: T. W. Forbes, Chairman

John H. Wakeley

S. Howard Bartley

Dated: October 21, 1970

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DEDICATION AND ACKNOWLEDGEMENTS

During the 26 months necessary to develop this thesis from a germ of an idea to a completed volume, nine individuals especially aided in its production in their own way. This thesis is respectfully dedicated to them:

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INTRODUCTION AND LITERATURE REVIEW

Good visual acuity is obviously an essential component of safe driving. This thesis seeks to investigate acuity with special emphasis on the night driving situation, through the use of standard visual tests (Titmus and Snellen acuity tests). Near acuity, far acuity, and low contrast vision will be measured among the population sampled. By comparing acuity in daytime luminance against that in the nighttime condition, one can gauge the loss of acuity, both near and far, which the night driver faces. It is hoped that this investigation will help lead to an increased understanding of the visual handicaps the night driver encounters, and ultimately to the removal of these handicaps.

The concept of acuity is central to the subject of this paper, and there are several definitions of it. Lorrin Riggs defines visual acuity as the capacity to discriminate fine details of an object in the field of view (Graham, 1965). Fine, in the previous definition, is a relative adjective, but detail can be defined more concretely. Riggs specifies detail in three ways:

1. width of an object
2. angle subtended by the object at the eye
3. computed width of the retinal image (Graham, 1965, 321).

Angle subtended is the convention of most vision researchers, and it is expressed in units of minutes and seconds of arc.

Riggs additionally outlines four basic types of tasks to demonstrate acuity:

1. detection
2. recognition

3. resolution

4. localization (Graham, 1965, 322-326).

Detection simply involves a response from the subject as to whether or not the test object is present. In the recognition task the subject must name a critical aspect of the stimulus (e.g., the direction an arrow in pointing). In a resolution task the subject must respond to elements in a pattern. Localization involves displacements with respect to two test objects (Graham, 1965, 323-326).

Acuity must always be considered at a given level of illumination, since a person's acuity will change as illumination levels rise or fall. Basically there are three levels of illumination: scotopic, mesopic, and photopic. Scotopic occurs at just near the threshold illumination, and at this level only the rods are functioning -- thus, no color perception is possible. The photopic level is representative of daytime illumination, and at this level the cones are fully functioning so that color vision is possible. Intermediate to these two levels is the nighttime level, or mesopic condition. At this level the eye is dark adapting, but the cones are also functioning to some extent. The basic relationship between acuity and illumination is as illustrated in Figure 1. Acuity increases markedly as a function of illumination. Low values of acuity under dim illumination are due to the fact that only rods function at this level. As light levels increase and more cones come into play acuity increases.

Uniformity of illumination is also important to acuity. During a 1937 experiment, S. Hecht discovered that unless the background of his testing device was of uniform brightness, acuity scores would be significantly lowered (Hecht, 1937, 593).

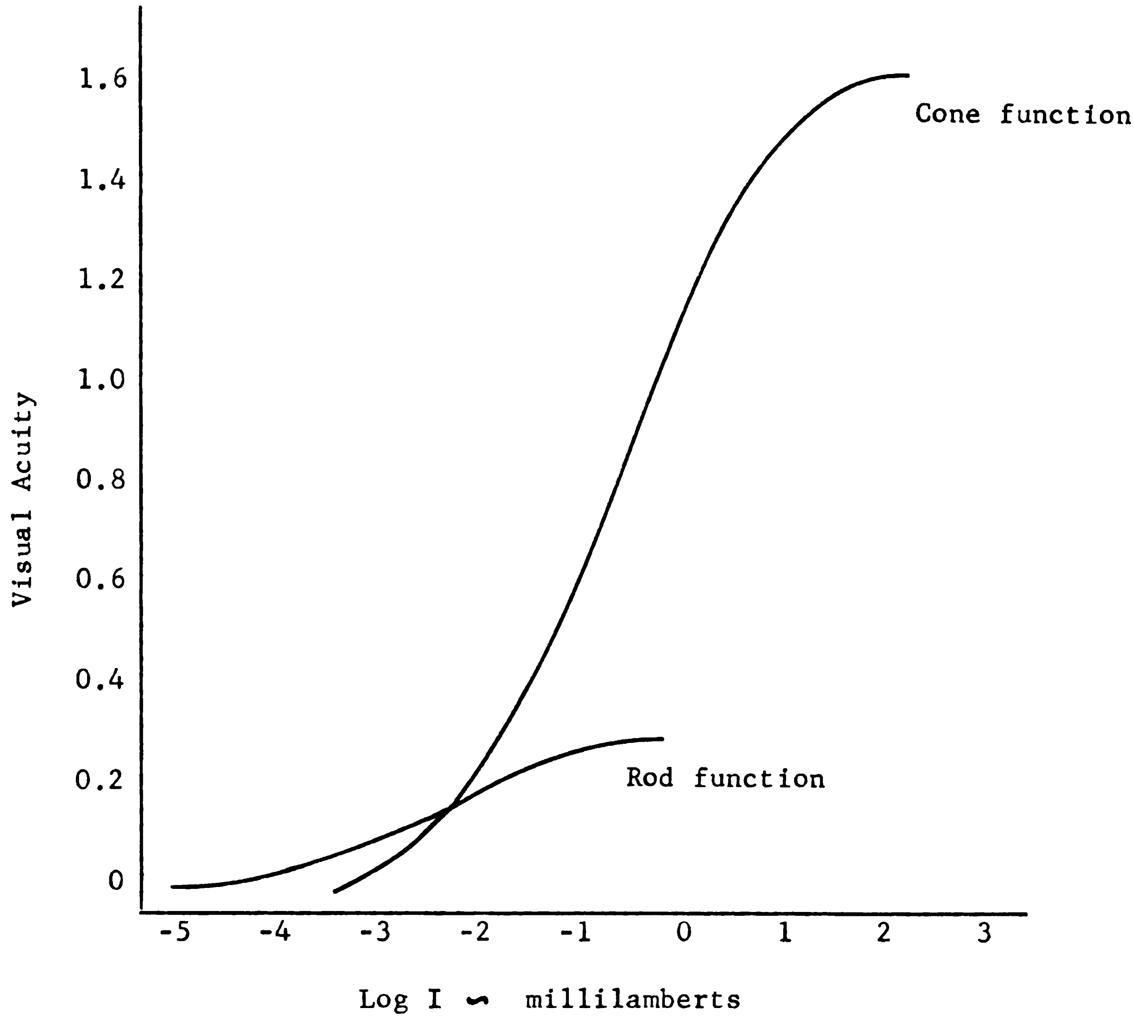


Figure 1. The Relation Between Visual Acuity and Illumination

Hecht replotted original data from Konig in millilamberts. (The two curves represent probability ogives fitted to rod and cone portions of the data.) (Woodworth, 1965, 385)

Luminance is generally described in footlamberts (ftl.). One footlambert is equal to 1.076 millilamberts, also a widely used standard. "A perfectly reflecting, perfectly diffusing surface, illuminated with a luminance of one footcandle has a luminance of one footlambert, regardless of the direction of view" (Judd, in Stevens, 1951, 957). A footcandle is the "illumination produced by a uniform point source of one candle on a surface every point of which is one foot away from the source" (Judd, op. cit.).

In addition to the illumination of the viewed object, the illumination level the S had adapted to immediately prior to his viewing the object is important. It generally takes 20 minutes for relatively complete dark adaptation to take place, although the majority of the adaptation will take place in approximately five minutes (about 90 percent). Adaptation is much quicker from mesopic to photopic than vice versa, being virtually complete in little more than a minute. Changes in the eye during this period include chemical changes in the retina as well as a change in pupil diameter. Generally as one ages, the speed and extent of these changes diminish.

Angle subtended (or the size of the "fine" detail) and illumination level (both of the viewed object and adaptation level) have been presented as important factors determining visual acuity. Contrast is another important factor in the determination of acuity, and is subsequently discussed in relation to night driving.

A study by Forbes, Vanosdall, Pain, and Bloomquist investigated the question of whether high contrast vision and low contrast vision (at simulated night driving levels) were part of the same function, or whether separate skills were involved in two types of vision. They tested 396 drivers on the Night Vision Performance Test (designed by Dr. Merrill Allen). This device consists of a low contrast target in a dark housing. The test was given in mesopic (.2 ftl.) and photopic (10 ftl.) lighting. The Titmus vision tester was similarly used at these levels of illumination for far acuity and low contrast tests. The results showed that low illumination scores correlated .50 to .65 with normal (photopic) acuity. Older age groups had people who did poorly on both tests. Results did not indicate that there were any age groups specifically handicapped with respect to low contrast vision. Work is continuing in this area with even lower contrast targets (Forbes, _et al._, _op_. _cit_.).

O.W. Richards makes the point that a common brick subtends 12 minutes at 200 feet, with a contrast of 25 to 50 percent on a moderately clean asphalt road at night. Richards thus concludes that five to 10 minutes of arc at this contrast level are representative of potential causes of concern to the night driver. Better vision may be required to read signs or see objects on poorly lighted streets. Those on modern highways are designed to be readable at legal speeds with 20/40 vision (Richards, 1966). It is not a surprising fact that objects of high contrast may be perceived where a similar sized object of low contrast may not be seen under the same conditions. Richards concluded that decreasing contrast did not affect the acuity function to any great extent above 30 to 40 percent contrast. With less contrast, vision decreases rapidly. Sixty year olds required 25 percent or greater contrast to see a 20/200 letter at 0.01 ftl. at the standard 20 foot testing distance. At 10 percent contrast objects smaller than three and one half minutes are not likely to be seen. Richards adds that if a 100 percent safety factor is allowed for field conditions, a half brick might not be seen at 100 feet during average road illumination, while a full brick most probably would be seen by these 60 year olds. By the end of the seventh decade, then, some individuals may not see well enough in low contrast conditions to safely drive at night.

Besides external factors of target size, illumination, and contrast level, individuals may have "internal" visual problems that affect acuity. With reference to the night driving situation night myopia is of particular importance. Night myopia is a phenomenon in which an individual tends to get nearsighted as illumination is lowered. Night hyperopia involves the individual getting farsighted as illumination is lowered. These two trends may cause a change in an individual's acuity under mesopic illumination, and thus a lens prescription based on photopic acuity tests may be inadequate for use in the mesopic condition. These phenomena are especially dangerous since individuals may attribute myopia or hyperopia to the normal acuity decrement everyone suffers at night.

H.A. Knoll has attributed a reduction in the amplitude of accommodation as one of the causes of night myopia-hyperopia. Most researchers (according to Knoll) agree on three factors as the main cause of night myopia-hyperopia:

1. spherical aberration
2. chromatic aberration
3. accommodation (Knoll, 1952).

In 1945 Cabello investigated the rapidity of the occurrence of night myopia. It was found that the first five minutes of dark adaptation produced relatively rapid night myopia. The next five minutes showed the myopia at a relatively constant level, requiring a minus 1.5 diopter correction in order to obtain normal vision. (A diopter (d) is a unit of measurement of the refractive power of a lens, or the degree to which it bends light; a minus correction indicates myopia, while a plus correction indicates hyperopia.) Cabello found that during the last five minutes of a 20 minute adaptation period myopia approached a limit of minus 2.00 d correction (Knoll, 1952). It is interesting to note that pupil dilation takes little over three minutes, on the average, and it is within this period that Cabello found most of the myopia developing. Older Ss took longer periods of time to develop the myopia, and likewise their pupils did not respond to the lowered intensity as quickly as younger Ss. This is evidence for pupillary aberration as a probable cause of night myopia (Knoll, 1952).

O.W. Richards has studied night myopia with respect to age, particularly in relation to highway driving. He mentions most night driving is done in an average luminance range of from 0.1 to 0.3 ftl. He tested 65 individuals in luminances of 10 to 0.01 ftl. Testing was done with free binocular vision. Richards' results were consistent with the usual acuity-illumination relationship, except at 95 percent contrast acuity was inferior to acuity at 85 to 91 percent contrast. Due to Richards' small subject sample size at this age, however, this may not be a significant difference (Richards, 1966).

Richards performed another experiment by changing lens corrections on a given individual, and noting the effect on acuity. By checking the lens that would produce best acuity in the lower illumination against the lens used in the daytime one could gauge the presence of night myopia-hyperopia. He found some individuals would be better off with a different lens prescription for mesopic and photopic driving illumination levels (Richards, 1966).

In a later article (1967) Richards mentions that night myopia may be inhibited through the use of atropine and homatropine. Some eyes develop presbyopia under the influence of drugs. Richards suggests several more reasons for myopia developing in certain individuals (compare to Knoll's list, above):

1. change in chromatic aberration with the Perkinje shift
2. increased spherical aberration from larger pupils
3. increasing convergence as lights dim
4. retinal curvature
5. forward movement of the lens due to the choroid vessels becoming partially empty in dim light
6. greater curvature of the eye from increased tonus in the ciliary process during dark adaptation (Richards, 1967).

Spectacle corrections for night myopia range from minus 1.50 d to plus 1.50 d for the Ss run in Richards' experiment (1967) in mesopic illumination. Richards' corrections were made for specific luminance levels. Richards found that a minus 0.50 d correction would provide the maximum benefit for the most people. Army tests have shown that by imposing a minus 1.00 d correction, about one third of its personnel would be handicapped with poorer acuity (Richards, 1967).

The fullest myopia will develop in scotopic levels of light, a condition that would be encountered by the average motorist during headlight failure, but myopia can and will develop at mesopic levels of light. Richards found that a few people improved with a plus 0.50 to 0.75 d correction. While approximately five percent of the total gained in acuity with the plus correction, 20 percent of the sample gained with minus d corrections. This finding implies that night myopia is many times more prevalent than night hyperopia. Again, Richards found that minus 0.50 to 0.75 d corrections gave the most improvement to the most people. He did note that no one with 20/10 or better vision found any improvement with lenses at mesopic levels, and approximately 80 percent of the population did best with no corrections at all (Richards, 1967).

Richards also found that night myopia was rare in the very young and very old. The greatest concentration of this phenomenon was in the 20s and 40s. He added that considering the small numbers in his sample, there was no marked indication of any age group significantly demonstrative of night myopia (Richards, 1967).

Richards' final conclusions were that 10 to 20 percent of the population would see better at night with a minus 0.50 to 0.75 d correction. More than 20 percent would see less well, though, eliminating the possibility of adding a minus correction to everyone in the population (Richards, 1967).

Thus it is possible that an individual may see well during the day, but not see well enough to drive safely at night. This points to a need to measure night driving visual acuity. Attempts to measure mesopic driving vision should focus on near and far acuity at mesopic lighting levels and a representative contrast level. By controlling illumination and contrast, the third determinant of acuity, target size, can be validly measured, and recorded in minutes of arc subtended. This, in turn, will tell just how "fine" a detail the night driver can accurately perceive.

THE PROBLEM AND EXPERIMENTAL DESIGN

A. The Problem

From the previous discussion of the literature it can be seen that the phenomenon of mesopic acuity loss may be a significant factor in nighttime driving safety. The first aim of the thesis was to attempt to detect persons who encounter a typical mesopic acuity loss, such as night myopes or hyperopes, through the use of such readily available acuity tests as the Titmus acuity tests (near and far acuity). The definition of nearsightedness (myopia) indicates that the nearsighted individual would see near objects relatively well and far objects relatively poorly. Thus a person developing night myopia would have a tendency to see near objects well as compared to far objects at low levels of illumination. It follows that the night myopic individual would show a greater drop in his far acuity score than his near acuity score. These individuals could not be predicted from correlation coefficients since they deviate from the group trend of a relatively even drop for both near and far acuity. An analogous argument was made for night hyperopes. These individuals would show a greater loss in near vision than for far vision as illumination levels drop.

As a second aim of the experiment, the Titmus far acuity test was correlated with the Snellen far acuity test in both mesopic and photopic conditions. By correlating the Titmus far acuity test to a widely used standard (the Snellen) an estimate of its validity was made.

Finally the low contrast Titmus test was included to check performance of experimental group extreme near and far acuity cases with the experimental sample as a whole on the low contrast function.

Specific Objectives

1. To determine the usefulness of the Titmus acuity tests in detecting unusual cases of mesopic acuity loss which might be detrimental to night driving.
2. To validate the Titmus far acuity test in mesopic and photopic conditions against the Snellen far acuity test in the same conditions.
3. To investigate the performance of the experimental subject group on the Titmus low contrast test.

B. The Experimental Design

To meet the experiment's three objectives four scores were obtained from each *S*:

1. the Titmus far acuity test
2. the Titmus near acuity test
3. the Snellen (far) acuity test
4. the Titmus low contrast test.

The experimental group was given the above four tests in mesopic light, after an adequate dark adaptation period, and then the same four tests in photopic light, after an adequate light adaptation period. Mesopic and photopic light levels were chosen to match realistic driving illumination levels previous investigators used.

A control group received the same treatment as the experimental group, except that the tests were given in mesopic light on both occasions. Use of the control group permitted investigation of two possible problems:

1. that the dark adaptation period was inadequate, and
2. that there was a learning effect from the first giving of the test to the second.

The acuity test scores were in minutes of visual angle subtended by target detail discriminated. The Titmus low contrast test was scored in percent contrast of the target against the field. The lower the visual angle, the finer detail discriminations the individual can make; and similarly, the lower the percent contrast score, the finer contrast discriminations the S can make.

METHOD

A. Test Room and Equipment

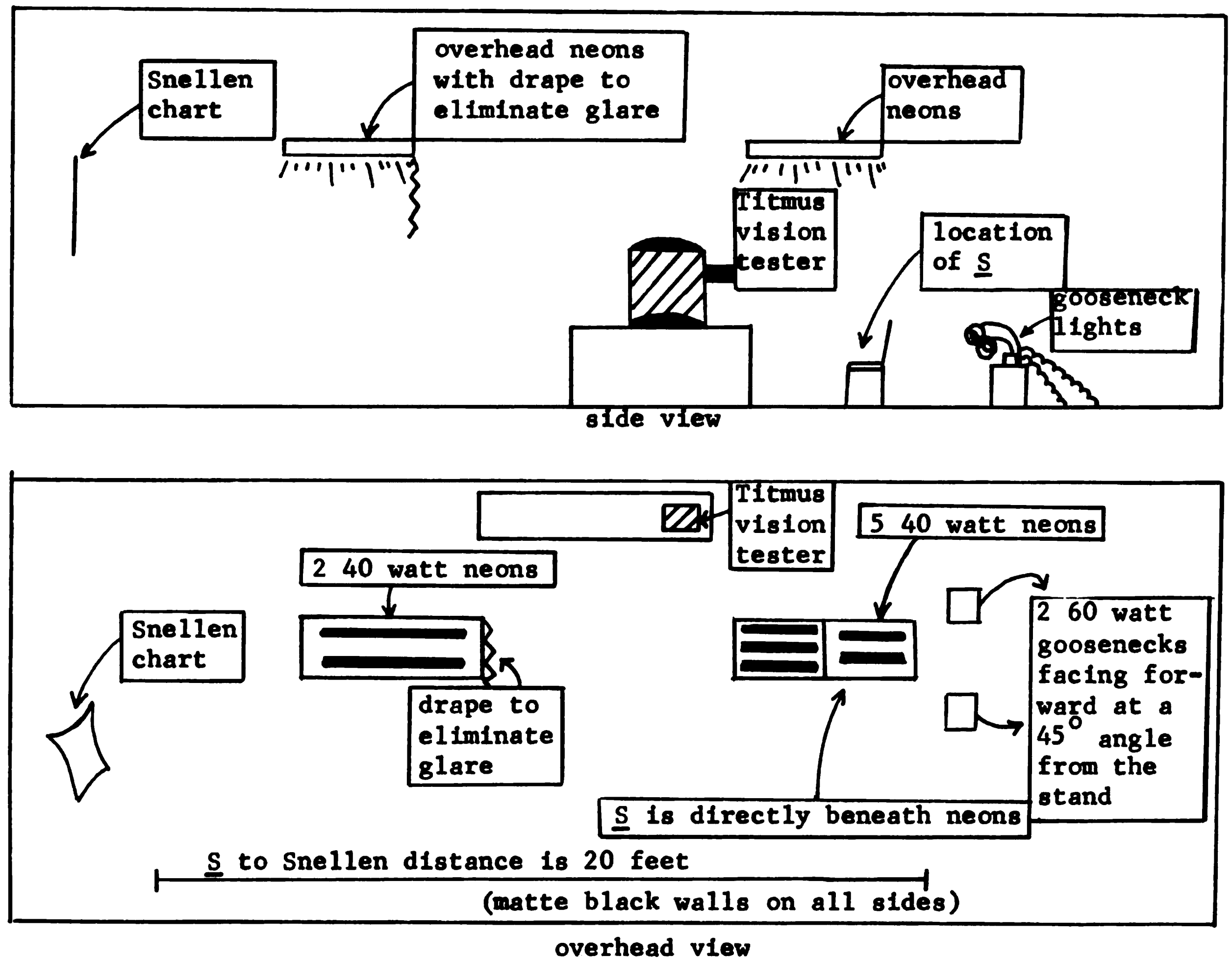
The testing room was a narrow rectangle with matte black walls. Seven (40 watt) cool white fluorescent tubes were required to bring the room to photopic illumination, along with two 60 watt goosenecks, as shown in Figure 2. Mesopic lighting was achieved through the use of the goosenecks only.

A drape was hung from the first set of fluorescent tubes in order to eliminate direct glare from the lighting, without blocking the *S*s' view of the Snellen chart. *S*s sat 20 feet from the chart in the room, with the chart hung at eye level (sitting). The binocular Titmus tester was placed on a table and *S* was required to look directly into it in order to take the three tests in it.

Each *S* took a near acuity test, a far acuity test, and the variable contrast test in the Titmus tester, in addition to the Snellen far acuity chart. The means and standard deviations of the luminance levels of these tests are presented in Tables 2 and 3.

A lighting level of .2 ftl. was used for the mesopic condition, and 10 ftl. for the photopic condition. These are levels that the driver would encounter on the highway during the nighttime and daytime, respectively (Richards, 1966, 1967). This is also the level that Forbes used in his study of low contrast vision (Forbes, *et al.*, *op. cit.*).

The Titmus presents two slides (one per ocular) to the *S*. The slides are mounted on a drum so that different slides depicting different vision tests may easily be switched. The Titmus test is internally illuminated and mesopic and photopic illumination were produced by a rheostat attached to a light source, this being four GE "night light"



Note: In mesopic condition only the two goosenecks were used; in photopic condition the goosenecks plus the seven 40 watt neons were used.

Figure 2. The Testing Room

bulbs of seven watts each. Each side of the drum is lit with a pair of the white coated bulbs.

The near and far acuity Titmus tests used the same type of test figures. A cluster of three Landolt rings and one complete ring were provided for each discrimination level. The S was required to name the location of the complete ring from the four alternatives. The variable contrast test required the S to give the location of a break in a single Landolt ring.

The far Titmus tests simulated a 20 foot distance from the S through the use of a mirror and a reduced image slide. A 14 inch test distance for the near test was simulated by reducing the size of the slide image to half that necessary from an actual 14 inches with placement seven inches from the S's eyes.

The far and near acuity tests measured acuity from 10 to seven tenths minutes of arc. The Snellen ranged from 10 to five tenths. The contrast on these three tests all were approximately 90 percent; the variable contrast test ranged from 69 percent contrast to one percent contrast. The variable contrast test figures all required discrimination of a two minute visual angle target.

Illumination measurements for mesopic and photopic conditions were taken from the background of the Snellen chart with a Pritchard photometer at a 20 foot distance from the chart. Internal Titmus lighting was measured off the background of the far acuity test, again with the Pritchard photometer. This instrument was also used to check contrast on the variable contrast test.

The Snellen proved remarkably easy to "tune" to mesopic and photopic lighting levels, mainly due to the fact that its lighting was obtained through the use of reflected light, with no internal illumination as in the Titmus. As can be seen in Table 1, actual mesopic and photopic illumination were almost identical for the Snellen with the desired .2 and 10 ftl. reflectance, respectively, from the background of the test. The Titmus far acuity test also displayed similar readings, but its greater standard deviations than the Snellen for the same series of readings indicated the lighting was not as uniform. The contrast levels of both tests at both mesopic and photopic illumination were close to 90 percent.

B. Subjects

The Ss were exclusively college students who were taking the MSU introductory psychology course. Ss were obtained through the use of a sign-up sheet, and the students volunteered for the experiment in order to partially fulfill a requirement for experimental credits. A total of 96 Ss were used: 25 in the control group, and 71 in the experimental group. Table 2 shows the age and sex distributions of both groups.

C. Procedure

Each S was run individually and the procedure took from 15 to 40 minutes per S. Ss were ushered into the experimental room and seated while experimentor read a brief description of the aim of the experiment. Ss were told that the aim of the experiment was to gauge loss of visual acuity at low levels of illumination, with emphasis on potential applications towards highway driving. Then the Ss were asked four questions relating to night driving.

After the introductory remarks and the four questions, experimentor would wait until five minutes had passed from the Ss' first having entered the experimental room.

Table 1. Brightness and Contrast Levels of Targets
Measurements Taken with Pritchard Photometer

				Percent Contrast
Snellen Mesopic	Figure (N = 4)	.021 ftl.	.003 ftl.	90
	Background (N = 7)	(.185)	.003	
Snellen Photopic	Figure (N = 4)	1.250	0.250	89
	Background (N = 7)	(10.550)	0.410	
Titmus Far Acuity Mesopic	Figure (N = 4)	.003	0.020	99
	Background (N = 7)	(.230)	0.220	
Titmus Far Acuity Photopic	Figure (N = 4)	.472	0.520	96
	Background (N = 7)	(12.710)	9.820	

NOTE: Circled background readings were used to determine .2 ftl. mesopic condition and 10 ftl. photopic condition.

$$\text{Percent Contrast} = \frac{B_{Bkgr.} - B_{Fig.}}{B_{Bkgr.}}$$

Table 2. Age and Sex Distributions

Experimental Group

Age	Male	Female
18	10	14
19	16	8
20	14	4
21	1	1
24	0	1
25	1	1
	N = 42	N = 29

Modal Age = 19   Modal Age = 18

Control Group

Age	Male	Female
18	2	5
19	9	5
20	2	
21	2	
	N = 15	N = 10

Modal Age = 19   Modal Ages = 18, 19

During this entire five minute period the room was at mesopic illumination, with the Snellen chart being covered with a white paper, and the Titmus being internally illuminated to the mesopic illumination.

The order of the four tests was balanced so that each of the 24 different combinations of the four tests was given an equal number of times (three times each in the experimental group, and one each in the control group). Upon completion of the set of four tests, the room was lighted to photopic illumination, and S was given 30 seconds to adapt to the new lighting level. The S was then given the same four tests as in the mesopic condition, and in the same order as in the mesopic condition.

The control group took the tests in mesopic lighting both times. They were given the two adaptation periods, but the lights remained at mesopic intensity throughout these periods.

D. Method of Analysis

Results of the three acuity tests given (Snellen, Titmus far, Titmus near) were measures of visual angle subtended from a low of .50 to over 3.00 minutes of arc. The Titmus low contrast scores ranged from one to 25 percent contrast. For convenience in graphing the acuity scores were lumped in step intervals of .25. Statistical analysis was performed on original data.

In addition to recording the original visual angle data in minutes of arc, derivative scores were calculated in accordance with the attempt to detect night myopes-hyperopes. Decrements were calculated for Titmus near and far acuity by subtracting for each S his photopic acuity score from his mesopic acuity score.

For all scores (including derived scores) means, standard deviations, and Pearson correlation coefficients were calculated. In addition, for certain pairs of scores two tailed Ts for correlated means were calculated.

RESULTS

Note that acuity results are presented in minutes of arc, but the Titmus low contrast test is presented in percent contrast of target against background. For reference, an acuity score of 2.00 minutes of arc is equivalent to the more well-known Snellen score of 20/40. A score of 20/20 is equal to 1.00 minute of arc.

A. Experimental Group

The Titmus near acuity test in the mesopic treatment resulted in a mean of 1.02 and a standard deviation of .26. The photopic treatment mean was .84, and the standard deviation .17. The normal acuity loss expected under lower illumination accounts for the difference here. The Titmus mesopic far acuity mean was 1.32, with a standard deviation of .61. The Titmus photopic far acuity mean was .94, and the standard deviation .29. Again the expected acuity loss occurred. The standard deviations rose as the means did, indicating greater spread of the scores around the mean. (See Figures 3-6)

The Snellen mesopic acuity mean was 1.52 and the standard deviation .47. The Snellen photopic acuity mean was .86, and the standard deviation .25. Again, the normal loss of acuity expected in mesopic conditions occurred along with a greater spread of scores in the mesopic condition. (See Figures 7 and 8)

The Titmus low contrast test mean was .074 in the mesopic condition and .028 in the photopic condition. The mean is again lower in the photopic condition, and the standard deviation again bears the same relationship. (See Figures 9 and 10)

The "derived" score used in this study was a decrement score, representing photopic acuity subtracted from mesopic acuity, for each

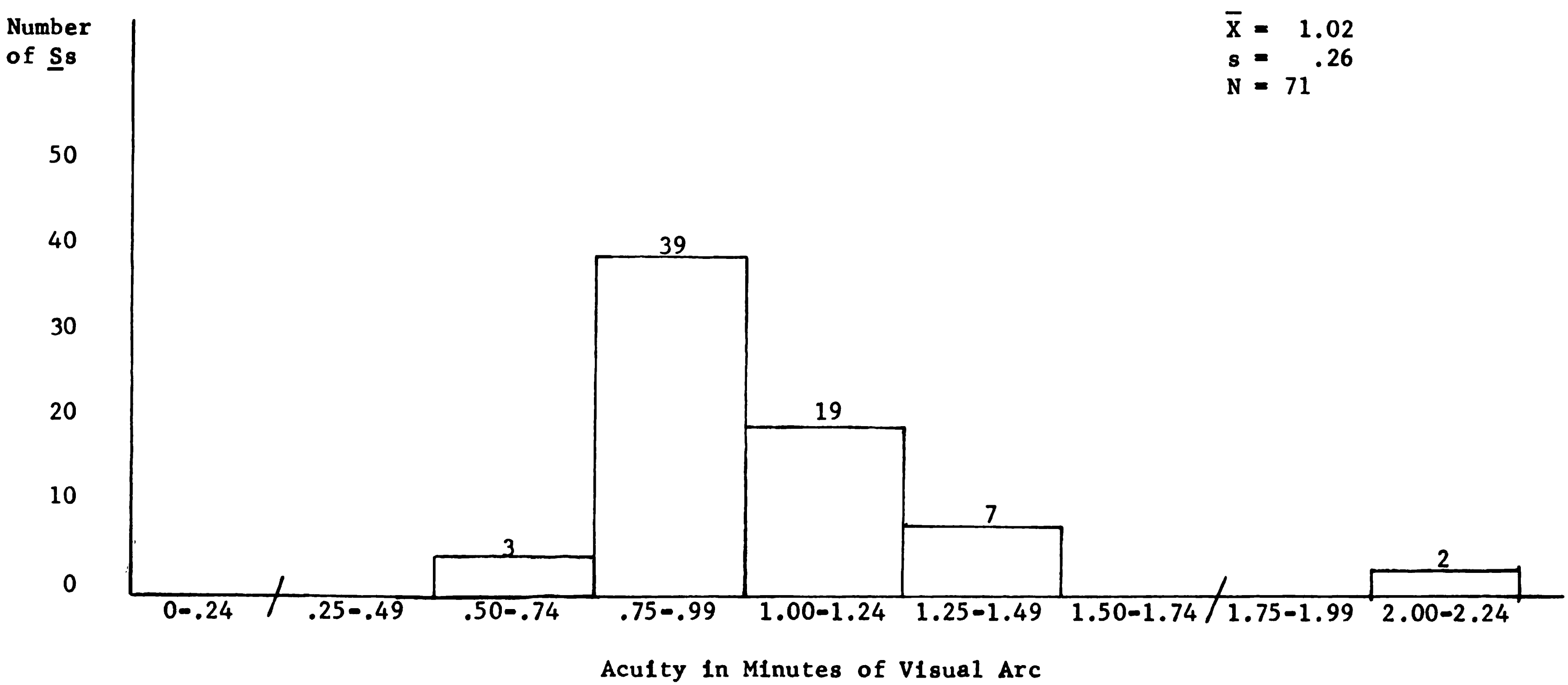


Figure 3. Titmus Mesopic Near Acuity

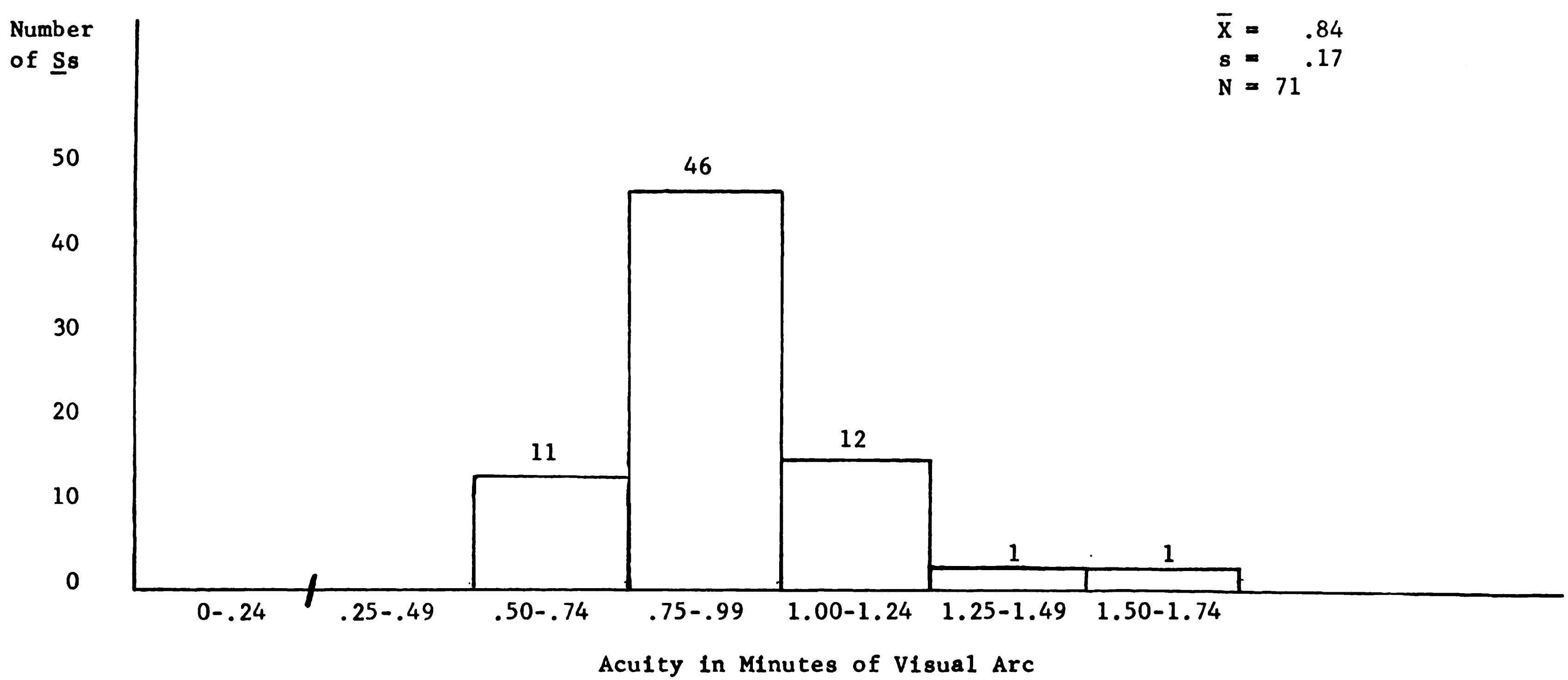


Figure 4. Titmus Photopic Near Acuity

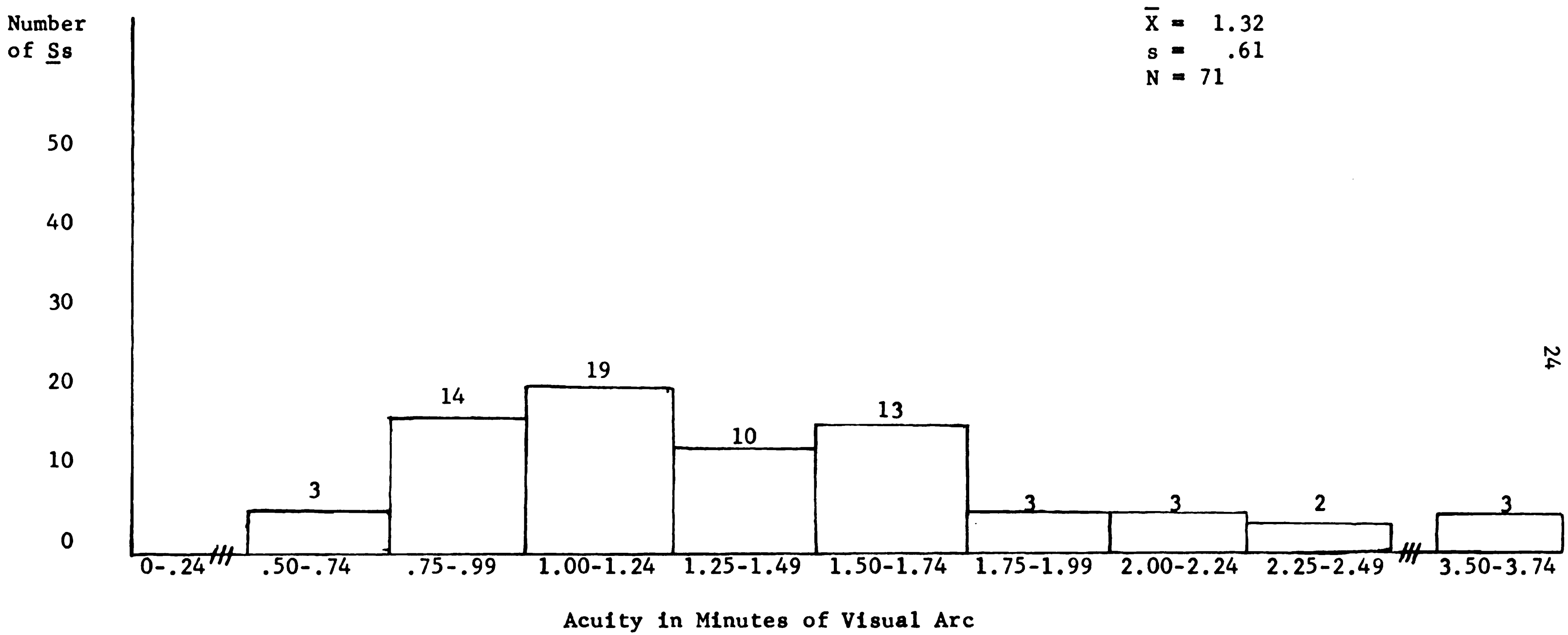


Figure 5. Titmus Mesopic Far Acuity

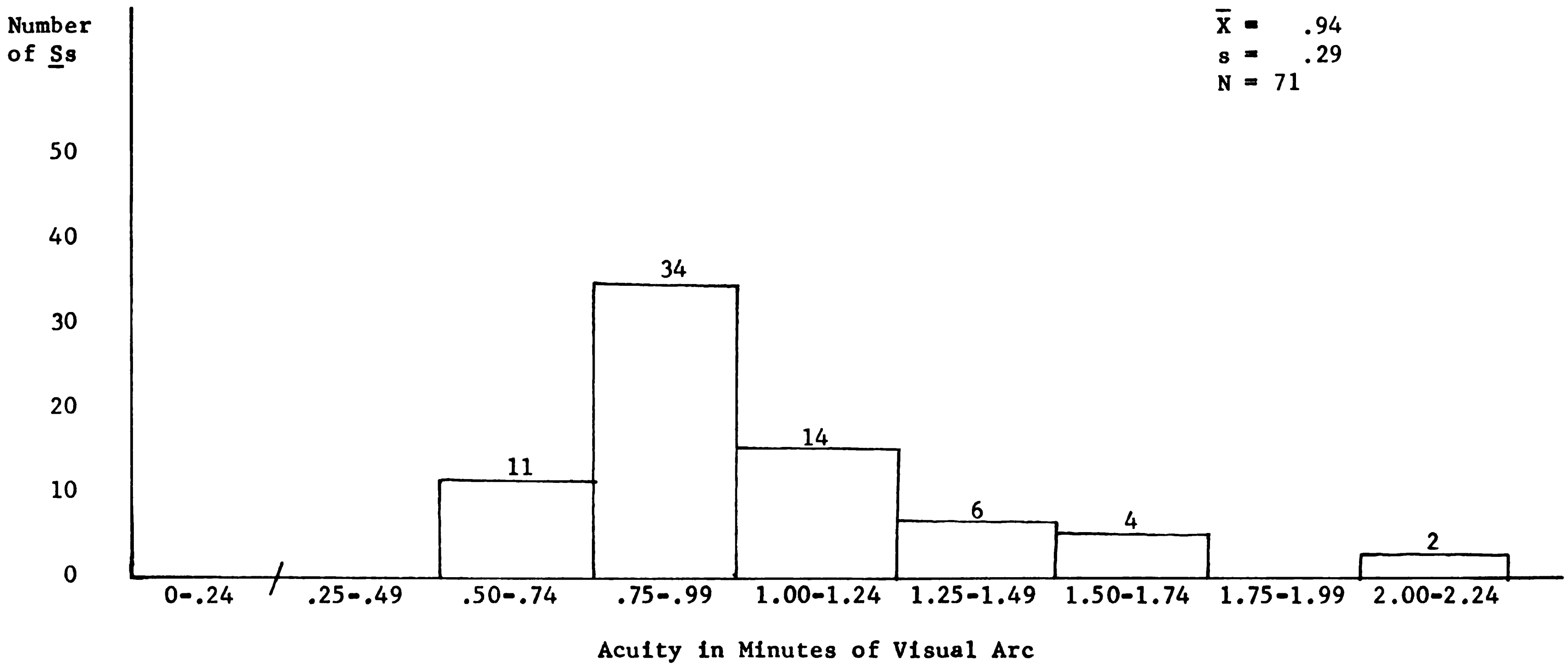


Figure 6. Titmus Photopic Far Acuity

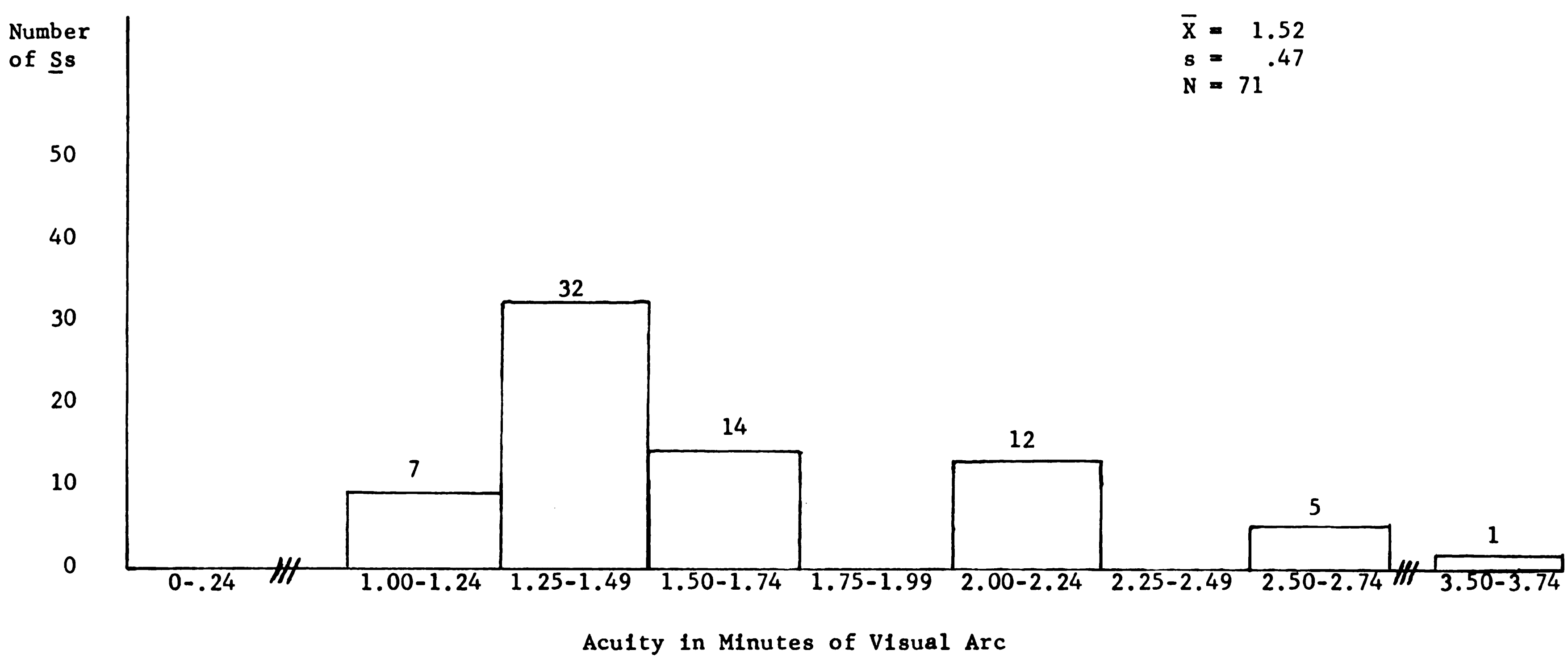


Figure 7. Snellen Mesopic Acuity

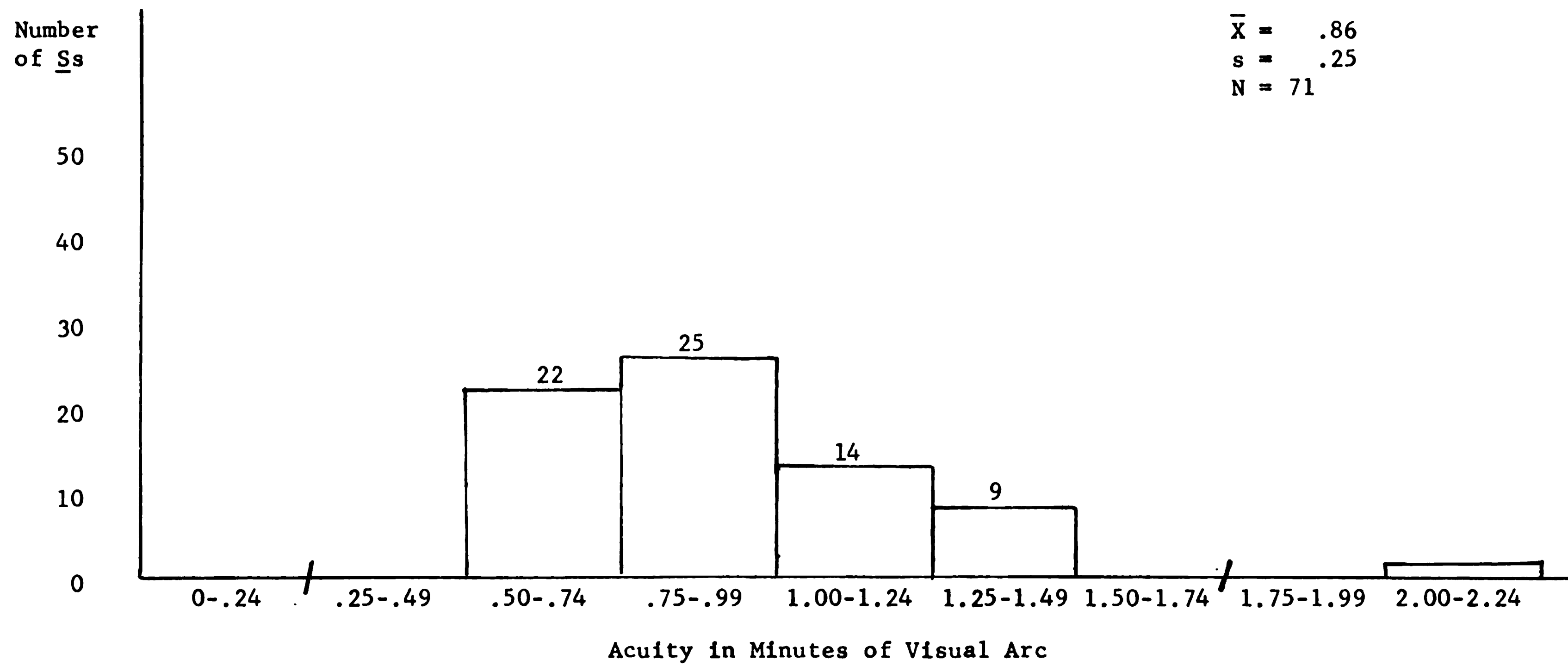


Figure 8. Snellen Photopic Acuity

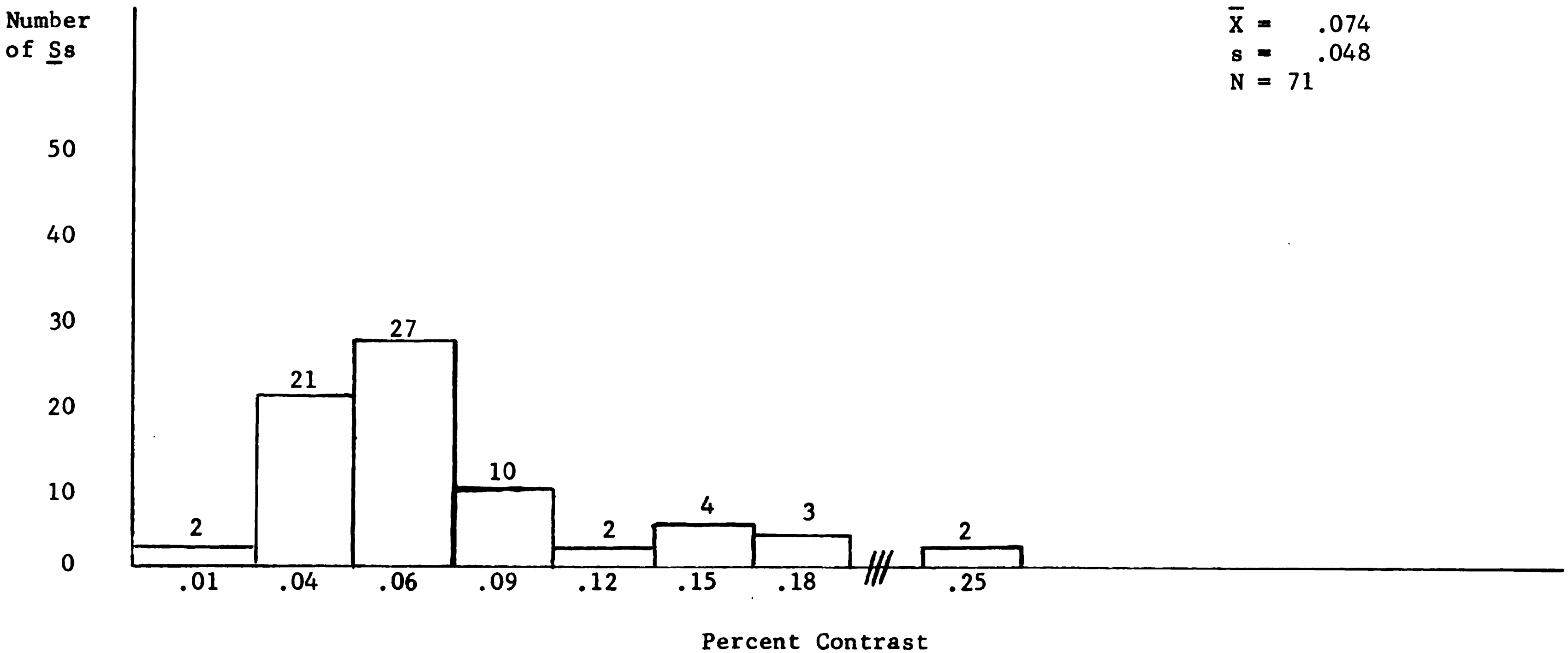


Figure 9. Mesopic Low Contrast Vision

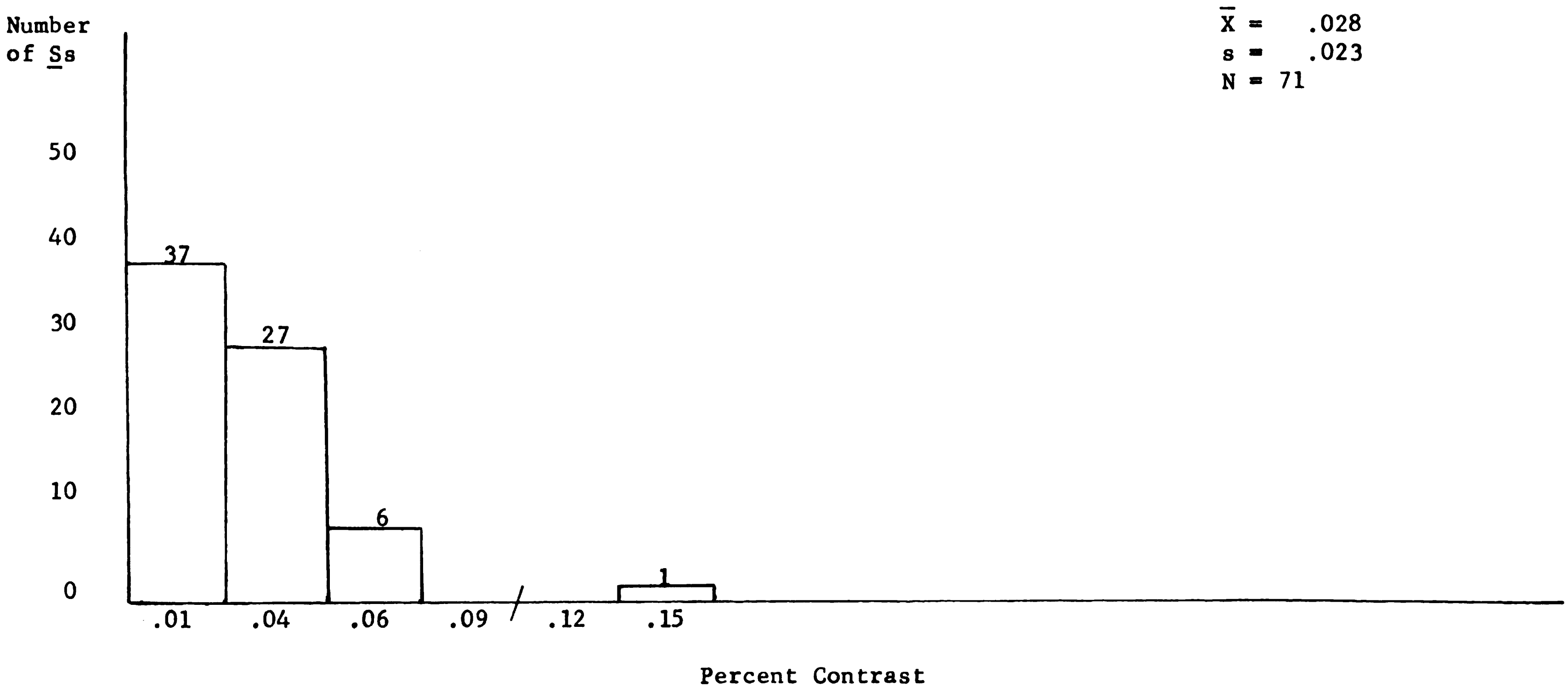


Figure 10. Photopic Low Contrast Vision

individual. These decrement scores were calculated for both near and far Titmus acuity. The larger the decrement, the greater the Ss' loss of acuity from the photopic to the mesopic condition. The Titmus far acuity decrement was .38 with a standard deviation of .46. The Titmus near acuity decrement was .17, with a standard deviation of .16. Far acuity suffered the greater drop, and in addition showed a more widespread distribution of these decrements, although both scores have high standard deviations. A few Ss had negative decrements. Strictly interpreted, these individuals actually had slightly better scores in the mesopic condition than in the photopic. The difference was so slight, however, that it was well within test-retest reliability error. (See Figures 11 and 12)

Table 3 shows the results of T tests and correlations between certain pairs of the tests. When the mesopic treatments were compared with the photopic treatments, across all tests, the Ts between all the means were significant at the .01 level. The correlations between mesopic and photopic scores of the same test ranged from .71 to .79.

This same table shows that the Snellen photopic and Titmus far acuity photopic tests correlated .70, but the difference between the means was significant. This same relationship is true for the mesopic treatment of the two tests, but in the mesopic case the Snellen test had the larger mean, while in the photopic case the Titmus had the larger mean.

Table 4 shows intercorrelations of all the tests given, and the derivative scores.

B. Control Group

Table 5 reflects means, T tests, and correlations between control group data. (In this group conditions were at mesopic light both times the test was given.) The Titmus near mesopic correlated with itself

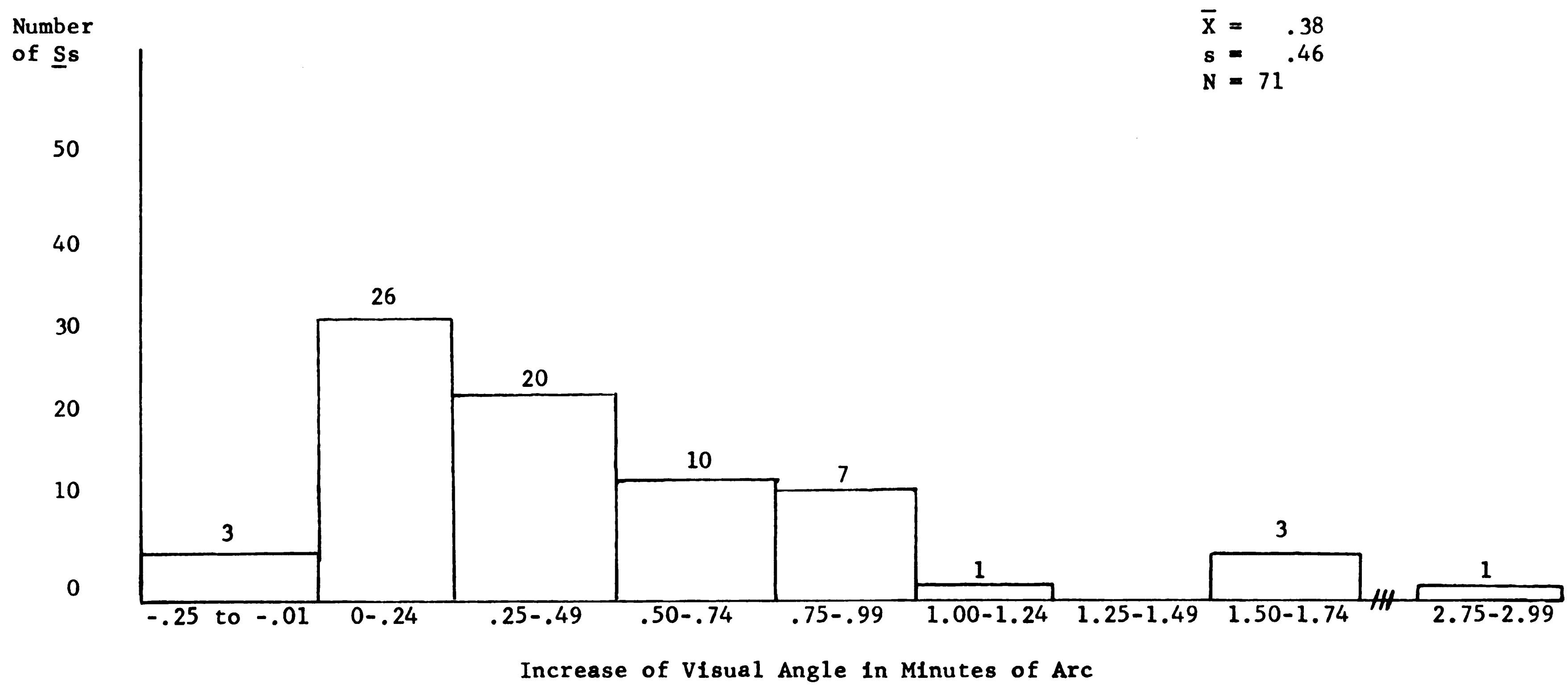


Figure 11. Titmus Far Decrement (Mesopic Acuity Minus Photopic Acuity for Each S)

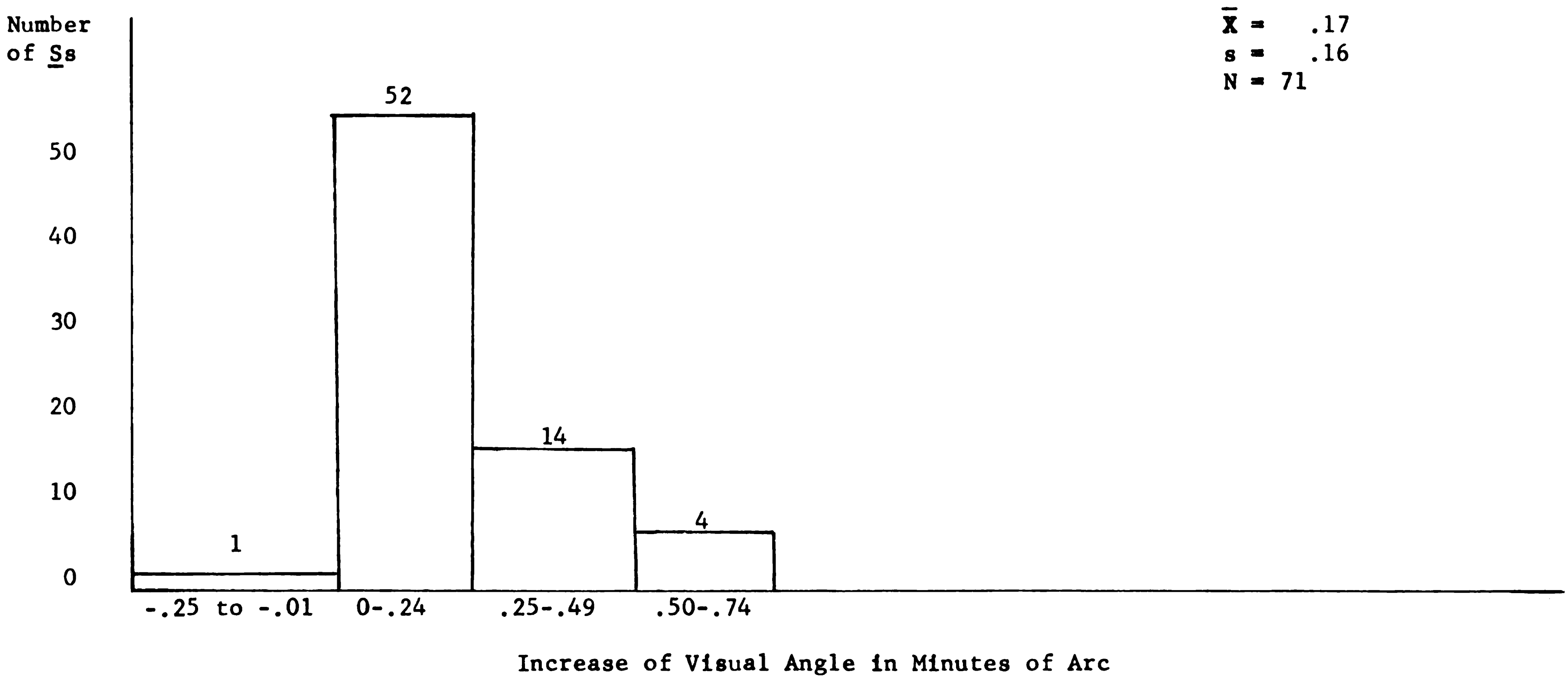


Figure 12. Titmus Near Decrement (Mesopic Acuity Minus Photopic Acuity for Each S)

Table 3. A Comparison of Titmus and Snellen Means (Experimental Group)

	$\bar{X}$	t (Two Tailed)	s	r
Titmus Photopic Near Acuity	0.84	9.28++	.17	.79
Titmus Mesopic Near Acuity	1.02		.26	
Titmus Photopic Far Acuity	.94	7.08++	.29	.71
Titmus Mesopic Far Acuity	1.32		.61	
Snellen Photopic Acuity	0.86	17.63++	.25	.77
Snellen Mesopic Acuity	1.52		.47	
Photopic Low Contrast Vision	0.03	8.78++	.02	.72
Mesopic Low Contrast Vision	0.07		.05	
Snellen Photopic Acuity	0.85	3.57++	.25	.70
Titmus Photopic Far Acuity	0.94		.29	
Snellen Mesopic Acuity	1.52	3.84++	.47	.70
Titmus Mesopic Far Acuity	1.32		.61	
Titmus Mesopic Near Acuity	1.02	4.64++	.26	.45
Titmus Mesopic Far Acuity	1.32		.61	
Titmus Photopic Near Acuity	0.84	4.27++	.17	.75
Titmus Photopic Far Acuity	0.94		.29	
Titmus Far Decrement	0.38	3.82++	.46	.15
Titmus Near Decrement	0.17		.16	

Legend:

$\bar{X}$ - Mean
t - T Test
s - Standard Deviation
r - Correlation Coeficient

++ Significant at .01
Experimental N = 71

Table 4. Intercorrelations: Titmus, Snellen, and Derived Scores

	TMN	TPN	TNΔ	TMF	TPF	TFΔ	SM	SP	MLC	PLC
TMN										
TPN	.79⧺									
TNΔ	.76⧺	.21								
TMF	.45⧺	.49⧺	.20							
TPF	.61⧺	.75⧺	.18	.71⧺						
TFΔ	.22	.18	.15	.90⧺	.32⧺					
SM	.17	.24+	.01	.70⧺	.55⧺	.60⧺				
SP	.27+	.45⧺	-.02	.65⧺	.70⧺	.44⧺	.77⧺			
MLC	.26+	.33⧺	.07	.63⧺	.56⧺	.49⧺	.71⧺	.59⧺		
PLC	.21	.25+	.08	.56⧺	.66⧺	.33⧺	.64⧺	.67⧺	.72	

Legend:

T - Titmus Acuity
S - Snellen Acuity
N - Near
F - Far
LC - Titmus Low Contrast
Δ - Decrement
M - Mesopic
P - Photopic

\+ Significant at .05
⧺ Significant at .01
(Two Tailed)
Experimental N = 71

Table 5. A Comparison of Snellen and Titmus Means (Control Group)

	$\bar{X}$	t (Two Tailed)	s	r
Titmus $Mesopic_1$ Near Acuity	.89	2.04	.17	.74
Titmus $Mesopic_2$ Near Acuity	.94		.17	
Titmus $Mesopic_1$ Far Acuity	1.13	1.15	.36	.55
Titmus $Mesopic_2$ Far Acuity	1.22		.44	
Snellen $Mesopic_1$ Acuity	1.42	2.30++	.43	.71
Snellen $Mesopic_2$ Acuity	1.28		.30	
$Mesopic_1$ Low Contrast Vision	.06	0.00	.04	.86
$Mesopic_2$ Low Contrast Vision	.06		.03	

Legend:

$\bar{X}$ - Mean
t - T Test
s - Standard Deviation
r - Correlation Coefficient

++ Significant at .01
Control N = 25

.74, and there was no significant difference between the means; the Titmus far mesopic correlated .55 with itself, again with no significant difference between the means. The Titmus low contrast test-retest correlation was .86, again with no significant difference between the means. The Snellen test showed a high correlation .71, but there was a significant difference between the means at the .01 level.

DISCUSSION

The primary aim of the experiment was to compare acuity scores obtained from the Titmus near and far acuity tests and determine if unusual cases of acuity loss, such as night myopes and hyperopes, could be detected from the results. For this analysis experimentor derived Titmus far and Titmus near decrement scores as a potential short cut to such detection (Figures 11 and 12). These scores gave the loss in acuity from photopic to mesopic conditions for near and far vision, and were calculated by simple subtraction of the near (or far) photopic score from the near (or far) mesopic score for each S.

A correlation of .90 was found between the Titmus far decrement score and the Titmus far acuity mesopic scores (Figure 5). The photopic correlation was only .32. Thus a large proportion of the variance of the derivative score could be traced back to one of the two "parent" scores (the mesopic score). In addition a subtractive disadvantage could occur with the decrement scores, i.e., a poor visual acuity score being masked by its subtractive derivation. Therefore the original acuity scores were the best data base to form realistic conclusions about unusual acuity losses.

Similarly the Titmus near decrement score correlated .76 with the Titmus near mesopic scores and .21 with the Titmus near photopic scores. Again there was little point in dealing with the derivative score since the majority of its variance came from a single score.

Since unusual mesopic acuity loss was of interest, experimentor examined the extreme cases in Titmus near and far mesopic acuity (Table 6). The three extreme cases in Titmus far mesopic distribution stood out quite apart from the rest of the distribution (Figure 5). A look at

Table 6. Extreme Cases of Titmus Near and Far Acuity

	Titmus Acuity Near Mesopic	Titmus Acuity Near Photopic	Titmus Acuity Far Acuity	Titmus Acuity Far Acuity	Low Contrast Vision: Mesopic	Low Contrast Vision: Photopic
Extreme Cases: Titmus Far Mesopic Acuity	1.14	0.86	3.50	2.00	.25	.15
	1.14	0.71	3.50	0.75	.18	.04
	2.00*	1.64	3.50	2.00	.15	.06
Extreme Cases: Titmus Near Mesopic Acuity	2.00*	1.64	3.50	2.00	.15	.06
	2.00	1.29	1.75	1.50	.04	.04

(Scored in Minutes of Arc)

* Same Individual

these cases shows that the first case showed a greater than average loss of acuity in the far acuity condition, but did not show any great loss in the near acuity condition. The second case showed the same relationship, but to an even greater extreme, this S ranging from 0.75 in the photopic far acuity condition to 3.50 in the mesopic far acuity condition. The third case showed a different relationship; his Titmus near acuity scores (both mesopic and photopic) were poorer than the others. This last extreme case in the Titmus far acuity situation was also an extreme case in the Titmus near acuity extreme cases.

An examination of the low contrast scores in this extreme group showed them to be poorer than normal, but not so poor as to cause concern in the night driving situation, this level thought to be 40 percent. The low contrast mesopic scores were .25,.18, and .15 with the experimental group mean at .074 (Figure 9). This correlation between relatively poor low contrast mesopic scores and relatively poor far acuity mesopic scores may be due to a common visual function; but the fact that the low contrast target is a simulated 20 feet from the subject's eye and subtended a visual angle of two minutes of arc complicated the situation. It is suggested that the low contrast test's targets be increased to four minutes of arc in order to better eliminate covariance of far acuity and contrast in the test.

There were two extreme cases in the near acuity mesopic scores that stood apart from the distribution, both with scores of 2.00 minutes of arc. One of these Ss also had an extreme far acuity score in mesopic and photopic conditions. The other individual had a 1.75 minute Titmus mesopic far acuity score -- not especially bad.

To sum, the Titmus was a useful instrument for detecting extreme cases using base data. Using an arbitrary cutoff of 3.00 minutes of arc, experimentor found three cases of relatively poor far mesopic visual acuity -- all 3.50 minutes. All three showed a similar record with relatively poor mesopic low contrast scores (but still not sufficient for concern in night driving) and a relatively small decrement in near acuity in mesopic light. This relationship between a large far acuity decrement and a small near acuity decrement was indicative of night myopia -- a more exact diagnosis on a direct lens testing device (such as Richards') would be needed to confirm this. The Titmus was useful as a mesopic acuity detection instrument though additional diagnosis and possible remedy should be undertaken after such detection.

The second aim of the experiment was to correlate the Titmus far acuity against the Snellen far acuity test in order to establish validity against a known standard. Table 3 shows the Snellen photopic acuity test had a mean of .85, and a standard deviation of .25, while the Titmus photopic far acuity test had a mean of .94 and a standard deviation of .29. These two tests correlate .70, but the difference between the means was not significant at the .01 level.

In mesopic conditions the Snellen test gave a mean of 1.52, while the Titmus far acuity test gave a mean of 1.32 with standard deviations of .47 and .61, respectively. Again the correlation between the means was .70, and again the difference between the means was significant. The Snellen was thus the more conservative test in the mesopic condition, while the Titmus was more conservative in the photopic condition.

Differences between testing conditions could account for the differences found. Snellen targets were letters of the alphabet, while the Titmus used Landolt rings. S would be more likely to guess correctly with the letters of the alphabet since he has had experience with them before. In addition the Titmus simulated the 20 foot distance through the use of slides and a viewer; the Snellen was an actual 20 feet from the S. Some few Ss had trouble getting the images the Titmus presented binocularly to merge, and others complained of glare from the viewfinder type oculars. The Titmus therefore appeared less valid than the Snellen, Minor but annoying problems prevented the Titmus from achieving a completely realistic simulation of the 20 foot distance. Correlations between the two tests were still impressive -- indicating they shared 49 percent of their variance. Although the difference between the means was significantly different, the difference was not of such a magnitude to discourage its use for visual acuity testing.

If we accept Richards' hypothesis that contrast does not become a critical factor in visual acuity until it gets below 30 or 40 percent, there were no Ss exhibiting such poor low contrast vision that they would be of concern for night driving. The worst cases in the mesopic condition were .25 percent contrast; under photopic conditions the worst case was .15 (Figures 9 and 10). Again we do note a lower mean (and a lower standard deviation) in the photopic condition, but there was no indication of any serious visual handicap in the low contrast condition. The young age of the sample may have been a reason for this. Observing the intercorrelation matrix, experimentor noted no pattern of low contrast correlations, except for a general higher series of correlations with the Snellen acuity and Titmus far acuity. Since the low contrast test tests vision at a simulated distance of 20 feet, this was probably due to the far vision function being common to all three tests to some extent.

Table 5 represented the last aim of the experiment. If there were no significant learning effects, and if the dark adaptation period were adequate there would be no significant difference between the first showing of the tests in mesopic light and the second. The results show relatively high correlations between the two treatments (.55 to .86), indicating high test-retest reliability, but there was one difference between the means significant at the .01 level, that of the Snellen acuity tests' first and second mesopic treatments. The Titmus tests behaved consistently in one direction while the Snellen again disagreed with the Titmus somewhat, although it too did have a high test-retest reliability. It was apparent again that the Snellen was somewhat at odds with the Titmus simulation of distance. Again the complications of internal lighting, simulated distance, and hard image fusion appear to have caused minor shortcomings in the test validity of the Titmus tests. Since the correlations were consistently high between the first and second mesopic treatments of each test in the control group, and the significant Snellen difference was not so great as to cause concern in this experiment (amounting to .20 of a minute of arc), the control group was concluded to have demonstrated no significant dark adaptation or learning effect.

SUMMARY AND CONCLUSIONS

Through the use of the Titmus Vision Tester near and far acuity tests at mesopic and photopic illumination, detection of unusual cases of mesopic acuity loss (at simulated night driving illumination levels) was attempted. Scores on the Titmus far acuity test, which simulated a 20 foot testing distance, were compared with scores of the Snellen eye chart at an actual 20 foot distance. Performance on a variable low contrast test as opposed to the higher contrast acuity tests was also undertaken to look for possible relationship to night myopia.

An experimental group (N=71) and a control group (N=25) were tested. The experimental group was given the Titmus near acuity test, the Titmus far acuity test, the Snellen far acuity test, and the Titmus low contrast test, in mesopic, and then again in photopic, lighting. Thus each subject set his own norms in the photopic condition. A control group was given the same tests in mesopic light both times. The purpose of the control group was to detect improvements in performance due to either improved dark adaptation or increasing familiarization with the tests. Subjects were drawn from the MSU student population and ranged in age from 18 to 25.

The results showed that:

1. The Titmus far and near acuity tests, when used in conjunction on Ss in mesopic and photopic lighting conditions were of value in detecting unusual cases of mesopic acuity loss, both near and far. Four extreme cases were found, and one S was an extreme case in both near and far mesopic acuity. Three of the extreme cases had far acuity scores of 3.50 minutes of arc, and as such represent potential causes of concern in the night

driving situation. To confirm the presence of night myopia or hyperopia further testing was suggested on more sophisticated apparatus such as that used by Richards (Richards, 1966).

2. The Titmus far acuity test correlated well with the Snellen, but did show significant differences between the means. This was attributed to a number of problems the Titmus far acuity test presents with its less than ideal simulation of the 20 foot testing distance.

3. There were no cases with Titmus mesopic low contrast greater than .25. This was not of a magnitude to cause concern in night driving. The fact that the subject ages were exclusively in their teens and twenties may have been a reason for this. The Titmus low contrast showed some correlation with other far acuity tests -- namely the Titmus far acuity and the Snellen. This was attributed to the fact that the Titmus low contrast test uses 20/40 targets at a simulated distance of 20 feet.

4. Finally, the control group scores showed high correlations between the first administration of the tests in mesopic conditions and the second. The Snellen test, however, did show a significant difference between the means while the Titmus tests did not. Differences between the two tests could have caused the difference, and the difference, although significant, was not of a magnitude to cause concern.

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