A SIMPLE TEST FOR STEREOSCOPIC PERCEPTION*†

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ANYONE who tries to give instruction in aerial-photo interpreting has the frustrating experience of not knowing whether or how well each of his students is able to see in three dimensions. Although stereoscopic perception is an essential qualification for the photo interpreter, many technical schools that now offer courses in photo interpreting are not equipped to test or measure this ability. One reason for this is that testing or measuring stereoscopic perception usually requires a lot of expensive equipment plus a specialist to operate it.

So the instructor is likely to confine his initial testing to the simple question—"Do you see it?" The chorus of affirmative answers tells him nothing. Time is limited. He hurries on to things he considers more important. Later he finds himself completely baffled by the astonishing lack of interpretive ability in a few of his students. He then may spend more time and effort attempting to train these few students than he should spend on the entire class. Even so he is not sure whether their slowness is due to faulty stereo vision or inadequate instruction.

The few students who lack stereo ability are accustomed to seeing objects in two dimensions and may logically assume that the magnified image with its highlights and shadows is all that the others can see. Still others, with limited stereo perception, may lack the ability to see small differences so important in stereoscopic work.

The instructor needs a simple test for stereo perception—one that is usable in the classroom during the first few hours of the course, and that requires no equipment other than the lens stereoscope. The stereogram and rating scale described here are intended to fulfill this need.

A Word About Stereoscopic Perception

The literature contains few articles devoted wholly to stereoscopic perception or methods of measuring it (see Bibliography) but almost every publication on aerial-photo interpretation emphasizes its importance.

Briefly, in order to see stereoscopically, a person must be able to focus his eyes on objects at various distances, to converge the lines of sight together on a single object, and to fuse these two slightly different views in his brain. In Figure 1 the mechanics of depth perception in binocular vision are illustrated graphically. Angles A and B, measured by the two small arcs (a and b) on the retinas of the eyes, are related to distance X between "objects" 1 and 2. The minimum angle (arc) that can be perceived by any individual is a measure of his depth perception.

Photogrammetrically, stereo perception has to do with the three-dimensional effect caused by viewing two photographs of the same scene taken from two different angles. It differs from binocular vision in that the two photographs serve as artificial perspectives.

It is easy to make a stereogram that illustrates the effect of stereoscopic perception. In Figure 2, two pairs of dots are shown with the upper pair spaced closer together. When viewed in stereo, the pairs of dots fuse, and because of the parallax difference the closer pair appears to float in space. This is an example of artificial perspective created by the draftsman. *Since we can control the parallax difference (and indirectly the artificial perspective) of such a stereogram by changing the spacing of the dots, we have only to make a stereogram with a series of finely graduated differences to have a measuring stick for stereo perception.*

Floating-Circles Stereogram Test

The test stereogram described here is based upon the above principle and so can be used to measure the degree of stereo perception instead of just to determine

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‡ Subsequent to writing this paper, the author accepted a transfer to the Intermountain Station of the U.S.F.S., at Ogden, Utah.

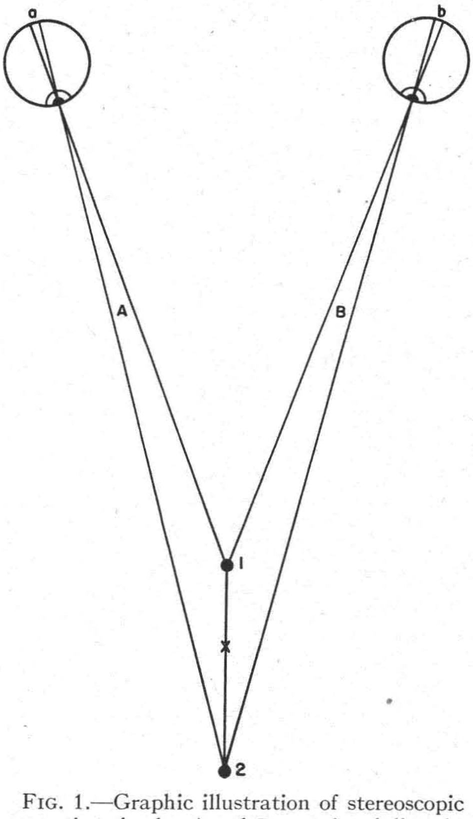


FIG. 1.—Graphic illustration of stereoscopic perception. Angles *A* and *B* are related directly to distance *X* between objects 1 and 2. These angles are measured on the retina of the eyes by arcs *a* and *b*.

its existence. With the aid of this stereogram and an inexpensive lens stereoscope, any instructor in photo interpretation can rate the stereo perception of his students in less time than he would use on a normal mid-term examination.

The test stereogram consists of two banks of 160 circles (Figure 3).* Each circle is approximately 0.03 inch in diameter. Each half of the stereogram is divided into 4 blocks containing 5 rows of 8 circles each. Centered in each block is a key letter. The rows of circles are lettered vertically and numbered horizontally so that the location of each circle may be described by letter and number, such as Block *A*, circle *A*-6.

Twenty-five randomly selected circles in the left bank of the stereogram are shifted slightly to the right. The amount of shift of these circles ranges from 0.045 inch at the top of the stereogram to 0.0005 inch at the bottom (Figure 4). The rest of the circles have been shifted out of line at random, but the same in both banks, so that the parallax difference of the key circles will not be obvious to the naked eye. When viewed through a lens stereoscope, the 25 key circles appear to "float" at various levels above the datum plane formed by the rest of the circles and the paper of the stereogram. The number of floating circles that each individual can identify (particularly in the lower blocks) is a fairly accurate measure of his stereoscopic perception.

* Figure 3 is the same as Stereogram II.

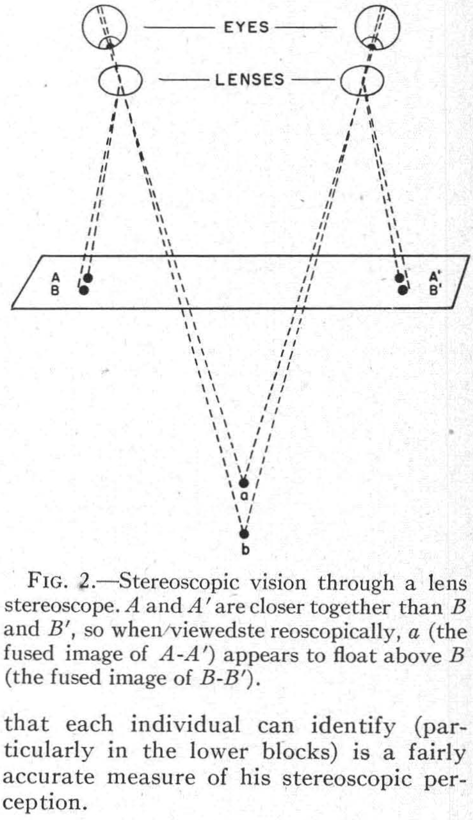


FIG. 2.—Stereoscopic vision through a lens stereoscope. *A* and *A'* are closer together than *B* and *B'*, so when viewedste reoscopically, *a* (the fused image of *A*-*A'*) appears to float above *B* (the fused image of *B*-*B'*).

HOW TO GIVE THE TEST

The testing procedure is simple. Each person is given a lens stereoscope and a test sheet (See page 334).[1] If inexperienced, he is shown how to determine the correct lens separation for his eyes and how to orient the stereoscope over the stereogram. He then examines the blocks systematically, scanning each row from left to right and moving through the blocks from top to bottom. He indicates the position of each

[1] Extra copies of this test sheet are available on request to the Central States, Forest Experiment Station, Columbus, Ohio.

floating circle by marking with an *X* the appropriate number on the answer sheet.

HOW TO GRADE THE TEST

Each floating circle correctly identified is counted as +4. (See "Key to Correct Answers" in Appendix.) Omissions and incorrect identifications are counted as −4. Thus a test with one floating circle omitted is scored as 96. If, in addition, another circle was incorrectly marked as floating, the score would be 92.

The Normal Rating Scale

A "normal" rating scale was prepared as a guide for instructors in interpreting the results of their students' tests (Figure 5). This rating scale shows graphically the mean, median, and distribution of 171 pilot tests. By plotting a test grade on this scale, the instructor can see at a glance the comparative rating of that individual.

Hints on Interpreting Errors

The instructor should make certain that each test approximates the normal pattern. A "normal" test usually has the floating circles correctly identified in the easier blocks (*A* and *B*), and the errors, if any, occurring in the more difficult blocks (*C* and *D*) at the end of the test. Major variations in this normal pattern and their probable causes are:

1. Errors concentrated early in test, with most circles in the last two blocks correctly identified.—This indicates that the student was not seeing stereo at the beginning of the test, probably because of poor orientation.

2. Clusters of circles in the outer banks incorrectly identified as floating.—This indicates that the student was looking out of the corner of his eye instead of shifting his stereoscope from left to right and viewing the circles from directly above. The curved datum plane created by looking through the lenses at an angle may cause the outer circles to appear above those in the center of the stereogram, and an inexperienced student will frequently list these as floating.

3. Many circles or clusters of circles incorrectly identified as floating.—Indication that the student did not have the stereogram properly oriented in stereo. In some tests this may be an indication that the student was guessing, and the grade will be far below his actual stereo ability.

4. Several floating circles throughout the test not identified.—Indication of haste or some other fault usually not connected with poor stereo vision.

In most cases the answer to these abnormal patterns is merely re-running the test. Occasionally if time is limited the instructor may choose to ignore one or two errors occurring early in the test where correct answers are given later. Probably the best approach is to grade each test as it is completed. Rechecks can then be made immediately where needed.

How This Test Was "Tested"

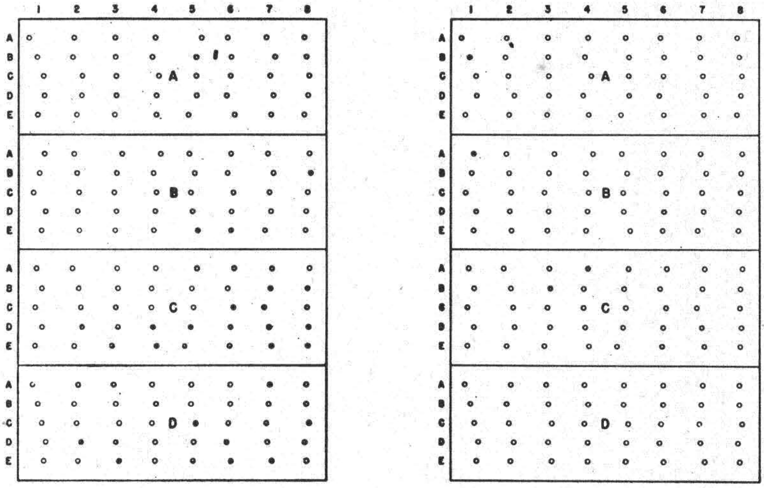
When the instructor has given this test to his class and graded the results, he has a pretty good idea of the relative ability of each student in that group to see stereoscopically. But he wants to know more than this—he wants to know what should be considered a "passing" grade. In other words, what is the point on the grading scale below which any student would be definitely handicapped by his eyesight in photo-interpreting work?

In order to help answer this question and to establish some sort of a rating scale by which any individual's showing on the test can be judged, a "pilot" test was run on 176 different people. The experiment was tried on both men and women from college-age to more than 50 years. More than half had no previous stereoscopic training or experience with aerial photos. The groups included:

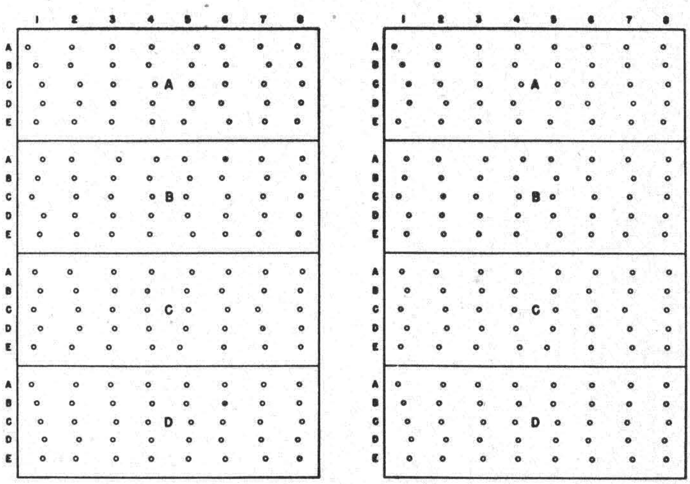
A. 45 foresters, other technicians, stenographers, and other office personnel.
B. 33 faculty members and students from classes in photo interpretation at a school of forestry.
C. 46 officers and airmen from a Photo Reconnaissance Technical Squadron, U. S. Air Force.
D. 32 faculty members and students from a class in photogrammetry at a school of civil engineering.
E. 15 engineers and technicians from the aerial-survey section of a state highway planning unit.

In addition, 31 faculty members and students from a forestry short course in photo interpretation were tested. Although the data were not used in this

FLOATING-CIRCLES STEREOGRAM TEST SHEET. (Page 1.)



STEREOGRAM I.—(Lens separation—2.25 inches.)



STEREOGRAM II.—(Lens separation—1.9 inches.)

FIG. 3.—The floating-circles test stereogram (continued on facing page).

INSTRUCTIONS FOR TAKING THE FLOATING-CIRCLES TEST FOR STEREOSCOPIC PERCEPTION

1. Adjust the lenses to the most comfortable spacing for your eyes.
2. Set the stereoscope up over Block A of Stereogram I. If you can readily superimpose the A's centered in each half of the block, use this stereogram for the test. If it is impossible to fuse the letters on this one, shift the stereoscope to Stereogram II below, which has a separation distance $\frac{1}{3}$ of an inch shorter.
3. After selecting the most "comfortable" of the two stereograms, adjust the instrument so that the A's are superimposed again. Then beginning with row A, record the num-

FLOATING-CIRCLES STEREOGRAM TEST SHEET. (Page 2.)

Name ____

Date ____

____

____

Mark the number of each circle in each row and block that appears to float above the datum plane formed by the paper.

A	1	2	3	4	5	6	7	8	
B	1	2	3	4	5	6	7	8	
C	1	2	3	4	5	6	7	8	Block A
D	1	2	3	4	5	6	7	8	
E	1	2	3	4	5	6	7	8	
A	1	2	3	4	5	6	7	8	
B	1	2	3	4	5	6	7	8	
C	1	2	3	4	5	6	7	8	Block B
D	1	2	3	4	5	6	7	8	
E	1	2	3	4	5	6	7	8	
A	1	2	3	4	5	6	7	8	
B	1	2	3	4	5	6	7	8	
C	1	2	3	4	5	6	7	8	Block C
D	1	2	3	4	5	6	7	8	
E	1	2	3	4	5	6	7	8	
A	1	2	3	4	5	6	7	8	
B	1	2	3	4	5	6	7	8	
C	1	2	3	4	5	6	7	8	Block D
D	1	2	3	4	5	6	7	8	
E	1	2	3	4	5	6	7	8	

ber of each circle that appears to "float" above the datum plane formed by the paper and rest of the circles.

4. When you have completed Block A, shift the stereoscope down to rest directly over Block B. After making sure that the two B's are superimposed, proceed as in 3.
5. Repeat the process for Blocks C and D.

CAUTION: BE SURE THAT YOU—

A. Set the stereoscope to a lens separation normal for your eyes, and you use the stereogram (I or II) that is within this separation range.

B. View the stereogram directly below the center of the lens, even though this means shifting the stereoscope to the right or left and vertically as the test progresses. Any attempt to look through the lens at an angle will produce a curved datum and make it harder to recognize the floating circles.

C. See that the letters centered in each block are superimposed—any other orientation will cause the wrong circles to float.

D. Read the stereogram systematically from left to right starting with the top line of Block A. Skipping around or reading vertically merely increases the difficulty, and may result in errors.

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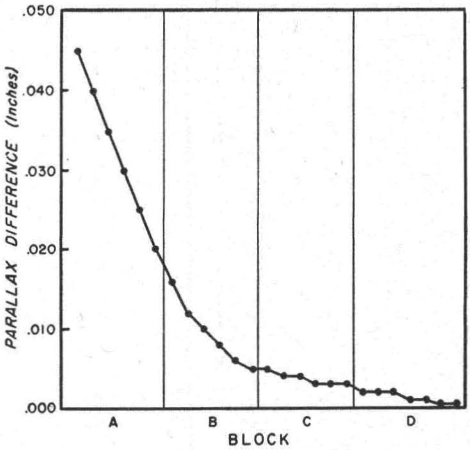

FIG. 4.—Relative heights (parallax differences) of the floating circles in the 4 blocks.

report, the results compared very favorably with the tests discussed here.

Of the 176 persons tested, five had so little stereo vision that they received a grade of zero on the numerical test. Their grades were not included in the averages and percentages shown in table 1.

ESTABLISHING A STANDARD

On the basis of the 171 pilot tests alone it would be difficult to say conclusively what an individual's rating meant in terms of his capability for a specific job. However, supplementing the results of the tests by past experience and by standards accepted by many photo interpreters will help shed some light on the subject.

Although, as indicated by this test, some people can recognize parallax differences of less than 0.001 inch, most photo interpreters agree that 0.002 (0.0508 millimeters) is about the limit of their ability to measure parallax difference on contact prints. This practical limit has been recognized in the design of the Forest Service parallax wedge with its minimum graduation of 0.002 inch. So a photo interpreter who is to measure spot heights or plot contours from aerial photos should be able to recognize 0.002-inch parallax differences most of the time.

On the rating scale curve, an interpreter who correctly identified all floating circles with more than 0.002-inch, and two out of three of those with 0.002-inch parallax difference would receive a rating of 80. The

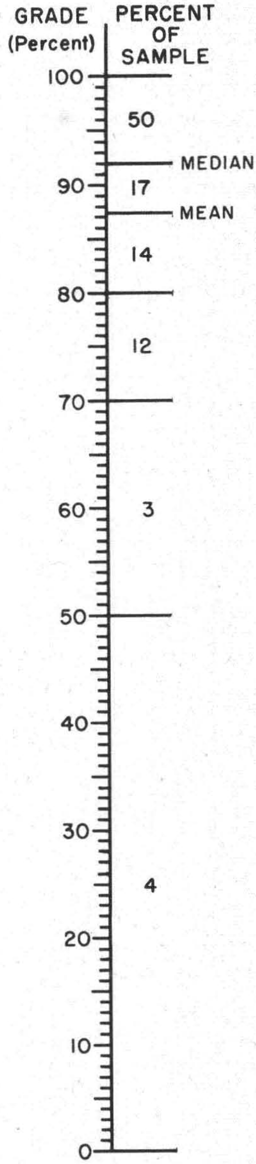

FIG. 5.—The normal rating scale.

rating scale indicates that more than 80 per cent of all persons tested received this rating or better.

A grade of 80 then seems a logical choice for a lower limit of persons capable of becoming fully qualified photo interpreters. This grade may be varied somewhat by further research, but it would appear that anyone who received a rating much lower than 80 would surely be handicapped as a photo interpreter.

The mean and median grades for the entire group of 171 persons were 87.7 and 92.0, respectively. There is no significant difference (at the level of one standard error) in average grades among the five groups tested.

EFFECT OF AGE

Age did not appear to have as much influence on stereo perception as was anticipated. Although it was expected that the average grades would be highest in the younger age classes and would decline, perhaps quite sharply, in the 40-year and 50-year-and-over classes, this was not the case (Table 1). In fact in some of the groups tested, average grades apparently improved through the 20-, 30-, and 40-year age classes, with the 40-year class best of all. However, statistical analysis of these data indicates no significant difference between these three age classes.

EFFECT OF EXPERIENCE AND TRAINING

As would be expected, mean and median grades were higher for those having training and experience than for those having neither. This difference is obvious in the distribution of test grades. Almost twice as great a percentage of trained and experienced persons received a perfect score. and there was a 50 per cent increase for those receiving 90 or better.

EFFECT OF GLASSES

About one-third of the persons tested normally wore glasses and took the test while wearing them. Although the mean and median grades were somewhat better for those who did not wear glasses, the difference was most marked for the inexperienced group and was not significant for the test as a whole. The distribution of test grades indicates a larger percentage of those who did not wear glasses received a perfect score. However, this relationship is reversed for the score of 90 or better,

TABLE 1

AVERAGE AND MEDIAN GRADES BY AGE CLASSES FOR 171 TESTS

Age class (years)	Number	Average	Median
		Per cent	*Per cent*
Less than 19	15	87.5	92
20–29	89	87.3	92
30–39	43	87.3	92
40–49	16	91.7	96
50+	8	87.0	90
Total	171	87.7	92

and of little importance for a score of 80 or better. It seems apparent that the use of glasses does not seriously impair stereo perception.

CORRELATION BETWEEN SUCCESSIVE TESTS

One measure of the reliability of any test is the similarity of results attained when the test is repeated a number of times. If the reliability of the test is perfect, similar results should be obtained when the test is given twice; the coefficient of correlation should be 1.00. Allowing for chance variation, a coefficient exceeding 0.9 is considered very good.

Twenty-two of those who took the first test were asked to take a repeat test using a similar stereogram but with the floating circles rearranged. The coefficients of correlation were 0.93 for all tests, 0.92 for those with experience, and 0.97 for those without training or experience.

COMPARISON WITH OTHER TESTS

For purposes of comparison, two other simple "tests" for stereoscopic perception were also included in the pilot test along with the floating-circles stereogram. The first of these consists of a stereoscopic line drawing of two pyramids (Figure 6).

FIG. 6.—Inverted-pyramids test.

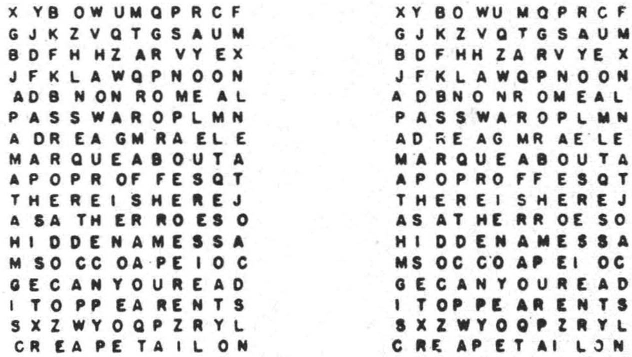

FIG. 7.—Hidden-message test.

These pyramids were drawn so that in stereo one of them appears upright and the other appears to be inverted. The problem is to identify which is which. This test was deliberately complicated by changing the apparent source of light in the second pyramid.

The second test consists of two banks of duplicate letters, certain of which have been shifted slightly (Figure 7). When viewed in stereo the reduced parallax of the shifted letters makes them appear to float above the datum plane formed by the balance of the letters. The message thus formed is visible only to those persons with some stereo perception.

As a testing device, simple stereograms, such as the two pyramids, are not very satisfactory. At best they can only separate those who cannot see stereo from those who can. And to anyone with a knowledge of perspective or parallax, the positioning of the pyramids is obvious without stereo vision. Furthermore, in a large number of tests, half should pass on pure guesswork.

A comparison of this test with the floating-circles test indicates the mean grade of the 33 per cent who failed the pyramid test varies little from the mean grade of those who passed. In another comparison (Figure 8) we find that all the experienced persons who made a perfect score on floating circles also correctly identified the pyramids. but only 68 per cent of the inexperienced with perfect scores did. This difference is less pronounced but still evident at lower grade levels. Obviously the pyramid test is a poor device for testing stereo perception in inexperienced persons.

The hidden-message type of stereogram is somewhat better. Pure guesses will not give correct answers, and the message is not readily deciphered without stereo vision. All five of the individuals who were unable to read it received zero grades on the floating-circle test. This test can be used to separate those who can from those who cannot see stereo, but it is not as good a testing device as the floating-circles stereogram because it affords no measure of stereo ability.

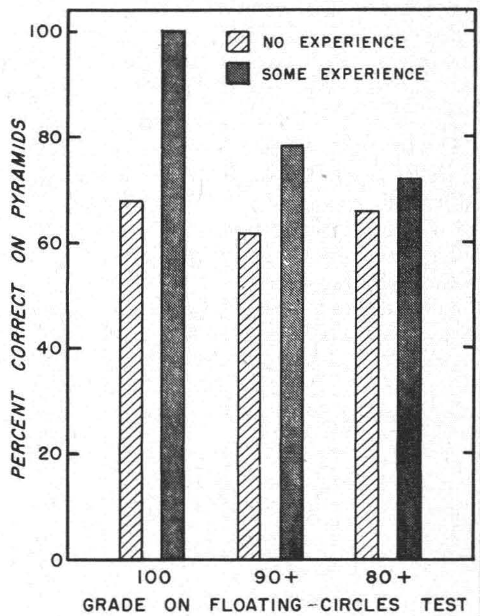

FIG. 8.—Effect of experience on inverted-pyramid-test results.

Summary

The lack of simple devices for testing stereo perception has handicapped practicing foresters, geologists, engineers, and others who employ photo interpreters. Although many technical schools now include training in photogrammetry and photo interpretation, few have adequate classroom facilities for testing the stereo perception of their students.

The floating-circles stereogram described, designed to be used with the inexpensive lens stereoscope, furnishes a practical means for testing this rather elusive sense. It is an improvement over previously used stereograms since it provides a measure of the degree of stereo perception rather than merely giving a yes-or-no answer.

The 171 tests discussed in this paper form the basis for a rating scale with a mean of 87.7 and a median of 92. Experience indicates that unless a student makes a grade of 80 or higher on the test, he will be seriously handicapped as a photo interpreter.

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Civil Engineering Department, Case Institute of Technology, Cleveland, Ohio

School of Forestry, University of Georgia, Athens, Georgia.

Appendix

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KEY TO CORRECT ANSWERS

The "floating" circles are listed below by block, row, and number. These answers apply to both Stereogram I and Stereogram II on the test sheet.

Block A: A-5, B-7, C-2, D-4, E-1, E-6
Block B: A-1, B-8, C-3, D-1, D-5, E-6
Block C: A-2, A-5, B-7, C-3, D-1, E-8
Block D: A-1, B-4, B-7, C-2, D-3, E-6
C-5.