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COMMUNICATIONS

BLOCK CAPITAL LETTERS AS TESTS OF VISUAL ACUITY*

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Discussion of Previous Results

1. In spite of the paramount importance of vision to the individual, and therefore of having accurate means of measuring visual acuity, comparatively little appears to have been done in the way of determining the best type and the best letters to use as tests, and the best methods of conducting the tests. I have found only the references I quote.

2. Previous experimenters Hay⁽¹⁾, Sheard⁽²⁾, Hartridge and Owen⁽³⁾, ranked the letters of the alphabet in order according to the difficulty experienced in reading them with prolonged exposure. They then arbitrarily made selections and recommendations. For example, Hay proposed a special type and suggested that the letters he found to be the easiest, *viz.*, A C E H L N O T, should be used. Sheard quotes the report of the Committee for standardizing Test Cards of the Ophthalmological Section of the American Medical Association. This committee suggested that 18 letters should be used (I am not clear whether they used the whole

*This work was carried out in the Psychological Laboratory of the University of Cambridge on behalf of the Committee on the legibility of Type of the Medical Research Council, who financed the inquiry.

alphabet in their experiments or not). These letters they classed in four groups in order of difficulty :

L T V U C
O Y F P D
Z N E R
S G H B,

and recommended that each line of the Test Card should contain one or two letters from each group.

3. Hartridge and Owen, on the other hand, recommended that letters of medium difficulty, *viz.*,

D T U Z F P X H N

should be used. Hartridge and Owen did not experiment with the letters G I M Q W.

4. Now though the correlation between the ranking of the letters, as found by these various experimenters may be high, it appears remarkable that "H" should be classed "easiest" by Hay, of "medium difficulty" by Hartridge and Owen, and "hardest" by the American Association. Closer examination of the various results discloses other remarkable discrepancies, some of which are set out below :

TABLE I

Ranking of certain letters in order of difficulty by previous investigators.

Letter	Hay (Hay Type)	Sheard (1) (Snellen Type)	Hartridge and Owen (2) (Green's Type)	Remarks
C	Easiest	4½	17	(1) Ranking of 18 letters. (2) Ranking of 21 letters.
O	"	6	19	
E	"	12½	4	
H	"	16½	6	
N	"	12½	5	
T	"	2	12	

5. It is true that the type was different in the three experiments, but I do not consider that this alone explains these differences in ranking. To suggest type-difference as the cause, in the absence of proof, leaves the whole question of the selection of the best letters for use in visual acuity tests in the air, while the method of selecting them—the easiest, those of medium difficulty, or those of all grades of difficulty—is purely a matter for arbitrary decision.

6. As it may be seen, these investigators ranked the letters in order of difficulty of reading and thus tacitly assumed that visual

acuity is synonymous with ability to read letters. Now in reading three factors are clearly involved :

(a) The physical formation of the image on the retina of the eye;

(b) the physiological transmission of the nervous impulses aroused by the retinal image to the visual sensory cortex, and then on to higher levels;

(c) the psychological recognition of the letter.

7. Of (b) little can be said; but that the psychological recognition of the letter (c) bears a uniformly constant correlation with the retinal image (a) is an assumption which cannot be granted in the absence of definite experimental proof. It is readily granted that there is a lack of correlation between visual images and perceptions in abnormal cases, *e.g.*, in the hypnotic state, and with the well-known optical illusions; there is a tendency to forget that the same lack of correlation between visual image and percept may occur in what may be regarded as our normal life. Hartridge and Owen hint at this factor in their paper (p. 547), where they state that they "are well aware that the recognition of a letter involves mental processes with a strong personal factor. It is quite possible that if as the result of experiment another pair of observers drew up a selection of letters of medium difficulty their list and ours would not agree. . . . It appears to us that this is a difficulty which is inseparably connected with the use of any kind of figure, letter or pattern for the purposes of Test Type." They did not attempt to solve the problem.

8. In my opinion the problem is fundamental and should be faced frankly. An endeavour must be made to account for the variations in the difficulty of reading letters if they are to be used as test objects; otherwise the tests will be untrustworthy when applied to the individual.

Object of this Inquiry

9. The object of this research was to make another inquiry as to the best letters to use as tests of visual acuity.

The Experiments

10. The experiments were of three kinds :

(a) Large-angle block capital letters (Green's Type) were exposed tachistoscopically, the whole alphabet being used;

(b) Selected large-angle block capital letters of different sizes were exposed tachistoscopically;

(c) Selected small-angle block capital letters were exposed on test cards for a long period.

The reasons for these experiments will appear below.

The First Experiment

11. The first experiment (a) was carried out on two groups of adults. The letters were drawn with Indian ink on white mill board. Each letter, with one exception, lay within a rectangle measuring 25 mm. high and 20 mm. broad, and the lines forming the letters were 5 mm. wide. The exception, "I," measured 25 mm. by 5 mm.

12. The letters were exposed tachistoscopically in random order for about 0.019 second, by means of a slit 37 mm. wide in a falling shutter. A white fixation point on the shutter indicated where the exposure would occur.

13. In the first group were 18 subjects who were seated at distances varying from 2 to 16 metres from the tachistoscope. The distances were chosen so that each subject made some mistakes in his reading. The summary of their results is given in Table II. The summary of the results obtained from a similar group of 25 subjects is given in Table III.

14. According to these results the ranking of the various letters of the alphabet in order of "difficulty" is as given in Table IV. I have added the ranking of Sheard and of Hartridge and Owen, and have marked the letters Hay found to be the easiest, for comparison.*

15. The general agreement between the results of my two groups is close, as is also their agreement with the results found by Sheard and by Hartridge and Owen; but we again find remarkable individual differences in the ranking of the letters, cf. B F K P, which call for explanation.

16. Further examination of Tables II and III brings out a new and important fact, that, though the mistakes seem sometimes to be due to random reports, *i.e.*, are pure guesses, this is by no means always true: often the mistakes group themselves, and form what I shall call a "Class." (I use the term "Class" for letters which are mistaken *inter se*, *e.g.*, C D G O Q. They have, it will be noticed, the same general outline.) It would seem that when a retinal image is produced, which is not sufficiently definite to be clearly discriminated, it is recognized as being THE letter of the group for which the individual has, probably for some psychological reason, a preference. There is one small class of two letters (F) and (P) which is illuminating in this respect. With the observers of Group 1

(F) had the rank 9, and (P) the rank 5; with Group II

(F) " " " 2½ " (P) " " 14½.

The reason, which emerges when the individual records are examined, is that the members of the one group gave more P's

* The order of difficulty for my subjects cannot strictly be inferred from these tables since omissions to make any report, which occasionally occurred, are not included.

TABLE II.—This table shows the mistakes made by the first group of 18 subjects. (136 alphabets.)

Letter Exposed	Letter Reported																										Total Mistakes
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	
A	-	2	-	-	-	1	-	-	1	-	-	2	1	1	-	2	-	2	-	-	-	1	-	-	-	-	13
B	-	-	2	10	1	-	3	3	-	-	-	2	3	7	2	4	2	2	4	-	1	-	-	1	-	-	47
C	2	1	-	2	2	-	15	-	-	-	-	-	1	1	10	-	1	-	-	-	-	-	-	-	1	-	36
D	1	3	1	-	-	1	7	-	-	-	-	2	-	1	8	2	-	1	-	1	-	2	-	-	-	-	29
E	-	4	2	-	-	4	-	1	1	-	5	-	3	-	-	1	-	2	-	1	-	-	-	-	1	-	25
F	-	-	1	-	4	-	-	-	1	-	-	1	1	-	1	10	-	1	-	2	-	-	1	-	-	-	25
G	-	2	3	1	1	-	-	-	-	1	-	2	-	4	-	4	1	2	3	1	-	-	1	-	-	-	60
H	-	-	3	1	-	1	2	1	-	-	1	-	11	15	1	4	-	1	-	-	2	1	1	-	-	-	42
I	-	1	2	-	-	3	1	-	-	5	2	4	-	-	-	-	-	1	-	3	-	1	1	-	1	-	25
J	-	-	-	1	1	2	-	-	2	-	-	-	-	-	-	4	-	-	-	2	-	-	-	-	-	-	12
K	-	1	-	1	1	2	1	4	1	-	8	1	12	-	1	-	10	-	-	-	-	2	2	1	1	-	49
L	1	-	1	2	1	-	-	-	3	-	-	-	-	1	-	-	2	-	1	-	1	-	-	-	1	-	14
M	1	-	1	-	-	-	1	16	-	-	-	-	-	31	1	1	-	2	-	1	-	-	-	-	-	-	60
N	-	1	-	-	-	-	3	-	-	1	-	6	-	-	-	-	-	-	-	-	1	3	-	1	-	-	20
O	1	-	5	17	-	-	3	-	-	-	2	2	-	-	4	4	-	3	-	2	-	-	-	1	-	-	44
P	1	-	1	-	1	7	1	-	-	-	-	4	-	-	1	-	-	-	2	1	-	-	-	-	-	-	19
Q	-	3	4	9	2	1	4	2	-	-	-	-	-	-	38	2	-	2	1	1	-	-	1	-	-	-	106
R	-	3	1	3	1	-	1	4	-	1	1	-	5	15	1	3	-	-	1	1	-	-	3	-	-	-	44
S	4	5	2	4	2	-	5	-	2	-	2	3	1	6	2	1	-	4	-	1	2	-	-	-	-	-	46
T	1	-	-	1	1	3	-	-	15	-	3	2	-	-	-	-	1	-	1	-	1	-	-	2	1	-	31
U	-	-	2	3	1	-	3	-	-	-	-	-	4	1	3	-	-	1	1	-	-	-	4	-	-	-	23
V	2	-	-	-	1	-	-	-	-	1	2	2	1	2	-	-	-	-	-	-	-	-	-	-	39	1	53
W	2	-	-	2	-	-	-	-	-	1	2	1	12	15	-	1	-	3	-	-	3	4	-	-	5	-	51
X	2	1	-	-	1	-	-	1	-	1	13	-	1	8	-	2	-	1	-	1	-	2	1	-	6	1	42
Y	2	-	1	-	-	3	2	-	-	-	3	1	-	-	1	1	-	-	-	5	-	19	-	-	-	-	38
Z	1	-	-	-	2	1	-	-	-	3	-	2	-	1	1	1	-	-	-	1	2	-	-	1	-	-	17

TABLE III.—This table shows the mistakes made by the second group of 25 subjects. (82 alphabets.)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	
A	-	-	-	-	-	-	-	-	-	3	-	1	2	-	-	-	-	-	1	-	-	-	-	-	-	-	7
B	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	4
C	-	-	-	-	1	-	7	-	-	-	-	-	-	-	6	-	-	1	-	-	-	-	-	-	-	-	15
D	-	-	-	-	-	1	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	8
E	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	4
F	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	3
G	-	2	42	2	1	-	-	-	-	-	-	-	-	-	1	-	3	1	-	-	-	-	-	-	1	-	53
H	-	-	-	-	-	-	-	-	-	-	-	4	6	-	-	-	-	-	-	-	-	-	-	-	-	-	11
I	-	-	-	-	-	1	-	-	2	-	2	1	-	-	-	-	-	-	-	2	-	-	-	-	-	-	8
J	-	1	-	-	1	1	-	2	-	-	1	-	1	2	-	-	-	-	1	-	-	-	-	-	-	-	3
K	-	1	-	1	1	-	-	2	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	9
L	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
M	-	-	-	-	-	-	22	-	-	-	-	-	-	13	-	-	-	-	1	-	-	-	-	-	-	-	36
N	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	1	-	-	-	-	5
O	-	-	2	8	1	-	6	-	-	-	-	-	-	-	-	1	-	-	-	1	-	1	-	-	-	-	19
P	-	2	-	-	-	5	-	-	-	-	-	-	1	-	-	-	3	-	-	-	2	-	-	-	-	-	11
Q	-	1	5	6	-	-	28	-	-	-	-	-	1	-	26	-	-	-	1	-	-	-	-	-	-	-	70
R	-	3	-	-	-	-	2	-	-	-	-	-	1	4	-	1	-	-	-	-	-	-	-	-	-	-	15
S	-	3	3	3	2	-	4	-	-	-	-	-	-	1	-	-	-	1	-	-	1	-	-	-	-	-	18
T	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	4	-	-	7
U	-	1	1	-	-	-	1	-	-	-	1	1	-	-	2	-	-	-	-	-	-	1	-	-	-	-	9
V	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	16
W	-	-	-	1	-	-	1	5	-	-	3	-	12	3	-	-	-	1	-	-	-	8	-	-	-	-	34
X	-	-	-	-	-	-	-	-	1	-	8	-	2	4	-	-	-	-	-	1	-	1	18	-	-	-	21
Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	21
Z	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	4

TABLE IV.—The ranking of the letters of the alphabet in order of “difficulty” as determined by various investigators.

Letter.	Rank of Letter according to the Results of				
	Banister.		Sheard (18 letters).	Hartridge and Owen (21 letters).	Hay's 'Easiest.'
	Group I.	Group II.			
A	2	8½	—	2	†
B	20	5	18	18	
C	13	16½	4½	16	†
D	11	10½	10	11½	
E	9	5	12½	4	†
F	9	2½	8	8	
G	24½	25	16½	—	
H	15½	14½	16½	5½	†
I	9	10½	—	—	
J	1	2½	—	3	
K	21	12½	—	16	
L	3	1	1	1	†
M	24½	24	—	—	
N	6	7	12½	5½	†
O	17½	20	6	19	†
P	5	14½	8	8	
Q	26	26	—	—	
R	17½	16½	14	20	
S	19	19	15	21	
T	12	8½	2	11½	†
U	7	12½	4½	11½	
V	23	18	3	16	
W	22	23	—	—	
X	15½	21½	—	8	
Y	14	21½	8	14	
Z	4	5	11	11½	

when either (F) or (P) was exposed, but was not discriminated, while the members of the other group gave more F's. I would suggest that this is the reason why Hay places (C) and (O) among the “easiest” letters while Hartridge and Owen regard them as being among the “hardest.”

Deductions from the Results of this Experiment

17. This experiment points to the tentative conclusion that, when the retinal image cannot be clearly discriminated, letters will be mistaken for those of the same class.

18. It then follows that the difficulty in reading letters is not primarily a physical difficulty due to defect in the eye, but a psychological one due to the fact that the same retinal image is associated with various objects. This does not mean that letters are unsuitable as test objects for visual acuity : on the contrary they ARE suitable if the choice of letters is determined in accordance with psychological principles, for faulty recognition will not normally occur

if the retinal image—the physical part of the act of perception which it is required to test—is distinct.

The Second Experiment

19. Granting the argument thus far it is obvious that two methods are available for the choice of letters—the letters must either : (1) belong to the same class, *e.g.*, C D G O Q, and each letter must be discriminated (Class Test); or they must

(2) belong to different classes, and class recognition alone must be required (Individual Test), *e.g.*, D and M may be taken as belonging to separate classes : D to the class C D G O Q; and M to the class H K M N W. Either C or D or G or O or Q will be considered correct when D is exposed; similarly either H or K or M or N or W will be considered correct when M is exposed.

20. From Tables II and III it appears that the two largest classes are C D G O Q and H K M N W, giving ten letters in all for the "Class" test; while the ten letters A D E F I J L M X Z appear to be in sufficiently distinct classes to justify their use in an "Individual" test.*

21. With these groups of letters I carried out the further experiments (b) tachistoscopically, and (c) with test cards.

22. For these two experiments with selected letters I used the same type as before, but the dimensions of the letters were reduced photographically : the sizes were chosen arbitrarily to be those on the last four lines of one of Curry and Paxton's Test Cards. The sizes were : D.=9; =6; =5;

23. The subjects were a group of 20 boys from the highest class of one of the Cambridge Secondary Schools. Their ages ranged from 14 years 7 months to 15 years 11 months. Three of the boys, whose sight was not normal, wore spectacles.†

24. The experiments were carried out in the school hall. For the tachistoscopic experiment (b) the letters of the two groups were exposed by means of the tachistoscope already described, all the letters of the four sizes being exposed each day. The order in which the different sizes were exposed was a random one, being decided by the order of the last figures in logarithm tables read downwards : the order of the letters was likewise random.

25. The boys were seated in three concentric arcs, at distances of 3, 4, and 5 metres from the tachistoscope. Each boy had a screen on his right, to minimize the possibility of an unintentional glance at a neighbour's report, and wrote down on a specially prepared form what he saw.

* When carrying out the "Individual" test, subjects were informed that the letters C G H K N O P Q W would not be exposed.

† I wish to acknowledge my indebtedness to the Head Master, Mr. Martin, for his willing help.

26. The experiment was carried out on six mornings : the last five records only are considered in what follows, the first day's records being regarded as practice. The illumination each day was daylight, and varied from 110 to 120 foot-candles as measured on the surface of the card.

27. The results of these experiments are given in Table V.

TABLE V

This table shows the numbers of letters read correctly by each observer in the tachistoscopic experiment with selected letters.

Maximum possible, for each observer with each size of type, 50.

Observer.	Class Test.				Individual Test.			
	Size of Type D.=				Size of Type D.=			
	9	6	5	4	9	6	5	4
I ...	41	29	18	13	50	44	34	31
II ...	42	23	20	18	48	38	29	27
III ...	48	37	34	23	50	50	46	42
IV ...	41	27	28	16	50	50	47	42
V ...	48	33	30	21	50	49	47	40
VI ...	34	18	14	9	50	44	30	22
VII ...	37	22	7	7	49	41	28	16
VIII ...	44	26	17	12	50	46	39	27
IX ...	40	28	32	20	50	48	46	39
X ...	49	34	21	19	49	41	32	22
XI ...	37	22	12	12	50	44	37	29
XII ...	46	31	31	17	50	50	46	45
XIII ...	47	40	34	26	50	50	45	37
XIV ...	46	35	21	19	50	49	44	39
XV ...	45	33	22	13	48	43	32	25
XVI ...	42	29	21	17	49	43	38	27
XVII ...	43	30	33	26	50	46	43	39
XVIII ...	42	32	19	10	50	49	41	20
XIX ...	47	38	23	32	50	50	47	46
XX ...	41	31	14	11	50	45	32	24
Total ...	860	598	451	341	993	920	783	639

Discussion of the Results

28. The figures show that the Class Test is much more difficult than the Individual Test : the total number of letters read correctly in the Class Test is 2,250 out of 4,000 ; in the Individual Test the number read correctly is 3,335 out of 4,000.

29. Another noticeable fact is that the rate of increase of mistakes with smallness of type is more rapid with the Class Test than with the Individual Test. The difference is perhaps not so great as would appear from a casual glance at the table, for the falling off in the second test is minimized by the fact that many subjects could read the second largest type in this test correctly. A better comparison will be obtained if all records are omitted where less than 80 per cent. correct replies are given for the largest type ($D.=9$) and where more than 90 per cent. correct replies are given for the next type ($D.=6$). These corrected figures are :

	Class Test.				Individual Test.			
	Size of Type $D.=$				Size of Type $D.=$			
	9	6	5	4	9	6	5	4
Number of correct replies	752	536	418	313	443	383	292	223

30. It is seen then that with the Class Test the number of correct replies for the fourth type ($D.=4$) is 42 per cent. of that for the first type ($D.=9$); with the Individual Test the number of correct replies in type four ($D.=4$) is 51 per cent. of those for type one ($D.=9$).

31. The inference to be drawn from this is that for test purposes it is better to use letters chosen from the same class or classes rather than letters chosen from different classes, since the former test, having a greater rate of increase of mistakes, will give a sharper line of demarcation between the letters which can be read correctly and those which cannot.

32. Another very important reason why the Class Test is to be preferred to the Individual Test also emerges from this experiment, though it is not evident from Table V. A reference to Tables II and III will show that the letters E and Z were not classed together by these two groups of subjects; but with this third group of boys a new Class (E) (Z) makes its appearance. I thought this might possibly be due to an "age" factor—not that that would alter any deduction which might be made from the experimental fact—but a fourth group of 12 adults whom I tested later also produced an (E) (Z) Class.

33. Now if new classes may make their appearance in this rather unexpected manner it is obvious that, when using the Individual Test, the investigator may think he is using letters of

different classes, but he can never be sure that the assumption holds for the given individual. Unless he can be sure of this, the test must be untrustworthy.

Deduction

34. The conclusion, therefore, which is finally reached is that the letters to be used as tests for visual acuity should not be chosen from those found experimentally to be of equal difficulty. They should be the letters belonging to one or two classes—classes which are possibly universal.

Further Matters and the Third Experiment

35. The objection may be raised that the tests are tests of perception and not of visual acuity. That is so, but except in abnormal circumstances, errors in perception will not be found when the retinal image can be clearly discriminated. It seems probable that the errors of the nature I am discussing—reporting “C” when “G” or “O” is exposed—normally occur only when the retinal image is no longer distinct. This point may therefore be taken as a measure of the visual acuity of the individual.

36. Another objection which is likely to arise is: the test, as suggested, will be one of ability to discriminate small differences. Will this not be found to vary with the “Intelligence” of the individual? To try this out I tested the group of boys using a Group Test (*see* Appendix), and correlated the intelligence-ranking with the ranking in falling off in discrimination, counting as highest the one whose percentage fall, *i.e.* :

$$\frac{\text{Marks obtained with smallest type}}{\text{Marks obtained with largest type}} \times 100$$

is the highest. The correlation coefficients are $+0.09 (\pm 0.015)$ for intelligence and the class test, and $-0.01 (\pm 0.15)$ for intelligence and the individual test.

37. I do not, of course, place any great reliance on this result; but, such as it is, it does not show any evidence of the acuity ranking being affected by intelligence as measured by the test I gave.

38. Objection may also be raised to the method of testing. The tachistoscopic test is very different in nature from the usual test card. In the former test a large-angle letter is exposed momentarily; in the latter a small-angle letter is exposed for an indefinite length of time. It is not permissible to assume that the effect obtained by a large short-duration image is the same as that from a small long-duration image. This is a reasonable objection, which is on analysis twofold :

(a) that the errors in recognition may not be of a similar nature in both cases; and

(b) that, if the mistakes are of a similar nature, it does not follow that the results of testing agree, *i.e.*, the visual acuity measured by the tachistoscopic method may not agree with that obtained by the Card Test.

39. To decide this point I carried out my third experiment, using test cards obtained from Curry and Paxton and my own cards made up as "Class" and "Individual" tests. The experiments were, as before, carried out in the school hall, the boys were seated in rows at distances of from 5 to 7 metres from the cards. An examination of the results shows that the first objection is not valid. The mistakes made in recognition, when the letters are becoming difficult to discriminate, are of the same nature whether the exposure is made tachistoscopically or otherwise. I give in Table VI a classified list of the mistakes made with the test cards. It has to be remembered that all the letters of the alphabet were not used, and that the various letters were not exposed an equal number of times. But the point I wish to emphasize is the nature of the mistakes. Letters wrongly reported tend to be those of the same "Class." For example from

				Table II	Table III	Table IV
it is seen						
that C was	mistaken	for	G	15 times	7 times	24 times
" G	"	"	C	37 "	42 "	23 "
" H	"	"	M	11 "	4 "	22 "
" H	"	"	N	15 "	6 "	11 "
" M	"	"	H	16 "	22 "	26 "
" M	"	"	N	31 "	13 "	20 "

40. The second criticism I have not been able to decide finally. Owing to school examinations and holidays I was able to obtain only one set of readings with the card test which can be compared with the tachistoscopic test. The correlation coefficients between the ranking of the boys of the three rows in order of their visual acuity according to the results of the five tachistoscopic exposures and the card test are $+0.51 (0.226) \pm$; $+0.19 (\pm 0.18)$; $+0.68 (\pm 0.13)$ which would seem to suggest that this objection is not of importance. Results of experiments published elsewhere⁽⁵⁾ also indicate that this objection is not valid.

41. On the face of it, it would seem that the two methods may be taken as testing the same general physical factor of visual acuity. But even if the tachistoscopic and card tests are not found to correlate very closely it still seems to me a very moot point

whether the former is not the better test to apply. Without any doubt the tachistoscopic test approximates very much more closely to normal conditions. It is but seldom that one has to gaze for a long time at an object, which gives a small retinal image, in the attempt to recognize it.*

The usual situation, whether in the study or in the field, is a relatively large image and a short exposure. Anyone who has

TABLE VI.—Mistakes made by 20 boys when tested with test cards.

Letter Exposed	Letter Reported.																									
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	-	-	-	1	-	-	1	1	1	-	-	-	-	1	5	-	1	-	2	-	-	-	-	1	-	-
B	1	-	-	2	-	-	2	-	-	-	-	-	1	5	-	-	-	-	-	-	-	-	3	-	-	1
C	1	-	-	3	1	24	-	-	1	-	-	-	-	6	-	1	-	-	-	-	-	-	-	-	-	1
D	-	11	-	3	2	-	2	-	-	-	-	-	2	3	6	-	-	1	-	-	-	-	-	-	-	-
E	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-
F	-	1	-	1	-	-	-	-	1	-	-	-	-	1	8	-	1	-	5	-	-	-	-	-	-	-
G	-	-	23	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
H	-	-	1	2	-	-	-	-	-	-	-	-	22	11	-	-	-	-	-	-	-	-	13	-	-	-
I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
J	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
K	3	-	1	4	-	-	-	-	1	-	-	-	1	1	-	-	-	-	-	-	-	-	6	-	-	-
L	1	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-
M	-	1	-	1	2	26	-	8	-	2	-	-	20	3	-	1	-	1	-	-	-	11	1	-	-	-
N	2	-	1	-	-	-	-	-	-	1	-	46	-	-	-	1	-	5	-	2	-	-	9	-	-	-
O	-	2	16	4	-	16	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
P	-	-	-	-	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q	2	-	7	1	-	33	-	-	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-
R	2	-	-	1	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-
U	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
V	-	1	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	11	1	-
W	-	-	1	-	-	-	1	-	7	1	-	1	-	5	-	-	-	-	2	-	-	5	-	1	-	-
X	6	1	-	2	-	-	1	7	1	-	1	-	-	-	-	-	-	-	-	-	-	2	-	1	2	-
Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-
Z	-	2	-	12	-	-	1	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-

worked with test cards at limiting distances knows how the letters seem to become blurred and to disappear, as is to be expected.

42. There are obvious objections to the form of tachistoscope used. The chief is that the eye of the subject tends to follow the mark on the sliding shutter as it falls. A second is that the exposure is shorter for the lower than for the upper parts of the test letters. These defects can easily be overcome by using a

* I have had considerable experience with hunters and trackers in India who have proverbial good sight, and have found that their phenomenal sight consists in having the perceptual side highly developed. After a period of training, I have been able to see and "spot" game with at least equal facility. The same is undoubtedly true of the best signallers who have to interpret semaphore and heliograph messages.

tachistoscope of a different pattern. I would suggest that, as has already been suggested elsewhere⁽⁵⁾, tachistoscopic exposures should be used in further experiments of this nature. It would be an advantage if tachistoscopic exposures could also be used for clinical work owing to the comparatively small amount of eye strain involved.

43. The well-known effect of changes in the illumination on visual acuity *vide*⁽⁵⁾ is illustrated by the result of a set of exposures I gave to the 20 school boys on a wet day when the illumination on the card was 10 foot-candles, as compared with the usual 110-120 foot-candles. The average numbers of letters read correctly (Tachis. Class Test, possible 40) were 11.6 with a mean variation of 3.56 on the wet day, and 22.4, with a mean variation of 3.32 on the bright days. It will be noted that the "Scatter" of the individual readings, as measured by the mean variation, is proportionately more than twice as great when the illumination is poor as it is when the illumination is good. Without further research I am not prepared to suggest any cause for this; but it emphasizes strongly the necessity, when testing vision, of standardizing the illumination.

Summary

44. Previous investigations as to the best letters for use in tests of visual acuity have led to discordant results.

45. From this inquiry it appears that the discordance is chiefly due to the fact that errors in naming letters have been assumed to be due to physical faults in the eye, whereas they are much more frequently due to psychological causes: a given retinal image, *e.g.*, of the letter "C," if not quite clear and definite, being named "C," "D," "G," "O," or "Q" by a given individual for psychological reasons which it is not possible to foretell.

46. These experiments indicate that the letters which are most suitable for use as test objects are those which are mistaken one for the other, *e.g.*, C D G O Q and H K M N W.

47. It is also suggested that, when applying the tests, a tachistoscopic exposure of the letters may be found to be better than the present system of test cards which entails prolonged exposure.

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APPENDIX

1. Put a nose on this face :
2. Put a dot below this line : _____
3. Write g on the egg-shaped figure :
4. Make a boy's name by adding one letter to Joh
5. Make two crosses under the shortest word in this sentence.
6. If 3 and 7 added together are less than 12, put the figure 2 between these two dots . . .
7. If Tuesday comes after Monday, make two crosses here, but if not, make a circle here or else a square here
8. Show by a cross when the nights are longer : in summer ? in winter ?
9. Notice these two numbers : 3, 5. If iron is heavier than water, write the larger number here, but if iron is lighter write the smaller number here
10. In *this* sentence, there are precisely forty-eight letters.—If a particular word in the sentence had been omitted, the number of letters would have been forty.—*Find the word referred to and put a line under it.*
11. If in the following four words **e** comes just after **a** more often than just after **i**, then underline each word containing both an **e** and an **i**; but if **e** comes just before **a** more often than just after **i**, then underline each word containing both an **e** and an **a** :
 receive feather teacher believe
12. A list of words is given below. One of them is needed to complete the thought in the following sentence: The roads became muddy when the snow
 Do not put the missing word in the blank space left in the sentence, but underline the word in the list which is just above the word needed in the sentence.
 water
 is
 melted
 snow
13. You are looking at a clock face in a mirror.—Write the time now indicated on it on this line