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Eric Stuart Bruce M.A. Oxon

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THE RELATION OF PERSISTENCE OF VISION TO MODERN RAPID VISUAL SIGNALLING.

By *ERIC STUART BRUCE, M.A.Oxon.*

Thursday, February 2nd, 1899.

Lieut.-General Sir ANDREW CLARKE, G.C.M.G., C.B., C.I.E., R.E.,
in the Chair.

ANYONE who watches a body of soldiers signalling with flag, lantern, or heliograph, cannot fail to be impressed by the intelligence, agility, and skill displayed. It is a performance involving not only accurately timed movements of arms or hands, but an arduous exercise of what is the most subtle, sensitive, and highly complicated sense-organ created by Nature—the retina of the human eye. The efficiency which has been attained in modern rapid visual signalling in the ideal possibility of twenty words a minute and the practical working of twelve words a minute, is the result of considerable labour and time expenditure on the part of those who are responsible for the selection and training of signallers, for though there are more difficulties than one to be contended with in the production of a reliable signaller, there is one master difficulty which makes the process of selection laborious, tedious, and often disappointing. This is a difficulty arising from a property inherent in the retina of the human eye, and which is called Persistence of Vision. I venture to think that any system which tends to alleviate the burden which this optical fact imposes upon the instructors of rapid signalling, will have the consideration of a Government which before all others has realised the necessity of inter-communication in the operation of war and excelled in its development.

I have taken for granted that all here present know that by persistence of vision I mean the retention by the retina of the impression of any object for a short time after the object itself has been withdrawn. The images which thus remain on the retina after the exciting cause is withdrawn are called sometimes positive accidental images, sometimes incidental images, and sometimes consecutive images.

We can recognise persistence of vision without the aid of any instrument. Were it not for persistence of vision the rain shower would be falling drops, not lines of water; the meteor in the skies would be bereft of its glories, being merely a fiery ball leaving no glittering path behind it; and in man's imitation of a meteoric shower—a display of fireworks—the most elaborate Catherine-wheel ever designed would resolve itself into a few points of fire. Foremost amongst the older instruments designed to illustrate persistence of vision was the Zoetrope. In this, successive positions of the bodies of men and animals in motion were in turn so rapidly brought before the retina that the synthesis of the various impressions gave a fairly lifelike representation of the actions of the subjects. But now the Zoetrope has been improved into the Cinematograph, in which instantaneous photography supplies faithful representations of the different positions of objects in motion, and in place of the puppet-like performance of the Zoetrope we have photographs which come to life, and any past scene, whether it is the bustle of a railway station, the execution of a ballet on the stage, the breaking of a tempestuous sea on the shore, or the grim realities of a naval engagement, can be preserved and re-acted for the delectation of posterity. It has been my privilege to add another instrument to the list of those devised for illustrating persistence of vision. My claims for novelty and usefulness in the instrument I have invented and called the Aerial Graphoscope are :—

1. While it shows the general effects of persistence of vision in a striking manner so that a whole audience can see them, it carries its penetrative qualities of instruction further than the older instruments designed to illustrate the phenomenon; for instance, it appears to be the only instrument which shows the difference in intensity between the real image and the incidental image, and the gradual fading from the retina of incidental images.
2. It forms a most delicate test of the exact duration of persistence of vision on the individual retina, and it is in this second capacity that it applies to the subject we are specially dealing with this afternoon, viz., the relation of persistence of vision to modern rapid visual signalling.

Before I treat of the special application of this instrument for measuring the duration of persistence of vision, I will explain the general action of the instrument to you, and show you how it emphasises the existence of persistence of vision.

The vital principle of the instrument is this narrow lath of wood, painted white in front, with a grey centre gradually diminishing in shade to white. This lath can be rapidly revolved at its centre by means of a multiplying wheel or, if it is preferred, by an electric motor. On the lath, which is now at rest, I throw a small portion of a magic-lantern picture representing a statue. When the lath is revolved rapidly you see the

whole picture before you apparently in space [experiment shown], the explanation being that as the lath revolves it receives the different parts of the picture in turn. Owing to the fact that the retina of the eye retains for a short time any impression presented to it, the various portions have not time to fade before the whole picture has been successively projected on to the lath. The picture therefore does not really exist as a whole in the place where it appears. As a whole it emanates from each one's retinal organ and is developed by each one's individual powers. It may therefore be correctly described as an image in space, and its ghostly character is made apparent when I place this lighted candle behind the revolving lath, the real objects being seen through the vision.

When a lath of 76 centimetres long and 5 centimetres broad was revolved by an electric motor placed 1 metre 14 centimetres from the nozzle of the lantern, the number of revolutions per half-minute required to produce a really steady image was 318. The lath used this afternoon is 5 centimetres wide, so as to obtain a very brilliant picture, but the persistent image is obtainable by using a surface of only 1 millimetre in width.

I can further impress upon you how vividly this instrument shows persistence of vision by a series of experiments. I take out the slide from the lantern and revolve the lath, thus obtaining a phantom disc. When I let the little ball fall between the lantern and the incidental disc we see four shadows of the falling ball at the same moment. When I revolve this iron ring we see a number of distinct rings at the same time. When I take this piece of zinc, with a slit in it, and project the slit on the disc, moving it backwards and forwards in the lantern, the image of the slit is not only multiplied, but so distorted as to give the appearance of hieroglyphic writing. I have mentioned that the apparatus shows the difference in intensity between real and incidental images. When we consider persistence of vision in its relation to army signalling we shall see that the distinction between real and incidental images is of great importance, so I will now make it manifest to you by means of this instrument.

You will have noticed that the centre of the lath is tinted grey, gradually diminishing in shade to white from the centre towards the extremities. This has been done to preserve the artistic effect of any picture thrown upon it. It is, in fact, there to reduce to some extent the effect of the variance in intensity between the real and the incidental image; to give the centre of the picture as far as possible the same intensity of illumination as the outer portions. The centre of the lath in revolving is always before the eye. Here there is no incidental image. When there is no picture in the lantern and only the bright disc shown, though that centre is tinted grey, there is a brilliant centre in the disc, white in comparison with the outer portions. Here you see the difference in intensity between the real and incidental image. Let me call your attention also to the diminishing intensity of the illumination of the disc from its centre towards the extremities as it becomes less and less

re-inforced. This shows the gradual fading from the retina of incidental images. I now fix a piece of white paper upon the central portion of the lath and then throw a picture upon it as it revolves. The contrast between the central portion and the rest is still more strongly marked.

The exact time that the persistent image remains on the retina varies with the intensity of the illumination with which objects are perceived and with the sensitiveness of the individual retina. Probably also, the perception of persistence varies with the sensitiveness of that complex mechanism which connects the rods and cones of the retina with the grey matter of the brain. It is conceivable, too, that the brain itself has a part in determining the time of persistence. Other circumstances are also responsible for variation in the duration of persistence. By means of actual tests that I have taken with the Aerial Graphoscope the same person can have a very different capacity of persistence of vision at different times of the day according to the circumstances under which he is placed; for instance, within a few minutes his capacity of persistence of vision may widely differ if within those moments he has taken violent physical exercise. In many cases persistence of vision shows different durations for objects viewed under the light of different colours. It also varies with the condition of the retina at the moment. Persons who have rested the retina by being in the dark show a different capacity from that shown when the retina is more fatigued. I have mentioned that the Aerial Graphoscope affords a most delicate test for ascertaining the time of persistence on the individual retina. In this respect, the apparatus promises to be useful not only in physiological laboratories but in schools of army and navy signalling as a means of testing the retinas of would-be signallers as to their capacity of persistence of vision.

The tables before you refer to some hundred tests I have taken with sixty-seven persons under varying conditions. We have seen that to produce a good steady image on the incidental disc a speed of some 318 revolutions a half-minute is desirable. The persistent image is, however, visible, though not steady, at a much lower rate than that, the exact rate being a matter of individual capacity. If we ascertain the rate of revolutions at which each individual can just see persistence, we can calculate his particular capacity of persistence.

The arrangement of apparatus I have employed for the purpose is as follows. A lath 76 centimetres long and 5 centimetres broad was revolved by an electric motor, provided with means of counting its revolutions. The motor was worked by means of a 5-cell electric storage battery, through a resistance with sliding contact. The lath was placed 1 metre 14 centimetres from the nozzle of the lantern, in which there was an oxyhydrogen blow-through jet. In the lantern was placed a slide representing a statue. I have this arrangement here. I will commence revolving the lath 27 revolutions the half-minute. At this speed some persons in the audience probably see a complete image of the statue, others require a faster speed. I therefore move the sliding contact so

that more resistance is thrown out of the circuit. The lath revolves faster and faster, thus accommodating the capacities of the various retinas in the audience, until we reach a point when the statue is visible to the whole audience.

Table I. shows a group of 25 tests I took in 1895. The low rate of 27 revolutions per half-minute, at which the persistent image was just visible to myself and assistant, both accustomed to observe the incidental disc, was taken as the lowest limit for the test. This was the mean of four readings, the variations in the running of the motor being but slight. The persons taken for the test were of both sexes and of various ages and classes, and described themselves as of good sight, except two marked on the list. None wore glasses. In the Tables I. and IV., M stands for male, F for female. The apparatus used for the earlier tests of Table I. was somewhat more rough-and-ready than that employed for the later groups; but I consider the results of the tests sufficiently accurate to quote, as several of the tests were the mean of four readings, the variations in the running of the motor being but slight. I may also add that one person that I had tested with the rougher form of apparatus came out the same when tested again with the more improved arrangement. In this group you will notice that 14 of the 25 persons could see the persistent image at the low test rate selected, viz., 27 revolutions per half-minute. This gives a long persistence on the retina—as much as 2·2 seconds. In making these calculations it was necessary to remember that the lath being revolved at its centre, each part of the picture is re-inforced twice during each revolution. The shortest persistence on this list is ·652. The reason for the high readings is doubtless the brilliant oxyhydrogen light employed in the lantern, and placed at such a short distance from the revolving lath. They show that one of the most determining factors in the duration of persistence of vision is the intensity of the illuminant under which objects are seen, and that the quotation of any average for persistence of vision such as $\frac{1}{30}$ or $\frac{1}{36}$ of a second, without any reference to the nature of the illuminant, is exceedingly vague.

The results of Table II. are of special interest, as it tabulates tests of 26 subjects before and after bodily exertion. The subjects were school-boys selected from various schools. They all undertook to be tested first, in their normal condition, and secondly, immediately after violent exercise in the form of running for several minutes. No one was tested the second time until he was panting for breath. In the results of these tests it will be noticed that the persistence of every subject was altered by running except one, who registered the same figure, viz., 1·05 in each case. The record of seven was lowered, but that of nineteen was heightened. From this result it would seem that bodily fatigue tends to prolong persistence of vision, which I believe is the tendency of illness. These tests have not been treated in any way from a medical point of view, but I may point out one case appearing in Table IV. of a person enjoying perfect health, who said she had never known a day's illness in her life; she comes out at 1·39, a medium reading.

As I mentioned in my recent lecture on persistence of vision at the Society of Arts, it would seem that the varying durations of persistence of vision in different individuals and under different circumstances tend to support the photographic theory of vision, which seems to have had considerable confirmation from certain experiments with X-rays on the retina—shadowgraphs having been observed on the retina, as if it were a sensitive plate. Since by this theory an actual photograph of everything we see is fixed on the retina by one chemical process, and removed by another, may we not suppose that these chemical processes would go on at the same rate in the retina of different persons, and that the rate of the removal of the visual photographic image corresponds to the rate of the removal of what we call the incidental image? Perhaps also it is reasonable to expect that after the system has been weakened by bodily exertion, the speed of the removal of the photographic image would be lowered.

Table III. shows tests made under different colours compared with white light, the rays from the lantern passing through red, green, and violet glasses. These tests were made with five females. Those marked in the table * are the mean of three readings. The reason why I occasionally took the mean of three readings was not that the subjects were undecided, but because I was anxious to be sure of the accuracy of the tests by obtaining several uniform runnings of the motor. It is satisfactory to state that the motor gave very uniform readings, coming out time after time exactly the same figure. With regard to these colour tests, there have not yet been a sufficient number of tests to lead to any definite conclusion, though in most cases a different reading is obtained.

The first three persons who were tested for colour were also tried after the retinal rest produced by being kept in the dark for some minutes. The first two give a higher reading of persistence than under white light, the third a lower. No. 1 of Table IV. is remarkable as having taken the highest number of revolutions in the half-minute to see persistence, the figure being 101. She described herself as being of good sight. In this list two tests of persons wearing glasses are tabulated, the persistence of one comes out at 1·304, the other at ·779.

To pass now to the main point of this lecture, the bearing of these facts upon modern rapid visual signalling : When I move my hand rapidly backwards and forwards in front of this candle, the flame is alternately hidden from and exposed to view, but you see the candle flame all the time, owing to persistence of vision. Thus in the same way, a light inside a signaller's lantern is visible, through persistence of vision, when the shutter obscures the actual light from reaching the eye. In reading the signals, the signaller is discriminating between real and incidental images, a rather delicate operation, for I have shown you by an experiment the difference between real and incidental images is one of degree of illumination. It seems evident that the signaller's sharp reading of dot and dash will depend upon the persisting capacity of his retina. Is not, therefore, a good signaller likely to be one whose persistence of vision is

abnormally low? According to this theory, No. 1 of Group IV. would be the best signaller. No. 8 represents the reading of a highly trained signaller, which is '76.

It would seem that one of the most important tests for a signaller is that of his persistence of vision—a test which has not been hitherto applied. In a lecture delivered by Colonel Keyser before the members of this Institution on 10th February, 1893, he says that out of a batch of twenty men struck off to form a signalling class, the average number who are likely to prove of any use as efficient signallers is seldom more than three. The reason of this small proportion being qualified to serve as signallers is explained by the tables before you. This is, doubtless, the varying capacity of persistence of vision in different retinas. It is for detecting the differences that I propose the use of the Aerial Graphoscope in the hands of the signalling instructors. Its possible value in this respect was, I think, completely summed up in the discussion which followed my recent paper at the Society of Arts by one who has had vast experience of army signalling in peace and in war. I venture, therefore, to quote the words of Colonel Keyser as published in the *Journal of the Society of Arts*, 21st January, 1898. He says:—"It might afford a means of testing men for persistence of vision, and so save the instructors a great deal of time and trouble by weeding out men who would necessarily fail in the final examination, not for want of diligence or attention, but simply because they were physically incapable of ever making good signallers."

But it would seem that the subject should not only be tested under ordinary circumstances, but under all kinds of conditions, such as after fatigue. Perhaps those only should be selected whose persistence exhibits little fluctuation under a variety of circumstances. For instance, in the fatigue list, No. 4, being '821 before running, and 1'304 after running, would hardly be a fit subject for a signaller. A fitter one would be No. 8, being '659 before running, and '612 afterwards, combining a low degree of persistency with a not very great divergence under the two circumstances.

The possible modification of a signaller's capacity for persistence of vision after fatigue may explain unexpected deficiencies in signalling, which may have been in the past ascribed to indolence or carelessness on the part of an individual. This fatigue list seems to emphasise a necessity for signallers pointed out by Colonel Keyser in the discussion following Colonel Kennedy's paper on Army Signalling, 30th April, 1897. He says:—"I have always held that signallers should be carried if possible. You must remember that the work of a signaller begins after the marching is over. I have often seen signallers after a long and weary march, before they have been able to have a wash or have anything to eat, sent off at once to occupy a new post some miles away, and very often with a very stiff up-hill climb. I think all signallers should be carried in some way or another. Cycles, certainly where there are roads, or where it is suitable country, might be used. Of course, in a hill campaign like Chitral, or

some of the other Indian campaigns; it would be utterly impossible to use cycles, but there the signallers might be mounted on mules, or very small common bazaar ponies, which would not cost very much, and I am sure the extra work which you would get out of the signallers would more than repay the trouble and expense of mounting them."

But the fatigue tests show that it is not merely the relaxation of the mental energies, which always more or less accompanies bodily fatigue, that has to be grappled with. This may be overcome by a determined will and rigorous application. It is the alteration in the working of the retinal mechanism after exertion that has to be feared, for this may transform an apt and skilful signaller into one that is useless and an encumbrance.

Since signalling with flags is more fatiguing than signalling with lantern or heliograph, the former method of signalling would seem to tend to diminish the competency of the retina sooner than the latter. It would be interesting to hear the opinion of those who are practised in signalling, as to whether they have noticed that a difficulty in reading signals arises sooner with the flag method than with instruments merely manipulated by hand.

It is highly probable that many circumstances other than bodily fatigue also tend to alter the capacity of the retina for retaining the image. I have already mentioned that it is affected by illness, and, therefore, it is important that a signaller should be in good health. I consider the results of these tests as only the commencement of the research I have undertaken, and I have mapped out a programme of further tests, such as before and after retinal fatigue, under different climatic conditions, etc., which may be useful and of interest. I have been often asked whether I have not noticed that the mind can affect the duration of persistence of vision, and whether it is not possible to educate a defective retina up to the required standard. This is a difficult question to answer. We can track the vibrations produced by light on the sensitive layer of the retina through all the complex structure of that organ. From rods and cones it is conveyed to the fibrous layer, then along the fibres of that layer to the fibres of the optic nerve, then along the fibres of the optic nerve to the grey matter of the brain. There we lose the thread. In that grey matter of the brain, knowledge ends and conjecture begins. It is, however, conceivable that just as the retina affects the brain, so by a reflex action the brain can affect the retina. Perhaps it may be found that a person whose persistence appeared at first long may be educated to retain the image for a shorter period. There seems just a possibility that the Aerial Graphoscope may be used to educate the eye.

It has been suggested to me that in the case of testing soldiers with the Aerial Graphoscope it would be difficult to secure veracity of statement as to the precise moment a person sees the continuous image. That a soldier who was ambitious of becoming a signaller might wait to say he saw the continuous image until the lath was revolving fairly fast, even if

he had really seen it at a lower rate of revolution. There is always a possibility of deception in such a test as this, but I think it would be quite easy to guard against such deceptions; for instance, in my own tests, I have frequently tested the same person three times over. If, when tested under the same conditions, there is a discrepancy between the readings, it is a case for suspicion. In most of my repetition tests, however, the figures came out the same or nearly so, and I have every reason to believe the statements of the subjects were genuine.

In May, 1890, Lieutenant W. C. Crutchley read a paper before the members of this Institution "On a system of signalling between men-of-war and merchant-vessels," in which he pointed out the advantages which would ensue upon the adoption of visual signalling by the Morse code in the merchant service, especially in the case of large mail steamers. He pointed out that at that time there was absolutely no system of night signalling at all on our large ocean-liners, and only an inadequate means of signalling by day. This neglect has also been enlarged upon at this Institution by Lieut.-Colonel Harrison, who estimated that "thousands of lives and millions of property have been sacrificed in collisions" for the want of a system of night signals in the mercantile marine. I believe I am correct in saying that the present year shows no advance in this respect. I presume that the reasons urged would be that the selection and making of signallers is a process requiring too great an expenditure of time and energy. Possibly the knowledge that the process of selection can be simplified by scientifically testing the persisting capacity of the retina, may suggest that there is no longer an insurmountable barrier against every large liner having at least one competent signaller amongst the crew.

In making these suggestions, I have been especially anxious to avoid saying anything that might seem condemnatory of the Morse system of signalling, which has been brought to a high degree of accuracy and perfection. On the other hand, the facts before the meeting should rather elicit our admiration of those officers who have produced such excellent results in spite of the presence of so formidable an enemy as persistence of vision. In conclusion, I venture to hope that those in authority will think the method of testing for persistence of vision worth a trial, in case it may in practical working fulfil my hopes that it will lighten the burden of training signallers and bring visual signalling to a still higher standard of certainty.

TABLE I.—AERIAL GRAPHOSCOPE TESTS OF PERSISTENCE OF VISION.

Miscellaneous Group of Twenty-five Persons.

—	No. of revolutions } per $\frac{1}{2}$ minute }	gives	{ Persistence of vision in seconds.
1 M. - -	27* (self)		2·2
2 M. - -	27* (optical assistant)		2·2
3 F. - -	27		2·2
4 F. - -	27		2·2
5 F. - -	27		2·2
6 F. - -	37		1·62
7 M. child-	37		1·62
8 F. - -	27		2·2
9 M. - -	75		·8
10 F. - -	27		2·2
11 M. child-	27		2·2
12 M. child-	27		2·2
13 F. - -	41 (shortsighted)		1·46
14 M. - -	27		2·2
15 F. - -	27		2·2
16 M. - -	27 (sportsman)		2·2
17 F. - -	27		2·2
18 M. - -	92 (engineering student)		·652
19 F. - -	34 (shortsighted)		1·76
20 F. - -	72 (sister of engineering student with high record above)		·83
21 F. - -	40		1·5
22 M. - -	50		1·2
23 M. youth	27		2·2
24 M. child	34		1·76
25 M. child	36		1·6

Average 1·36.

Mean 1·19.

* Mean of four readings.

TABLE II.—AERIAL GRAPHOSCOPE TESTS OF PERSISTENCE OF VISION.

Group of Twenty-six Boys before and after Running (First Readings).

—	Before running.			After running.		
	No. of revolutions per $\frac{1}{2}$ minute	gives	Persistence of vision in seconds.	No. of revolutions per $\frac{1}{2}$ minute.	gives	Persistence of vision in seconds.
1	52		1.15	38		1.58
2	66		.909	71		.845
3	44 (head boy of school)		1.363	53		1.13
4	73		.821	46		1.304
5	37 (third boy in 4th form)		1.62	32		1.87
6	65		.923	34		1.76
7	44 (top boy 4th form)		1.363	42		1.428
8	91		.659	98		.612
9	51 (middle boy in 5th form)		1.176	46		1.304
10	53 (5th Standard)		1.13	48		1.25
11	51 (nearly top of his class)		1.176	50		1.2
12	39 (top of Standard 5; very clever; best example I have had)		1.53	40		1.5
13	49 (fourth in 7th Standard)		1.22	42		1.428
14	54		1.1	56		1.07
15	74		.8108	53		1.13
16	57		1.05	57		1.05
17	50		1.2	47		1.27
18	82		.73	53		1.13
19	69		.87	73		.821
20	82		.73	42		1.428
21	58		1.03	63		.95
22	56		1.07	50		1.2
23	92		.65	67		.89
24	53		1.13	43		1.39
25	59		1.01	40		1.5
26	60		1	55		1.09

Average 1.05. Mean .98.

Average 1.23. Mean 1.07.
7 boys' persistence was lowered,
18 increased, and 1 boy the same.

TABLE III. — AERIAL GRAPHOSCOPE TESTS OF PERSISTENCE OF VISION UNDER WHITE LIGHT AND COLOURS. (FIVE PERSONS FEMALE.)

—			No. of revolutions per $\frac{1}{2}$ minute }	gives	{ Persistence of vision in seconds.
<i>White Light.</i>					
1 -	-	-	63*		·95
2 -	-	-	70*		·857
3 -	-	-	36		1·6
4 -	-	-	51		1·176
5 -	-	-	36		1·6
Average 1·236. Mean 1·23.					
* Mean of three readings.					
<i>Red Light.</i>					
1 -	-	-	63*		·95
2 -	-	-	60*		1
3 -	-	-	36		1·6
4 -	-	-	46		1·304
5 -	-	-	73		·821
Average 1·147. Mean 1·1.					
* Mean of three readings.					
<i>Violet Light.</i>					
1 -	-	-	67*		·89
2 -	-	-	60*		1
3 -	-	-	28		2·14
4 -	-	-	60		1
5 -	-	-	60		1
Average 1·206. Mean 1·38.					
* Mean of three readings.					
<i>Green Light.</i>					
1 -	-	-	61*		·98
2 -	-	-	53		1·13
3 -	-	-	37		1·62
4 -	-	-	72		·83
5 -	-	-	39		1·53
Average 1·21. Mean 1·15.					
* Mean of three readings.					
<i>After being in the Dark.</i>					
1 -	-	-	51		1·17
2 -	-	-	59		1·02
3 -	-	-	46		1·304
Average 1·164. Mean 1·15.					

TABLE IV.—AERIAL GRAPHOSCOPE TESTS OF PERSISTENCE OF VISION.

Miscellaneous Group of Eleven Persons.

—	No. of revolutions } per $\frac{1}{2}$ minute }	gives	{ Persistence of vision in seconds.
1 F. - -	101*		·594
2 M. child	68*		·88
3 F. - -	96 (long sight)		·625
4 F. - -	46 (short sight with glasses)		1·304
5 M. - -	79 (signaller)		·76
6 M. - -	43		1·39
7 M. - -	71		·845
8 M. - -	56		1·07
9 F. - -	43 (always in perfect health)		1·39
10 M. - -	77 (with glasses)		·779
11 M. - -	70		·857

* Mean of three readings.

Colonel F. C. KEYSER, C.B. (late Inspector of Army Signalling):—As the lecturer has kindly alluded to me two or three times in his paper, I think that perhaps I might say a few words. First of all I should like to thank him very much indeed for the most excellent lecture we have just listened to, and which has been so ably thought out and so well prepared. I am sure it has been most interesting to all of us who take any interest in signalling, and although I am sorry to say that old age has turned me out of the coach, yet I still take a very deep interest in a matter which I had charge of a very few years ago. I really think there is a great deal in Mr. Bruce's system. I hardly see myself how we could work it out in a school of signalling; and I think perhaps it would be more useful at the hospital, where men might be sent up to be tested for their eyesight before they were allowed to join a class for signalling. It is heart-breaking work for a signalling instructor—I am talking of a regimental instructor now—to have to work for hours and hours for long weary weeks to turn men out as efficient signallers, and then to find out at the end of the time that his labour has been thrown away. Not, as I have said before, that the men have not taken the trouble to learn; they work hard and do their best, but they have not the sight for it. However long they work at signalling, although they know the details perfectly well, when it comes to practising at quick work they find their powers fail them, and they are no good as signallers. I have nothing more to add except to thank the lecturer very much. I am only delaying you from hearing my very able successor, Major Rhodes, who is on my right, and I know burning to give you his experiences, and as they are very much later and more developed than mine, I am pleased to make way for him.

Major E. RHODES, D.S.O. (D.A.A.G. for Signalling):—As regards the utility of this invention as applied to signallers, we are, of course, all agreed that one of the first requirements for a signaller is good eyesight, and by that we mean, not only long sight, but quickness of vision; that is, his eye-lens must have both rapidity and definition. Officers and non-commissioned officers previous to coming to the School of Signalling are tested for eyesight,

and a medical certificate is forwarded by their commanding officers to the effect that "the course of signalling they are to undergo at the school is not likely to be prejudicial." The test applied is the customary counting of spots held at a certain distance from the eye. Regimental signallers, though specially selected for qualities of intelligence, steadiness, etc., undergo no preliminary test for eyesight before commencing a signalling course; but any men who, after a few days' probation, do not come up to the average in reading, or intelligence, are returned to duty. This rough-and-ready way of determining the survival of the fittest is really no test of the special adaptability of the eyesight of the men that are left, as the rates of reading at this period of instruction being very slow, the advantage of the rapidity of the eye-lens does not yet make itself manifest, and probably later on, when the quicker rates of reading are practised, the men with abnormal persistence of vision will have to be eliminated. There is no doubt that a "signaller's eye" can be acquired to a certain degree by careful training and practice, in the same way that anyone without a special ear for music can attain a high degree of excellence in playing an instrument, but in both cases it takes considerable time and trouble. In the early stages of reading the lamp, beginners find a difficulty in distinguishing letters composed of similar elements, such as H, which consists of four dots, and S, which is composed of three; or V, three dots and dash, and U, two dots and dash; or B and D, their opposites. What they usually do is to read two dots when they should be reading three; three dots when four are sent, etc.; i.e., the eye fails to take in a dot. A battalion I inspected last year which had been trained to read with great accuracy on the flag, failed on the lamp because they continually omitted a dot in the reading of certain letters. This was not from want of practice, for their commanding officer had taken considerable trouble with the signalling of his battalion, and the result of the flag-work showed this to be the case; but they had been practising at too short a distance, about 200 yards, and when they were inspected at 500 they consequently failed. They missed the stronger illuminant, and could not adapt their persistence of vision to the longer distance. Another interesting point to notice in the lecture is the effect of physical exertion on the eye, but I am afraid we cannot pack our signallers in cotton-wool and only produce them when wanted; in fact, as a rule they are not even mounted. I had a letter from an officer with the Egyptian Frontier Field Force only the other day, describing how the signallers had on different occasions to send their messages, and then double after the column. If these men had been graphoscoped, I take it their records would have been interesting, and shown great eye disturbance. The *Times* of India mentioned the signallers in the Tirah operations as being the hardest-worked men in the expedition. From these facts it appears, that however detrimental the graphoscope may show exertion to be to the eyesight of signallers, there is no way of avoiding it for them, it can only be modified by mounting and brigading the signallers themselves. I think if the lecturer could produce for us an instrument which might be purchased for a few shillings, and by means of which regimental instructors could determine roughly the persistence of vision of their men, he would be conferring a great boon on the signalling service. Instructors would get an idea of those men who would be likely to read at the highest rates; they could devote more individual attention to those whose graphograms showed them to be not quite so apt, and, finally, they could reject at the commencement of the course those who failed to attain a certain standard. Another alternative would be, as Colonel Keyser suggests, to provide medical officers with the instrument for them to test every recruit, and record on his medical history sheet his persistence of vision. This would guide signalling instructors in making their selections for a class. I may add, that of the 67 officers who passed through the school in 1898, only six failed in reading. Of the 130 non-commissioned officers who passed through the school, only two failed to read the passing-out test, that is, 12 words a minute.

Lieut.-Colonel A. STEWART HARRISON (late 1st London R.E. Volunteers):— I do not think that this audience is quite aware of the immense importance of the issues at stake in connection with this lecture. You have witnessed in these experiments the death-blow of the Morse code for all purposes of visual signalling. That seems to be a very bold statement to make, and I will, with your permission, Sir, justify it. You are well aware that the Morse code has been in use in the Army and the Navy for over thirty years; that it was the refuge found by Lieutenant Colomb (now Vice-Admiral Colomb) from the chaos and confusion that constituted the "modern" signalling at the time he made his inquiry; that it was taken up without any idea of an accurate kind as to the persistence of vision. It was taken up as a last resort, and it was unfortunately foisted upon the Services by the mere fact that it was in connection with an "electric" cable. The Morse code is a series of dots and dashes made by sending a current through a magnet, and it was made by the tapping of the finger with a motion of something like the 16th of an inch. You find the Morse code parodied to-day by a man working a flag with a 6-foot pole, trying to make something like the same time as his compeer with an electric instrument. Now, what is the result, gentlemen? That at this moment the greatest naval Power in the world has no recognised means of communication between its mercantile marine commanders, and this has been going on for thirty years. You ask why do we not have this system applied to the mercantile marine? I will tell you. It takes three months of the most assiduous attention by the best men in the Navy to make a Morse code signaller. How are you to get these men into the mercantile marine? That three months is passed by the soldier and the sailor, receiving the pay of his country; do you propose that each officer in the mercantile marine shall give up three months' wages to learn signalling? The thing is preposterous! And now go a step further. Twenty officers shall enter, and only three shall pass. I appeal to the gentleman behind me who gave evidence in this room. I say that if you take twenty picked men from a regiment you will only get three of these twenty to pass the tests that are imposed to make them "signallers." Now, I ask you, gentlemen, how long will the patience of the nation bear this? When the "Drummond Castle" was running on the rocks a vessel was passing and saw her. The captain of that vessel had not the slightest means of communicating with the "Drummond Castle." He saw her with her several hundred passengers and crew going to an absolutely certain death, and he had no means of warning them. Do not you think that the time has come when something ought to be done? What is it that stands in the way? Why, this preposterous system of signalling. Of course, you understand that I am a crank, as they call them in America. I have invented a system of signalling, and therefore I want my system adopted. But what we have first to do is to prove that the Morse code is miserably ill-adapted for the purposes for which it is required. With my system of signalling I will enable any person in half-an-hour to read signals, and will make an expert in a week. When you can get a Morse code to do that, keep it on. Until then, gentlemen, I condemn the Morse code—I think it stands self-condemned. The table the lecturer shows gives the persistence of vision in one man, in the best I think, it is '625, and in another '652. Take the average as '650, and you find that a man can receive impressions at the rate of 98 per minute. But in order to read 16 words by the Morse code you must receive 202 impressions per minute. Consequently the difference between 202 and 98 is to be found by the specialised gift of neglecting the consecutive image. The image is seen by the man with his eye, and we know it must be there, but his brain rejects it, and that is the reason you get very good signalling. That is a special thing, and it is admitted that out of a large number of men you will only find a few men who can do it. Now take another point. Fatigue, exhaustion, mental emotion, all these come in, when reading the Morse code, in the most disastrous fashion. In the system I propose there are a fixed number of points—:9. [The speaker here handed copies of diagrams to the audience. A copy of

this diagram is to be found in No. 249, p. 1246, of the R.U.S.I. JOURNAL for November, 1898.] Those diagrams a very child can read. The image remains, and there you have a system which the Board of Trade can take up, which they can compel every officer to pass in, and refuse him his certificate if he could not read it. In that way you would bring the mercantile marine to its proper position. That magnificent vessel the "Oceanic," which the newspapers went into raptures over the other day, will be commanded by a man and officered by men who will be utterly unable to communicate with other officers of other ships. It is perfectly possible that the captain of a vessel might meet the "Oceanic," and might know perfectly well that right in her path—she going at the rate of 22 miles an hour—lay an iceberg or a derelict, and the only thing he could do would be to make a flare, and make the "Oceanic" believe he was making signals of distress. Ought such a state of things be tolerated for one moment? Is it not the primary duty of members of Parliament when they next meet, in face of the facts which the lecturer has brought forward, to cause an immediate inquiry into the efficiency of the present system of signalling? And it is perfectly useless asking soldiers to do it. The soldier who is fond of experiments is the man who never gets on. The naval officer who tampers with signalling will be kept always low on the list. The mercantile marine officer suspected of a desire to perform experiments will never get a ship as long as he lives. Who is to do it? Parliament must appoint a Commission, unprejudiced, fair-minded, and scientific, to investigate it. I have said that thousands of lives are sacrificed in collisions because the captain of one vessel does not know what the other is going to do. Parliament must make the inquiry, and then the yachtsmen of England, with their wealth, intelligence, and courage, can carry out the scheme until it becomes practical, and then within the next five years a woman may see her husband go away on a ship with the certainty that he will not be run on the rocks by the ignorance and incompetence of the officers to whom she has entrusted his safety.

Vice-Admiral Sir NATHANIEL BOWDEN-SMITH, K.C.B. :—I had not intended, Sir, to join in this discussion, had it not been for the attack just made by the last speaker on the Morse system. The lecturer introduced the Morse system, and spoke in praise of it. At the present moment the Morse system holds the field, and it has been in existence for some thirty years in the Army and Navy, and also used by the Post Office. Although it is the system used by the Army and the Navy and the Post Office, and although we have all used the same signs for the letters of the alphabet, there was a time when we used different signs to express the numerals. Now, however, I believe I am right in saying we all use the same signs for both. How, therefore, if all these Services are using this system of signalling, and with very fair success, can it be with justice so severely condemned? The reason why sometimes at night there is a difficulty in taking in a signal, is because the signalman will operate too quickly, and the lecture I have just heard, showing the difference in the retentive power of the eye in various persons, explains the reason why there should be a uniform length in the long and short flashes. We will take the case of my own Service, the Navy. A small cruiser, which has been some time detached, joins a fleet at night, and the flag-ship commences flashing at her, the signalman operating very rapidly. The unfortunate signalman on board the cruiser, who is not so quick through want of practice, does not take it in readily; whereupon the flag-ship man, to show his smartness, and finding that his poor colleague on board the other ship is in difficulties, makes the signals faster still. There should be a uniform length in the long and short flashes. The advantage of the so-called Morse code, which was introduced into the Navy by Admiral Colomb, is that it can be worked by sight or sound; you can use it by night or day, in thick weather as well as in fair. The last speaker, I think, objected to it on the plea that it took a soldier three months to learn the Morse system, and I may say that it takes an ordinary seaman about the same time: but I don't think three months is a long time to learn a system of

signalling. As regards the mercantile marine, I agree with the last speaker that there is no organised system at present whereby vessels can communicate with each other during the night. We have magnificent ocean steamers crossing the sea, and yet they cannot speak to each other at all by night, and only very slowly during daylight with flags, which is a slow process, and if there is no wind will not blow out. During the night they may pass, but cannot speak to each other, even though one may be in serious trouble. The only thing that will bring signalling about is a general demand on the part of the public. The sole requirements for this signalling are a lantern and one or two signalmen—two men would be best, but one would suffice. You must remember that besides the lantern you can make your signals by sound, using the steam whistle or other instrument. The mercantile marine do not, I suppose, carry signalmen on account of the expense. But the expense would be trifling. There are plenty of time-expired men from the Navy who have learned signalling, and who would be quite ready to serve on board vessels as quarter-masters or able seamen, and act as signalmen for a small daily allowance in addition to their ordinary pay. With a signalman on board our mail steamers, they might talk to each other whenever necessary. It would make travelling more popular, and enable passengers to obtain news in the day-time by semaphore, which is quicker than the Morse, but it will only be brought about by the general demand of the travelling public. I think we are much indebted to Mr. Bruce for his interesting paper, which will doubtless be read by many officers in various parts of the world, and I can only express my regret that there is not a larger audience to witness his illustrations.

Lieut.-Colonel ALLAN CUNNINGHAM (Royal Engineers):—This very interesting lecture, Sir, brings before us the possibilities of illustrations from other branches of sensation as well as that of sight; and as I think that what has been said about persistence of vision is to some extent to be explained by an effort of memory, as well as by real persistence of vision, I will just draw an illustration from another branch of sensation. Take the case of feeling; it is said to be the bluntest of our sensations. We have heard lately, for instance, a great deal about pin-pricks. Well, it takes a little time after a prick before any sensation is felt at all; a still longer time before the sensation of pain is aroused. A certain physiological change occurs, I suppose, in the structure of the skin and flesh and nerve, and the transference of the sensation to the brain. When the exciting cause is withdrawn that state of change of structure still remains, and the sensation goes on. That corresponds with the persistence of vision—it is a persistence of feeling. After a time I suppose the structure returns to its normal state. Then, properly speaking, I suppose we ought to say the sensation has ceased, but we still have the memory of the pain lasting for a little time, but probably by an effort of will that can be shortened and overcome. With regard to the sensation of vision,—by these beautiful experiments here we see that after a thing has been actually withdrawn from the eye some change has taken place in the structure of the retina, either chemical or physiological, and the sensation of that vision remains for a time. These sensations are fleeting. People talk of fleeting impressions and lasting impressions, but we see by these figures that visual impressions last for a considerable period, quite long enough to be measured, and the *memory* of them probably lasts a little longer; but the duration of this mental impression is capable of being shortened by an effort of the will. The figures on the tables are very interesting indeed, as showing the great change that has come to pass in our notions of the duration of visual impressions. It used to be said in the days of long ago that the perception of a thing lasted for about the tenth of a second, and that it was necessary for fresh impressions to succeed each other at intervals of a tenth of a second, in order that a series of impressions might blend together to form a whole picture. The cinematograph, which is the best illustration of this, I suppose, would lead one to believe that the persistence of vision must be less than the tenth of a second. But I am quite sure

that in that instrument the succession is far more rapid, and there is no doubt those who exhibited them would not make them unnecessarily rapid, because the films are very expensive. Here we have in the table the impression lengthened up to over two seconds; a great many figures show two and one-tenth seconds. The lecturer has spoken about the application of his invention to army signalling, to test the capabilities of men whom it is desired to train as good army signallers, as if the persistence of vision was the only point, or one of the principal points, to be taken into consideration. But I should think that acuteness of vision is also equally important. The acuteness of vision which will take up a thing and not require it to be too long before the eye before the eye takes the impression in as a real recognisable visual impression, is a very important thing, as well as to have the quick effacement of that impression after the exciting causes are withdrawn. I speak with a good deal of interest in connection with army signalling, as I was one of the first to introduce army signalling into India; for only a short time, it is true, I was connected with the work of army signalling instruction, but I was one of the very first. I should think it would be a thing very easily and quickly tested, to have a hundred men tested once for all before they were put into the army signalling class, and then have the result tabulated after they had passed the army signalling class compared with the figures which had been obtained by this instrument. I think the lecturer has only produced two or three instances of army signallers. By having about a hundred men tested before they went to the class it would be very soon set at rest whether this is a good and sufficient test or not. With reference to the Morse system, I should like to say something in defence of it. It is really a very useful system, and it needs very little to put it into use. Anything whatever will do. The flag-signaller may have lost his flag, but his handkerchief will do just as well for short distances. His hat would do almost as well, and even his hand. The commonest lamp will do for short distances when the proper appliances are not at hand. The rough-and-ready things that may be used for the Morse system makes that system a very useful one. Then, the fact that there is a whole army of trained civil telegraphists available everywhere, every one of whom could be turned, if needed, into army signallers in a very short time, is another advantage. They all know the Morse system, and it requires only a short additional training to enable them to take up the military flag and lamp system of signalling. There is one thing noticeable about the figures shown on those rotating laths: they have a surprising effect of solidity. The apparent disc must be nearly plane (when the lath is sufficiently rigid); and yet, when the picture thrown on the lath is a statue, the effect of solidity is really very wonderful, and it is difficult to believe one is looking at a single image, and not at a pair of images prepared for binocular vision.

Mr. A. O. GRANGER, of Philadelphia (late United States Army):—I am a stranger here, and do not know whether it is proper for me to speak or not. My experience in connection with signalling has been rather limited. It was confined to observations during the civil war in the United States, when I was connected with the Union Army at General Sherman's headquarters on the march to the sea, and other campaigns. While the subject has been very fully covered here this afternoon, yet there is one rather minor point which I should like to emphasise in connection with the very interesting paper that has been read, and that is the necessity in the Army of having signalmen carried—not to have them go *tramping* 15, 20, or 30 miles a day. They should in every case be mounted. In the Northern Army, during the war in America, the signalmen were all mounted the same as the cavalymen. It seems to me very desirable indeed that they should be mounted or carried in some way, and the importance of accurate signalling is so great that if it is necessary that the men should be "put up in cotton-wool" to produce them at will, then even that should be done. That signalling is an extremely important thing we all know who have been connected with an Army in

time of war, and while the point I am discussing is a minor one in Mr. Bruce's paper, yet I know from experience and observation that it is necessary to have the signalmen in good physical condition at the end of the day's march.

Major A. GLEN (14th Middlesex (Inns of Court) V.R.C.) :—I have had, Sir, some little experience in the training of Volunteer signallers with Colonel Keyser and others, and I appreciate the advantage, both to signalling instructors and those who may otherwise waste their time unprofitably in the endeavour to learn signalling when they cannot do so, of an instrument such as Mr. Bruce has suggested to us, which would tell us beforehand whether a man is going to turn out a good signaller or not. It would be of great advantage. But I confess he has not yet altogether convinced me that the test of persistence of vision is necessarily the test of whether a man would make a good signaller or not. There is a figure in his table which perhaps induces me to have some doubt on the subject. I notice that in Table IV., No. 5, who was described by Mr. Bruce as a highly trained signaller, had his persistence of vision destroyed at 79 revolutions in a half-minute. That fact means that when the lath went faster than 79 revolutions a half minute, the image of the lath was blurred and he obtained a persistent image. The lath having two ends, for each revolution there would be four apparitions in a given spot of a piece of white lath. Therefore that figure 79 seems to me to mean that the signaller has the blurred image when he gets up to about 320 distinct impressions in the course of a minute. Now in signalling at the rate of twenty words a minute, there are 360 elements of dots and dashes. Major Rhodes will correct me if I am wrong.

Major RHODES :—873 units. There are 78 letters, and therefore 873 units.¹

Major GLEN :—I am much obliged. I had forgotten it was so many as that. Now it seems to me that if the most highly trained signaller gets over 800 impressions of elements in the course of a minute, the persistence of vision which disappears at 320 elements in a minute has really nothing to do with his power of signalling at all, because it is obvious that his impression of the signalling at that pace or beyond that pace will be a blur. His persistence of vision will run the signals of the flag or lamp, or whatever it is, all together. Moreover, one's own experience is that in lamp signalling, or signalling with the heliograph, as long as a single word is being read, there is really a perpetual light in sight. The light does not appear and then go out, so that you see a blackness and then light again afterwards; there is a continuous light with a flickering in it that you have to appreciate, and it is that flickering that enables you to read the signals. For those reasons I feel a little bit doubtful, and I should be glad if the lecturer would explain the matter perhaps a little further as to how this persistence of vision is a test of a man's capacity for appreciating that flickering in the light or the movement of the flag.

Mr. BRUCE, in reply, said :—Amongst the many suggestive remarks which Major Rhodes made, there is one I should just like to speak about. As the principle of the revolving lath is so simple, there is no doubt a rough apparatus could be produced at a very reasonable cost for the purpose of placing in the

¹ There was a misunderstanding here. I was speaking of "elements," and Major Rhodes of "units." There are only 246 elements in twenty words, that is, a signalling lamp will give 246 flashes (some short and some long) in signalling twenty words (or three alphabets, or seventy-eight letters). But whether the number of distinct flashes per minute be taken, or the proper interval between them, namely, three units, the figures support the lecturer's suggestion; for they show that a message flashed at the rate of twenty words a minute, would have appeared blurred to Nos. 4, 6, 8, and 9 on Table IV., but not to the signaller, No. 5.—A. G.

hands of signalling instructors. The instruments with which I have taken my tests were made to run very accurately. To prove their accuracy I may say that the tests came out time after time at the same reading. Of course, some expense was incurred in getting such smooth and accurate running; but if only a rough apparatus is wanted it can be produced at a very reasonable cost, as the principle of the invention is simple. Concerning Colonel Harrison's remarks about the Morse system, I have already expressed my opinion that I think the Morse system has done admirable work. For myself, I am not likely to be very much opposed to the Morse system, as I have an invention for signalling, viz., my electric signalling balloon, which is based entirely on the Morse system. In a signalling balloon the signals are necessarily slower than with the lantern, flag, or heliograph. The incandescent lamps inside the balloon take a certain time to incandesce, rather tiresomely long, and it makes it necessary in practice to go about four or five words a minute. I do not think in that case persistence of vision comes in at all. I think even if it were necessary to go as slowly as that in all signalling, I should say go slowly and keep the Morse code. I do not, however, think it is necessary to go as slowly as that except in balloon signalling. The slowness in the case of balloon signalling has been rather urged against my method, but I have always maintained that the great point about balloon signalling was the altitude. There are many cases where a forest may come between two signalling parties and you cannot get the altitude in ordinary signalling, and you have, perhaps, to build something up. But in balloon signalling where you can raise a balloon 500 feet or more, it is possible to get to a useful altitude. Therefore, I have always urged that slowness was not a very great disadvantage compared with the alternative of not being able to send a signal at all. At any rate, I do not think in the case of slow signalling with the Morse code, persistence of vision would come in. If it is only a question of speed, it is better to retain the Morse code, than not to have it at all. Concerning some remarks of Colonel Cunningham, I think he spoke about the length of the duration of persistence in the cinematograph. It is very short, of course. It necessarily would be much shorter in the cinematograph than in the aerial graphoscope, for this reason, because the light has to go through the films, whatever the films are made of. The films obscure much more light than the glass slides which are used with the aerial graphoscope. The lantern here is very near the lath, and a very brilliant light is inside the lantern, and that is why the figures in the tables are generally high. If the light in the lantern had been turned down to half its candle-power, you would have seen a great difference in the readings of those tests; 2.2 is a high figure to quote for persistence of vision. I think the effect of solidity which Colonel Cunningham has mentioned is certainly very striking. The figures appear to stand out in relief. I think it is partly a mental effect, as the subject stands out, as it were, from a background, and all the slides which I have shown this afternoon are blacked in, which helps to bring out the effect of relief. As regards Major Glen's remarks about the flickering, flickering is an effect of persistence of vision. The simple experiment with the candle showed that the image of the candle is always on the eye, even when the hand comes in front of it—it remains on the eye from persistence of vision. It is really a discrimination between the incidental image, and that is the nice point. I showed you that upon the lath when I covered up the blackened centre with a piece of white paper. You saw the difference then in the middle of the picture. The picture was practically spoiled because of the difference between the real part and the visual part which is not really there. The latter is the persistent part, and therefore in the case of a signaller he has really got a nice point to discriminate, as to where the real begins and the persistent ends. Therefore, those who have the persistence very long are likely to muddle up signals more than those who have it very short.

The CHAIRMAN (Sir Andrew Clarke):—I think I shall be anticipating your wishes, and especially the wish of the Council of this Institution, in offering to Mr. Bruce

our thanks for his interesting lecture. This lecture has, to my mind, a double significance. First of all to our soldiers and sailors the question of signalling is nowadays becoming a very important one, and as progress is made in war this matter will become of still greater importance. The presence here to-day, and the part taken in the discussion on this paper, of Major Rhodes, who is primarily responsible for the efficiency of the signalling staff of the Army, I think we may assume, indicate the interest the Head Quarters Staff take in this subject, a subject second to none in these days of long ranges and smokeless powder, of the various factors which go to the creation of a modern Army properly equipped to command victory. The other point is that we rather welcome in this hall those of our civilian brethren who are devoting their abilities and their time and their means to measures connected with the defence of the Empire. Therefore I think I shall be meeting your wishes when I convey to Mr. Bruce the most cordial thanks for his very interesting lecture. I have known him, I think, now for fifteen or sixteen years, working on this subject, and I hope this expression of our recognition of the good work he has already done will encourage him to continue that work. I perhaps owe an apology to this meeting for allowing a question to be discussed which was not exactly before us, but I cannot help thinking that the remarks which have fallen from Colonel Harrison, and the reply from Sir Nathaniel Bowden-Smith, may be of benefit. If it will not lead to the adoption of the system of my friend, it may be of good in improving the Morse system, which he so strongly condemned. I will not detain you any longer, but just ask you to authorise me to offer our thanks to Mr. Bruce for his very interesting lecture.