EFFECT OF TRAINING ON THE ABILITY TO RECOGNISE OBJECTS MOVING AT HIGH SPEED

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It is known that in order to obtain a clear VISUAL definition of a moving object it is essential for its image to remain stationary on the retina for a brief period. When the relative velocity between the subject and his surroundings is low this is achieved by the eyes executing pursuit movements, which are reflex in nature and which help in keeping the image of the surroundings stationary on the retina. However, at high velocities the reflex fails thereby causing the image of the object to move across the retina with consequent deterioration in visibility. This is, in fact, the reason for the poor visibility of terrestrial objects from modern aircraft flying at high speed.

During the course of certain experiments on visibility of moving objects it was observed that it was sometimes possible to attain clear visibility (for fraction of a second) of an object moving at a high angular velocity. The question arose whether this ability to see fast moving objects momentarily could be improved by training and so the present laboratory investigation was undertaken to determine this point.

Apparatus

The test object consisted of a black letter of English alphabet which subtended a visual angle of about one degree when the subject was seated at a distance of 45 inches. It was pinned on a white sheet of paper and its movement was brought about by fixing the white paper on to a white belt moving in a vertical direction from above downwards. The belt was made of a white canvas cloth, 12 inches in width, and it moved around two cylinders about 30 inches apart fixed on a wooden stand, Fig. 1.. By coupling the system to a motor through an integrator it was possible to vary the speed of the object continuously from 25 to 150 inches per second. The illumination of the test object and its background was provided by a 60 watts frosted bulb placed at a distance of one foot and an angle of 45 degrees from the centre of the screen. With this arrangement the brightness of the surroundings of the object was reasonably uniform. The bulb was provided with a suitable shade for preventing any direct light from reaching the eyes of the subject.

Mechanism used for recording the time of appearance and disappearance of the object through the slit is shown in Fig 2. An aluminium foil, 1 centimeter in breadth was stuck to one side of the belt in the same horizontal plane as the test object. Two pairs of contacts mounted on clamps were brought so close to the moving belt that the "feet" of the contacts were all the time touching the belt, one of the pairs being close to the

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upper border of the slit and the other at its lower border. When the part of the moving belt carrying the aluminium foil came to the region of the copper "feet", the latter was short-circuited by the aluminium foil and a change of potential was produced which was fed to an amplifier. The output from this was connected to one beam of a double beam cathode ray tube.

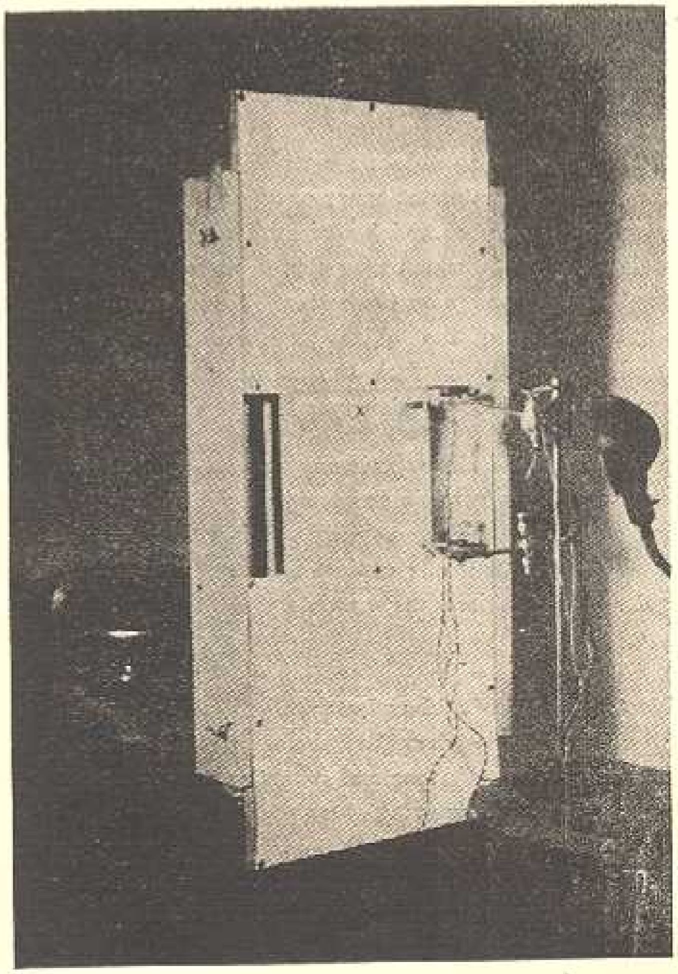

Fig. 1. Front view of the apparatus.

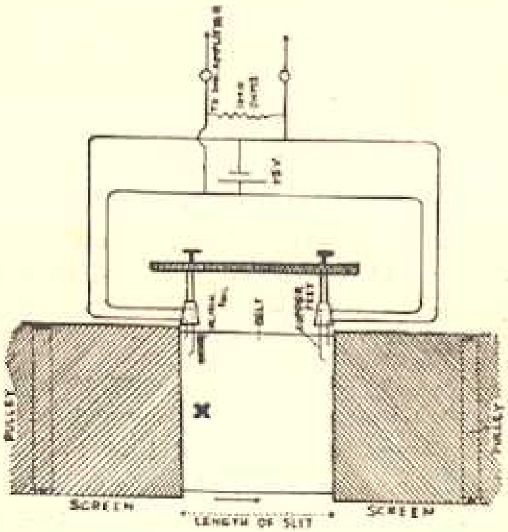

Fig. 2. Diagram showing the circuit of the mechanism used for signalling the appearance and disappearance of the object.

Arrangements for Recording Eye Movements

The eye movements were studied indirectly by recording the changes in the corneo-retinal potential produced by eye movements. This method has been described by Mowrer, Ruch and Miller (1) and by Fenn and Hursh (2). Lord and Wright (3) found this method very suitable in the study of eye movements during reading. Hartridge (4) considers this method superior to optical methods of recording eye movements. The potentials were recorded with an amplifier, double beam cathode ray tube (Cosser 89 J) and oscilloscope camera. Two silver chloride electrodes embedded in lucite were strapped, after application of electrode jelly, half an inch above the eye brows and little below the lower eye lid respectively. The earth electrode was strapped to the side of the neck below the right ear.

The time constant of the amplifier was 0.8 sec. This permitted satisfactory recording of the eye movements as the speed of these and consequently the rate of change of the corneo-retinal potential was fairly rapid. Unfortunately, as the amplifiers were not directly coupled, it was not possible to establish a base line level for a suitable point of fixation of the eyes. This would have been a desirable feature and would have yielded much more valuable information.

The output of the amplifier was connected to the second beam of the double beam cathode ray tube. Permanent records were obtained with an oscilloscope camera and photographic paper. A suitable calibrator provided 250 μv square wave signals. Time marks of 100 milliseconds were provided by a synchronous motor.

Experimental Procedure.

Two subjects (A & B) were chosen, who had a visual acuity of 6/6 (Snellen's) in both eyes without glasses and had normal mobility of the eyes. Experiments were conducted in a dark room. Prior to the experiments, the subject was kept in the room for a period of 10 minutes to allow adaptation to the brightness of the surroundings of the test object.

The subject was seated in a chair so that his eyes were at a distance of 45 inches from the test object. His head was fixed with a suitable mouth piece to a heavy stand. Two screens in front of the belts were adjusted so that their edges were about 12 inches apart which yielded an angular range of 15 degrees of an arc. A letter was fixed on to the belt and the movement of this was set at a constant speed. The subject was asked to observe the object as it repeatedly traversed the slit and to indicate as to whether he was able to recognize it. He was allowed free movements of his eyes and no special instructions were given to him as to how he should move his eyes. The speed of the object was then altered and the procedure repeated. Several tests were carried out to determine the speed limits beyond which it was difficult for each of the subjects to recognize the test object. At the end of each trial the subject was allowed a rest of about 5 minutes.

Subject A was now trained to see the moving object at high speeds as follows:

The movement of the object was set at a speed at which the subject was unable to recognize the object. The subject was instructed to move his eyes rapidly from above downwards each time he observed the object appearing at the upper border of the slit. After he had observed the object for about 5 minutes, he was given a rest period for a few minutes and then the process was repeated with a new setting of speed. Nine such sittings, each lasting for a period of one hour, were given over a period of three weeks and observations were made regarding the progressive improvement in the ability of the subject to recognize the object moving at high speeds. At the end of three weeks, records of eye movement patterns were taken of the trained as well as untrained subject as follows:

Electrodes were applied as mentioned previously, care being taken to ensure that these did not interfere with the movements of the eyes. The subject was now instructed to move his eyes from one border of the slit to the other. A record of these movements was made and served as an index for determining the amplitude of change in corneo-retinal potential, corresponding to a 15 degree angular displacement of the eyes. The object was then fixed on the belt and the speed of the latter was adjusted to a suitable value. The subject was instructed to watch the object as usual and as he was doing so his eye movements were recorded. In some experiments the subject kept his eyes closed while the object was set at a particular speed. Eye movements were recorded from the moment he was instructed to open his eyes.

Results and Discussion

Subject B as well as subject A before training were able to recognize the object as long as its angular velocity did not exceed about 50° per sec. Between 50 to 55° per sec, the object was indistinct and it could be recognized only on occasions. Beyond an angular velocity of

55° per sec. the object became progressively indistinct and it was impossible to recognize it. Beyond angular velocities of about 85 to 90° per sec, the visibility of the object was reduced to a faint streak. During the first three sittings of the training period there was no improvement in subject A's ability to recognize the object moving at higher angular velocities. In the 4th sitting, however, the subject was occasionally able to recognize the object at angular velocities higher than 80 degrees per second.

The subjective sensation was a momentary distinct appearance of the object which appeared stationary. After the 4th sitting there was a progressive improvement in the number of times the subject was able to get a clear glimpse of the object moving at angular velocities of more than 80° per sec. until at the end of the 9th sitting he was able to see the object distinctly each time it traversed the slit. The object could be easily recognised, while moving at angular velocities as high as 150° per sec. whereas the untrained subject was not able even to detect the presence of the object on the belt at this angular velocity. The trained subject stated that he was making no effort to see the object and that he was hardly conscious of any movements of the eyes. Between angular velocities of 50 and 80° per sec, however, there was no appreciable improvement in the visibility of the object which, therefore, could not be recognised at these angular velocities.

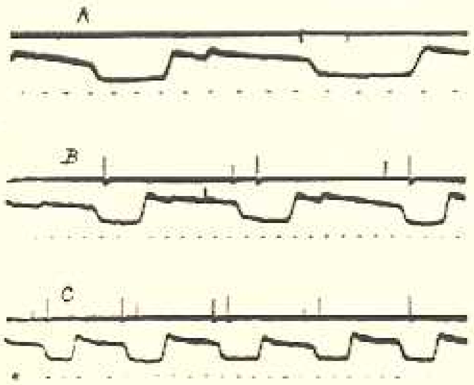

Fig. 3. Eye movement records of subject A showing rapid downward movements of the eye Angular velocity of the object was 89°/ per second in records A and B. In C the angular velocity was 150°/ per second From above downwards in each record, time of appearance and disappearance of object; changes in corneo-retinal potential, and time in 1/10 sec.

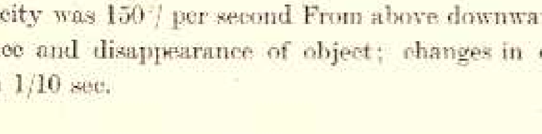

Fig. 4. Eye movement record of subject B. There are no rapid downward movements of the eye as seen in records of subject A. Angular velocity of the object was 120°/ per second. Sequence of traces same as in Fig. 3.

The eye movement patterns of the two subjects in respect of objects moving at angular velocities higher than 80° per sec. are shown in Figs. 3 and 4. The records reveal the presence of rapid downward movements of the eyes in the case of trained subject (Subject A) only. These movements are present during the time of exposure of the object at the slit and are obviously responsible for the ability of the trained subject to see the object distinctly. Further confirmation of this is provided by the eye movement record of subject A in respect of an object moving at 57° per sec, (Fig. 5). No rapid downward movements are present in the record which is in keeping with the fact that the subject is unable to recognize the object moving at this angular velocity.

Fig. 5. Eye movement record of subject A. The angular velocity of the object was 57°/ per second. Sequence of traces same as in Fig. 3.

The average angular velocity of the downward rapid movements of the eyes, though somewhat less than the post-exposure upward movements, was found to be as high as about 300° per sec. Although from the records it is difficult to detect any changes in velocity during the course of downward movements, the distinct appearance of the object for a moment, when it is moving at angular velocities of 80 - 150° per sec. can only be explained by assuming the presence of such changes in velocity of eye movements. Presumably, for a short period during the course of a downward eye movement, the angular velocity of the eyes and the moving object coincides, resulting in a momentary halting of the image over the retina.

The eye movement records suggest that each of the downward movement represents a voluntary response to the appearance of the object at the upper border of the slit. That this cannot be the case is evident from the fact that the time interval between the appearance of the object and the downward movements of the eyes, which varies from time to time, is frequently less than the visual reaction time interval which is approximately 200 milliseconds. It may be argued in this connection that under certain conditions in which a subject learns to respond voluntarily to a stimulus appearing rhythmically, he is able to make rhythmic responses by judging the time interval between two consecutive stimuli and further that he becomes conscious of his own time of reaction and so is able to synchronize his responses to the stimuli by making allowance for this time interval. If this were so, it is rather surprising why the movements do not at times appear before the appearance of the object at the slit. Further it is seen, for instance, that the time interval between the 4th and 5th downward movements (Fig. 6) happens to be 500 milliseconds. If the same time interval was to be repeated between the 5th and 6th movements, the latter would have occured before the appearance of the object at the slit. But this is not the case and the 6th movement takes place after 600 milliseconds, so that it lies within the next period of exposure of the object. Further instances of this nature are provided by Figs. 3 B and C.

Fig. 6. Eye movement record of subject A, showing the commencement of the rapid downward movements seen after the eyes were opened at beginning of signal. Angular velocity of the object was 150° per second. Sequence of traces same as in Fig. 3 trace is of signal.

Moreover the subject was not conscious of any voluntary effort involved in these movements of the eye. A full explanation of the physiological mechanism underlying these eye movements is, therefore, still required.

Conclusions.

1. With practice, it is possible to get a clear glimpse of objects moving at angular velocities between 80 - 150° per sec. The clear vision is made possible by rapid oscillatory movements of the eye in the line of motion of the object.

2. The manner in which the peculiar eye movement patterns under certain conditions are produced is not known.

3. Further work is required to determine the maximum time for which the eye movements can be performed and whether there is any associated fatigue of ocular muscles.

4. Training to see objects moving at high angular velocities may provide a partial solution to the problem of visibility under conditions of low flying.

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References

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