E Y E S T R A I N :

A BEHAVIOURAL DISORDER.

An investigation to test the hypothesis
that Eyestrain is due to retinal alternation.

A Thesis submitted by

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I. INTRODUCTION.

(A.) AIMS.

In general, the purpose of this investigation is to bring to light clearly and concisely the facts and theories relating to the condition termed Eyestrain, a hitherto neglected and inadequately explored subject. That there is a lamentable inadequacy of any really complete research into the problem under discussion, is reflected in the dearth of relative comprehensive literature. The more specific aims of this thesis have been set down in detail in another chapter.

(B.) JUSTIFICATION FOR RESEARCH.

The writer's attention had been drawn to the fact that the problem of eyestrain was and is more important and pressing than many have imagined. Nowadays more than ever before, the structure of civilization is making heavy demands upon the eyes. Never has there been such a multiplicity of occupations necessitating greater ocular efficiency, than in this modern industrialized civilization.

The / ....

The facts are that a very large percentage of the total population are afflicted by this eyestrain condition, and not enough effort and energy is being directed into the correction of this undesirable state of affairs. Furthermore the effort which has and is being exerted, is for the most part misdirected and so much wasted effort. This misdirection is no doubt due to an incomplete and faulty understanding of the problem.

The realization that the curing of eyestrain can and does lead to increased efficiency in industry and other occupations in which ocular competence plays an integral part, has for the most part prompted this enquiry. In some occupations, ocular competence is practically a pre-requisite for any degree of efficiency at all.

The fitter and turner in the railway workshops, the clothes packer in the factory, the architect, the draughtsman and the professional cricketer amongst others, cannot perform his or her particular occupation efficiently, if at all, with a sprained or broken arm. So, too, these selfsame breadwinners subject to eyestrain are similarly adversely affected. For the professional sportsman even are the effects of eyestrain important.

The motive of this investigation however is not an appeal for greater efficiency. This Thesis is a theoretical and experimental investigation into the condition of eyestrain, which investigation it is hoped will aid others in tackling the problem of therapy in a sounder fashion than in the past. If the application of this hypothetically improved therapy brings with it as it must, greater efficiency, then well and good. Like all works of a scientific nature, the leit-motif of this investigation is a little loftier than mere increased efficiency in work.

There seems to be no little doubt as to whether an analysis of this problem falls rightly within the domain of the Physiologist or the Psychologist. The general opinion appears to be that the Psychologist is here encroaching upon the preserves of the Physiologist. This is an unfair assertion. Eyestrain affects human behaviour and is itself human behaviour as will be made clear in this investigation.

This analysis will, inter alia, attempt to show that the condition leading to eyestrain is a behavioural one, based on the acquisition of a faulty set of habits.

Human behaviour is the very essence of Psychology, and a Physiologist with no resource to the primary laws of a Behaviourist Psychology can hardly succeed in a fair representation of the problem. The Psychologist with a Physiological background, or conversely, the Physiologist armed with a sound knowledge of Behaviour Science is the best equipped to tackle this problem.

C. ANALYSIS OF PROBLEM.

(1.) DEFINITION OF EYESTRAIN.

As the name implies, eyestrain is a condition of strain or fatigue of the eyes, in which that organ or any part of that organ is prevented from performing its particular function as smoothly and efficiently as it could, before the onset of that particular fatigued condition.

Since the function of the eyes is to enable the organism to perceive the visual world, then with the onset of ocular fatigue, the powers of perception of the afflicted organism are suitably reduced.

(2.) SYMPTOMS OF EYESTRAIN.

As with all fatigued conditions, there are certain attendant consequences of a physical nature in the eye-strain condition. These may be classified into:

(i) Ocular.

Here the patient is troubled by a feeling of tiredness in the eyeballs and across the forehead. This may be accompanied at times by a dull pain. In some cases, there may be conjunctivitis without any apparent cause. Usually there is a redness of the whites of the eyes. In addition, eyestrain patients are very liable to watering of the eyes when engaged in near work.

(ii) Visual.

Characteristic of eyestrain is faulty vision. This in spite of the fact that eyestrain is usually found in patients with normal healthy eyes. Objects are blurred, and there may even be diploplia or double vision. Sun-light and artificial light are constant sources of irritation to the eyes, and patients usually resort to wearing dark glasses.

Partial and complete loss of sight in one or both eyes, termed Amblyopia and Amaurosis respectively, may also be symptoms. This loss of sight in Amblyopia and Amaurosis is indefinite in character, with no objective or ophthalmoscopic signs.

Amblyopia occurs more frequently than Amaurosis, and is fairly common. Correction of the refractive error is a temporary cure, for the symptom returns with the removal of the spectacles. It is found that Amblyopia disappears with the curing of eyestrain, in which a more permanent and radical method of therapy is adopted.

(iii) General.

The patient is frequently subject to headaches when reading or performing other work in which ocular efficiency is put to the test.

Usually there is a general feeling of tiredness, listlessness, exhaustion and apathy, in addition to neuralgia in the face, neck and scalp.

When a patient complains of being subject to a combination of at least two of these three classes of symptoms, and not before, then the Doctor can be reasonably certain that he is confronted with a case of eyestrain. This criterion distinguishes eyestrain from mere tiredness of the eyes. The latter disappears with rest, whereas the former merely becomes a latent potential with rest, soon to return again as noticeable and irksome as ever.

(3.) CAUSES OF EYESTRAIN.

Previous investigations have established beyond doubt that eyestrain is traceable to the deviation from perfect or at least normal of the biunial bifoneal action of the two eyes. The lack of complete harmony between the two eyes in performing their functions as a single organ lies at the root of the trouble.

There is little doubt that eyestrain is essentially muscle fatigue resulting from asthenovergence, the inability to converge the eyes adequately in response to the distance of visually presented objects.

More specifically, the eyestrain condition may be due to retinal alternation of the two eyes, as one of a number of possible alternatives arising out of asthenovergence. The other alternatives are blurred vision, double vision or diplopia, monocular vision, Amblyopia, and finally, Amaurosis.

(4.) PHYSIOLOGY OF VISION.

The adult eye which is almost spherical in shape, and about one inch in diameter, is the organ of vision. Situated in the eye socket or orbital cavity, a bony case, it is guarded against external violence by a thick layer of areoalar tissue situated between the eyeball and bone.

Light rays are given off by visual objects, and entering the eye, are refracted. The refracting media of the eye are the Cornea, a transparent circular area in the anterior wall of the eye; the lens, a transparent biconnex disc one third of an inch in diameter, situated in the globe of the eye, immediately behind the iris, and held in place by a delicate annular or suspensory ligament which blends with the lens, and is attached circumferentially to the interior of the globe by means of the ciliary body; the aqueous humor, a clear limpid fluid in the anterior compartment of the eye, and finally, the vitreous humor, a gelatinous transparent substance in the relatively larger posterior compartment of the eye.

The refracted light rays are focussed upon the retina of the eye. The retina is the inner layer of the eye; essentially nervous in structure, it is the sight

receptor / ....

receptor, and is composed of a number of layers. The light rays on striking the retina, set up impulses in the layers of retinal rods and cones. From here the impulses are transmitted by nerve cells of the molecular layer to the ganglion cells layer, and from thence by the optic nerve to the visual area of the cerebral cortex.

The optic nerve is formed by the nerve fibres which are the axons of the ganglion cells. These nerve fibres turn horizontally a short distance from their origin, and converge towards the posterior wall of the globe, forming the optic nerve.

Though the image of the visual object as cast on the retina is inverted, we see objects the right way up through adopting the actions appropriate to the objects, in conformity with the laws of Behaviour. The visual area of the cerebral cortex inverts the image to the true position, because we have learnt to react to objects as being the right way up.

In monocular vision, light rays entering the eye from the outer or temporal half, and from the inner or nasal half are projected upon the nasal and temporal half respectively of the retina. So too with binocular vision, where the optic nerves, one from each eye, come together behind the eyeballs, forming the optic chiasma. At the optic chiasma, fibres from the nasal half of one retina cross with fibres from the nasal half of the other retina. The temporal fibres remain uncrossed.

Each of the two visual pathways thus formed, transmits impulses from the nasal half of one retina and temporal half of the other retina, to the visual area of the occipital cortex.

The theory of identical or corresponding retinal points explains why though there are two images to contend within binocular vision, one on each retina, we don't see things in duplicate. The eye muscles direct the ocular axes such that images fall upon points in the nasal half of one retina which are paired with corresponding points in the temporal half of the other retina. Thus single vision is brought about by the fusion of the two images into a single sensation.

The mechanism of the eye is such that for clearest possible vision, the eyes must be directed centrally or directly upon the visual object. Such central vision enables the image to fall upon the macula Lutea.

The macula Lutea is a small yellowish area of the retina, situated a little to the outer side of the Optic

Papilla, which is the blind spot of the eye in the posterior part of the eyeball. The most sensitive area of the yellow spot is the Fovea Centralis, a minute depressed area in the centre of the yellow spot. The fovea is the region of acutest vision on which the image falls. Peripherally the retina becomes less and less sensitive, the further away from the fovea, yielding dim ill-defined vision.

The focussing of the image upon the fovea depends upon the direction of the visual axis of the eye being such that the fovea of necessity is obliged to physically receive the rays of the visual objects. The visual axis is the imaginary line passing through the nodal points of the optic system, and connecting the fovea centralis to the point of fixation on the visual stimulus object. This central direction of the visual axis is learned by the organism through a process of reinforcement and non-reinforcement.

By this process, the organism learns to retain the correct habit which is characterized by success and consequent reinforcement. The wrong reactions are extinguished by virtue of their being unsuccessful, in accordance with the laws of the Behaviour Theory.

Normally / ......

Normally man's two eyes constitute one single organ of vision, which biunial or dual eye is conducive to better vision than each single eye on its own. To bring about the clearest and most direct binocular vision, the visual axes of the dual eye are obliged to intersect on the visual object. Any deviation from this condition will produce diploplia, since the two images of the visual object no longer are projected on identical or corresponding retinal points.

This intersection of the two visual axes on the visual stimulus object is termed Convergence.

(5.) CONVERGENCE.

Since the monocular direction of the visual axis on a visual object has been shown to be a habitual response to a stimulus object, so likewise is the binocular direction of the visual axes, convergence, a habitual response. The probability is that convergence in the mature organism is at least a semi-automatic response.

Keeping these deductions in mind, a definition of convergence may be submitted. Convergence is a

semi-/ ....

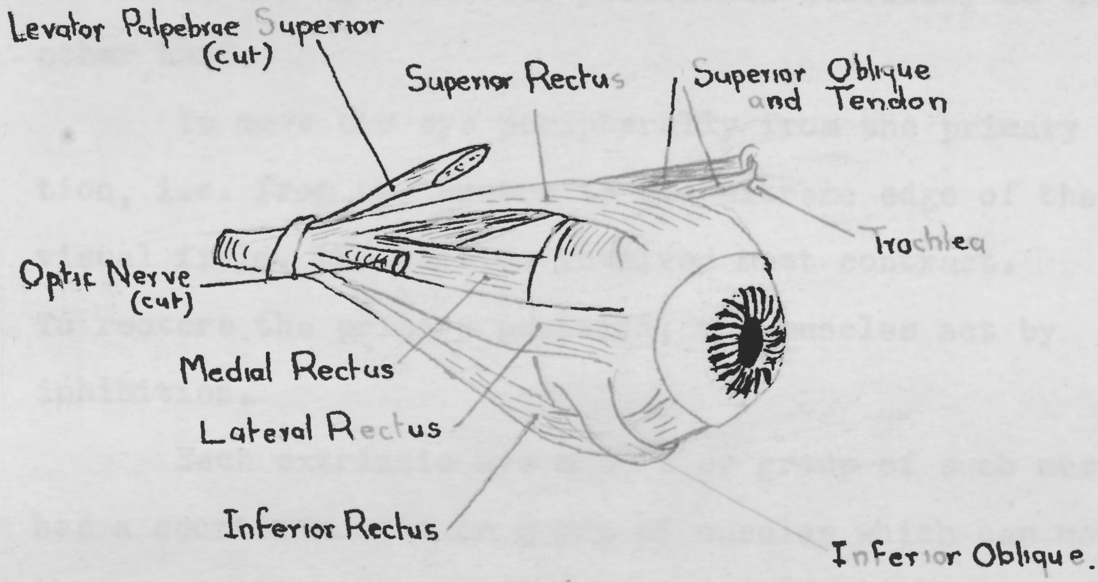
semi-automatic or at least a habitual response of the dual eye to a visual stimulus object, whereby the visual axes of the dual eye are directed so as to intersect on the visual object, thereby allowing for clearest vision. In action, convergence is an active rotation of the eye-balls, whether inward, outward or up-downward. Convergence is a visual movement, and in its absence, no bifoveally single vision is possible.

The directional adjustment of the eyes in converging is brought about by afferent nerves which convey impulses to the convergence centre via the oculomotor centres, i.e. the visual centres in the outer layer or bark at the back of the head, namely, the occipital cortex. Situated in the mid-brain on the raphe of the two brain halves lies the convergence centre.

From the convergence centre, the order is conveyed to the extrinsic muscles of the eye via the effector system. These extrinsic muscles perform the minute rapid movements of the eye in fixating an object by convergence.

(6.) THE CONVERGENCE MUSCLES.

The primary convergence muscles are the medial and lateral rectus. Of secondary importance in convergence are the superior and inferior recti, and the superior and inferior oblique



Muscles of the eye: DIAGRAM 1.

(7.) ACTIONS OF THE CONVERGENCE MUSCLES.

The extrinsic eye muscles act as tensors towards one another. The eyeball is held in place in the orbital cavity by fibrous tissue interwoven with strong elastic elements. When the eyes are at rest as in sleep or anaesthesia, the muscles are in a relaxed condition, and

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the elastic medium is in a state of equilibrium. The eyes are said to be in the primary position, a position involving a strong elastic positional stability. Any deviation from this primary position involves a reciprocal action between the muscles or group of muscles on the one hand, and this elastic positional stability on the other hand.

To move the eye peripherally from the primary position, i.e. from the centre to the extreme edge of the visual field, the muscles involved must contract. To restore the primary position, the muscles act by inhibition.

Each extrinsic eye muscle or group of such muscles has a counter muscle or group of muscles which can move the eye in the opposite direction. Thus, the medial rectus capable of moving the eye inwards, is opposed to the lateral rectus which moves the eye outwards away from the nose. When the one acts by contraction, the counterpart muscle actively inhibits.

The superior rectus moves the eye inwards and up. Its counterpart, the inferior rectus, moves the eye in towards the nose and down.

The inferior oblique acts out and upwards, while its counterpart the superior oblique acts down and out.

Movements of the eyes are brought about by the increase of pull over counterpull, and the decrease of pull over counter-pull. The increase is due to contraction of the convergence muscles, and the decrease to the inhibition or relaxation of the same convergence muscles.

Normally the convergence movement is free from undue strain, even though the primary position is one of slight divergence of the visual axes, and there is a calculable force involved in the rotation of the eyes from this divergent position to converge on a visual object at a distance. The force required is about one and a quarter grammes for three degrees (3^{o}) in animals, and probably more in the larger human eyes. For convergence on near objects, the force required becomes even greater, since the angle of rotation from the divergent primary position increases.

(8.) ASTHENOVERGENCE.

When convergence fails or is inadequately developed, then eyestrain develops. This under-development

of / ....

of the convergence habit is termed Asthenovergence. The dual eye is no longer able to respond perfectly to the visual object. The convergence habit is no longer performed smoothly and surely, and there is an added burden put on the convergence muscles, leading to strain and consequent physical symptoms.

The position is analogous to the athlete out of training who experiences physical discomforts in running a race. The convergence habit too is out of training in the sense that because of brain connections not being fully established, it is not in perfect working order.

The inability to converge probably has its foundation at the very beginning of learning. Asthenovergence may even be a response inherent in the organism, i.e. the subject whose convergence muscles are from birth constitutionally weak. It is not suggested here that in all cases in which asthenovergence is found the convergence muscles are inherently weak and under-developed. Far from it in fact.

(9.) ACCOMMODATION.

The human eye is further promoted along the path to clearest vision by the process of accommodation.

This / ....

This is the process whereby the eye is adjusted to varying distances of objects.

Light rays from objects at distances nearer and further than fifteen feet from the eye are focussed at varying distances behind the lens, resulting in indistinct images on the retina. Rays from the relatively nearer objects can't be focussed at as short a distance behind a lens of given refracting power, than the rays from the relatively more distant objects.

The ocular lens is, however, an elastic yielding structure, which by increased convexity for near vision, and decreased convexity for far vision, enables the eye to accommodate to this disparity in distances of visual objects. Increased convexity increases the refractive power, and is brought about by contraction of the ciliary muscle which draws the choroid forward. The suspensory ligament is slackened, and with reduced tension on the lens, the lens bulges forward. For decreased convexity, the suspensory ligament tautens through the reverse action of the ciliary muscle.

Normally, the two processes, accommodation and convergence, act together, though they are not interdependent. Convergence can perform its function without accommodation.

Eyestrain / ....

(10.) EYESTRAIN THERAPY.

In brief, the technique of the therapy is that the patient attends to a strip of white paper on a black background, about six metres distant from the eyes, and slightly above eye level.

The subject regards the stimulus object, the strip of white paper, through a frame which supports the head. The patient indicates by tapping with some object, whether the stimulus object is seen as single or double, tapping once in the former case, and twice for the latter.

The therapist meanwhile increases the degrees through which the patient is compelled to converge, by means of prisms. A series of eight prisms graded in degrees of one from one degree to eight degrees, and attached to a piece of wood or perspex, are used for increasing the degree of convergence. In addition, other prisms of varying gradations are inserted in the wooden frame at the higher degrees of convergence.

When vision becomes double, the therapist urges the patient to strive for greater convergence. If that doesn't help, the patient closes his eyes, and then opens

them / ....

them gradually, all the while trying to attain a single image. In the event of this still being unsuccessful, the therapist begins the process of increasing the angle of prism convergence again, starting a few degrees lower than that at which the operations were previously suspended.

The treatment period is about ten minutes per day until the patient is able to converge through a fairly high degree of prism. Normal convergence is about sixty five degrees (65°) of prism, and perfect convergence about eighty four degrees (84°) of prism. Between about twenty to twenty-four treatment sessions is usually sufficient to establish perfect or at least normal convergence, which number may be spread over a period of months. As with all other forms of behaviour, there are wide variations in individual cases with regard to the above figures. The variations are, however, mostly grouped on the one side, for it is seldom that a case is found in which less than twenty treatment sessions is sufficient to establish perfect convergence.

Patients are usually taken to perfect convergence, for then there is little chance of regression.

II. THE REVIEW OF LITERATURE.

In the introductory chapter, the assertion was made that little has been done and written regarding this problem. One notable exception is, Doctor Stutterheim. His investigations have revealed much that is important.*

The method of therapy discussed in the first chapter of this thesis is a revolutionary one which has produced consistently good results. To Doctor Stutterheim must go the credit for devising this therapy. Doctor Stutterheim was the first to break away from the traditional ineffective therapy of prescribing spectacles for eyestrain patients, and to seek a therapy elsewhere.

To criticize one who has done so much in this field seems unfair yet necessary. Here is rather a paradoxical situation in which the doctor has devised a therapy vastly superior to the outdated spectacle "cure", and that on a faulty theoretical foundation, as is expounded in his two books on the subject, namely, "Eyestrain and Convergence"

and / ....

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* "Eyestrain and Convergence" --N.A. Stutterheim, M.D.(RAND) -- London H.K. Lewis & Co. Ltd. 1937.

"Squint and Convergence" -- N.A. Stutterheim, M.D.(RAND) -- London H.K. Lewis & Co. Ltd. 1946.

and "Squint and Convergence". His theory fails from a psychological viewpoint.

In general, the doctor's theoretical treatment of the problem is an unrealistic one. Terms such as "mind" and "consciousness" are used altogether too loosely. Furthermore, he regards convergence as the power directing the two visual axes on the visual object, and this power is one which develops in the maturation. Here he errs, for convergence is a learned habit.

Nowhere does the doctor make allowance for convergence as a voluntary act. When convergence is perfect or at least normally developed, then it has become an habitual attitude or posture of the dual eye, developed as a response to visual stimulation. In this case, convergence is an involuntary response. However, if in the course of treatment, the patient experiences diplopia, and either on the advice of the therapist or on his own initiative, strives consciously to bring the two images into a state of fusion, then if the conscious effort has the desired effect, the act of convergence is no longer involuntary. In actual practice, this deliberate volition does occur from time to time. There is a drive to converge in order to eliminate diplopia, and this drive need not be unconscious.

Only when convergence has become at least semi-automatic in use is it completely involuntary. If the subject makes no conscious effort to converge, and the image is single, then convergence is involuntary. The fact that conscious effort to converge can result in fusion of the images, leads to the conclusion that convergence is a habit that is normally involuntary in normal subjects, and yet can be voluntarily controlled. During learning, the convergence habit is partly voluntary and partly involuntary. Once the convergence habit is fully established, it becomes a tonic activity replacing voluntary action.

Yet another contentious point is as regards the theory of the actual therapy. Stutterheim claims that this treatment is physiological and not physical. The question to be answered is what this treatment aims to do. The facts are that there is an insufficiency in the ability of the dual eye to converge on a visual object. The treatment aims at correcting this deficiency.

On the perfectly valid assumption that convergence is a habit, then, since with eyestrain subjects this habit is inadequately developed, the aim of the treatment is to more fully establish the habit and bring it to perfection.

The / .....

The convergence must be strengthened in order to perform its allotted function with all-round satisfaction.

The eyestrain patient is subject to a faulty perception which has its roots in the lack of convergence. If then this asthenovergence is corrected, a true perception will follow in its train. On the Behaviour Theory, habits are established and strengthened as a result of physical action. This is, of course, an over-simplification of one of the primary postulates of the Behaviour Theory, but serves adequately to promote the argument.

The therapy attempts to alter the perception of the eyestrain subject by correcting asthenovergence, and unless there is some form of physical action involved, the therapy is doomed to failure. Where formerly the patient perceived an object as double or blurred, he is now induced to see it as single.

On Doctor Stutterheim's assertion that this treatment is not physical, the expectation is that this kinetic treatment should fail to produce results. However, results do not justify this expectation, thereby indicating an error in reasoning somewhere.

The / ....

The error is that this treatment does incorporate physical elements. The passivity implied by Doctor Stutterheim on the part of the patient is not a true reflection of the therapeutical situation. The very attention of the subject to the visual object is a physical action. The eyes are adjusted to the oblong strip of white paper.

An even more important physical element is that operative when the patient taps to indicate the number of images seen at each successive increase in the degrees of prism.

Finally, comes the question of drive. The drive prompts the subject to converge in an attempt to cure his ailment, and this leads to a state of activity in the nervous system which precludes the possibility of complete passivity on the part of the patient.

One can but infer that the method of therapy was first devised, with the theory a later development to justify the therapy. A case of first erecting a building, and then laying its foundations.

Perhaps / ....

Perhaps Doctor Stutterheim's most valuable contribution in the theoretical field, was in isolating the dynamic relationship of the biunial eye as the underlying factor in causing eyestrain. His investigations enabled him to reject the three other possible causes of eyestrain, namely, the static and dynamic conditions of the single eye, i.e. refraction and accommodation, and the static relationship of the two eyes.

Doctor Stutterheim more than any other investigator has been instrumental in directing attention upon convergence as the kinetic factor of the dual eye, and the cause of eyestrain in general.

Hartridge [1] has suggested that eyestrain or visual fatigue may be attributed to the effort involved in dissociating the normally co-ordinated functions of convergence and accommodation. In far-sighted persons, accommodation of the lens for a near object must be performed without convergence, and when the individual is near-sighted, convergence must be made without any apparent change in the shape of the lens. This postulate as a

general / ....

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1 Carmichael and Dearborn; "Reading and Visual Fatigue", Houghton Mifflin Company -- 1947. The Riverside Press, Cambridge.

general principle is negated by the fact that many eyestrain sufferers are subject to neither of these two defects. Eyestrain is found as a rule in those who have otherwise perfectly good and healthy eyes.

There is no other investigation on this subject to warrant any serious consideration.

III. THE INVESTIGATION.

(A.) OBJECT OF INVESTIGATION.

Whereas it is freely admitted that eyestrain is essentially muscle fatigue arising out of the inability to converge the eyes in response to the distances and positions of visual objects, this thesis submits that this is not the whole story.

The crux of the matter is what is the particular response or set of responses that actually leads to the fatigued condition of the extrinsic eye muscles?
At this stage, the investigator submits that asthenovergence in itself is probably not the cause of eyestrain. If it were, one would have to acknowledge that the eyestrain patient is continually engaged in a conscious physical battle against heavy odds, to converge the visual axes on visual stimulus objects. The patient must strive

for clearest single vision in unfavourable circumstances, and this can only be done by converging which is a physical action.

This investigation postulates that rather is eye-strain due to the substitute response or set of responses that is built up to contend with this difficulty. Since the convergence response is proved to be unsatisfactory, the assumption is that the eyestrain patient, through a process of trial and error, learns an entirely new response which obviates what has proved to be a difficult if not an impossible response for the subject in question.

When the subject regards an object nearer than the minimum distance at which the visual axes can intersect, he must have either diplopia or monocular vision. The latter alternative can only occur if the image of one eye is momentarily suppressed. Assuming the two eyes to be equally good, the suppression of the image is likely to alternate between the two eyes, resulting in continuous retinal rivalry. The hypothesis is that this retinal alternation is the substitute response that is built up, consciously or unconsciously, and leads to eyestrain.

Retinal alternation involves the consequence that in order to maintain fixation on a single point, the eyes must move continuously sideways so as to fixate the point first with the right and then with the left eye or vice versa.

When the subject is scanning an object rather than fixating a single point, the scanning movements must necessarily be wider in extent, and include a larger number of regressive movements than with the person with normal vision.

Contrary to common belief, reading is not a completely smooth uninterrupted activity. The eyes in reading do not move steadily along the printed line, but make a series of rapid fixation jerks interspersed with relatively long pauses. The fixation period is presumably the period wherein comprehension of the completed material is attained either wholly or in part.

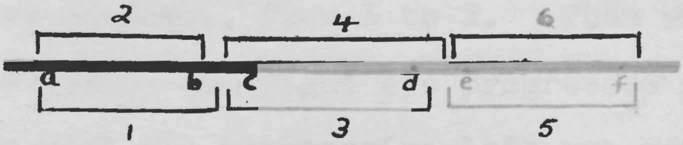
In addition to these progressive movements, the eyes perform regressive or corrective movements; short saccadic movements in the reverse direction to the normal left to right movements. These regressive movements allow re-fixation of the material appearing previously in the line of print, and in all probability, are for the purpose of correcting inadequate and faulty fixation and/or comprehension of the previous material. With the regressive movement there's a second fixation which remedies the former misreading in the line.

The number of saccadic movements made depends upon the number of fixations the reader requires to comprehend the line of print. Normally, the more abstruse the reading passage, the greater will be the number of eye movements. With eyestrain patients, however, there is in addition a second determinant of the number of eye movements. This additional determinant is a mechanical one, imposed on the organism by the faulty action of the two eyes.

The hypothetical retinal rivalry necessitates a greater number of progressive movements than in the normal patient. If the retinal rivalry doesn't lead to a greater number of progressive eye movements, a greater number of regressive movements will be required than is normal. The nett result will be that the total number of eye movements in the eyestrain patient will exceed that of the normal subject.

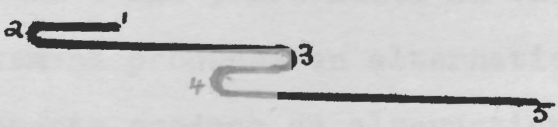
The abnormal amount of regressive movements is due to the fact that asthenovergence is likely to lead to a greater possibility of faulty or inadequate fixation of the reading material.

In the extreme case as illustrated below (Diagram 2) the expectation is that for each progressive movement, there will be at least one regressive movement. The action of the eyes will be such that say the left eye first fixates. Then the right eye fixates which involves a regressive movement of the right eye and a sympathetic regressive movement of the left eye. The following left eye fixation is a progressive movement whereas the alternating right eye fixation involves a regressive movement again and so forth till the end of the reading passage. In this case, the regressive movements are not likely to be wide in extent.



EYE MOVEMENTS IN EYESTRAIN SUBJECTS

DIAGRAM 2.



RIGHT EYE MOVEMENTS IN EYESTRAIN SUBJECTS.

DIAGRAM 3.

Diagram / ....

Diagram 2 illustrates the eye movements of eye-strain subjects in reading, when retinal alternation is continuous. In Diagram 2, a, b, c and d indicate imaginary fixation points along the printed line. The left eye, for argument's sake, fixates point a. The next fixation by the right eye of the second point, point b, involves a regressive movement indicated by 2. The left eye then fixates point c, and this is the progressive movement 3. The fourth movement is a right eye fixation, and this is the regressive movement 4.

In Diagram 3 is shown the movements of the right eye when the left eye has the honour of the first fixation. The second fixation as performed by the right eye involves a regressive movement, from 1 to 2. Then when the left eye fixates again, the right eye progresses from 2 to 3 in sympathy with the progressive left eye movement. Once again the right eye regresses from 3 to 4 and then progresses again from 4 to 5.

Diagrams 2 and 3 are based on the assumption that each eye movement produces an alternation. Probably not all the movements produce an alternation, since one eye may remain dominant for a longer period than the other. In this case, the proportion of regressive movements will decrease relative to that case where the retinal alternation is continuous.

As a consequence of the hypothetical preponderance of eye movements in both directions due to retinal rivalry, there is bound to be fatigue. The distance traversed by the eyes is increased, hence the fatigue.

The procedure then is to establish experimentally that the number of eye movements are in fact greater in eyestrain subjects as compared with normal individuals.

The difficulties involved in setting up an identical central group of normal subjects with regard to such variables as age, sex and intelligence inter alia, are enormous. This handicap to scientific validity of results was obviated by having eyestrain patients assume the dual role of experimental subjects and control groups.

The subjects were tested as regards the number and extent of progressive movements, eye movements, and the number of retrogressive movements at the very beginning of learning. These same tests are applied at successive stages of the therapy, as the convergence habit is built up from a stage of retardation to one of perfect development, i.e. from the abnormal condition of inability to converge under twenty one degrees (21^{o}) of prism, until the patient is able to converge through about eighty four degrees (84^{o}) of prism.

Forty nine degrees (49°) of prism convergence is roughly equal to an interocular angle of twenty six degrees (26°). Thus, the ability to converge through no more than twenty one degrees (21°) of prism is insufficient for normal reading. Convergence through sixty five degrees (65°) of prism is quite adequate for normal purposes while at eighty four degrees (84°) of prism convergence, the habit is said to be perfectly developed.

(B.) APPARATUS AND MATERIAL.

Ideally, eye movements should be measured by mechanical means, e.g. Newhall's method * whereby a vein or outer edge of the iris is observed for counting the eye movements. Still more satisfactory would be the use of a movie camera for recording the eye movements.

In the absence of any such mechanical aids, the experimenter was faced with three alternatives. The

first / ....

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* See Carmichael and Dearborn, p.152. "Reading and Visual Fatigue".

first alternative was the calculation of the reflected eye movements through a telescope. For want of a telescope, this method was discarded as being impractical.

The second alternative was the Peep-hole method. By this method, a hole approximately one quarter inch ($\frac{1}{4}$") in diameter is punched in the middle of the copy to be read. The copy is read, held straight up in front of the reader, with the observer's eye close up to the hole to enable the subject's eye movements to be observed and recorded.

Finally, eye movements can be observed during reading by reflection from a mirror. This latter alternative was selected as the lesser of two evils.

The experimental technique used in this investigation is a simple one, which most psychology students have employed at some stage or other in their curriculum. A plane glass mirror and reading passages of varying lengths and difficulty comprised the apparatus and material of this investigation. Reading passages in English and Afrikaans were used.

Method / ....

(C.) METHOD OF PROCEDURE.

In the experimental situation, the subject sat at a table with the reading passage in a plane normal to the line of vision. The mirror was placed on the plane of the table, just beyond the passage to be read, to enable the experimenter sitting on the other side of the table to observe the movements of the subject's eyes in reading.

The subject on receiving the go ahead signal, read the test passage four times in all at each stage of the experiment; binocularly aloud, binocularly silent, monocularly aloud and monocularly silent. The passages were read at normal reading speed, the subject attempting to grasp the import of the printed word. Monocular vision was achieved by the subject pressing down on the one closed eyelid with sufficient pressure to prevent free sympathetic movement of the one eye as in binocular vision.

The investigator counted the number of progressive and regressive eye movements as reflected in the plane glass mirror and recorded these. The progressive movements were calculated mentally, whereas for each regressive movement a stroke or dot was made on a piece of paper during the course of the experiment, and then the number of dots or strokes were totalled.

Certain / ....

Certain necessary precautions were adopted in conducting these experiments. The subjects were told to keep their heads as steady as possible while reading; accurate calculation of eye movements is difficult enough in itself without the added complication of head movements to contend with. The long sweeping movements from the end of one line of print to the beginning of the next line were not counted.

An even more important consideration was as regards the selection of the reading passages. The investigator did attempt to ensure that subjects were not confronted with passages either too difficult or too easy of comprehension. Varying degrees of difficulty of reading passages are bound to distort results. Admittedly the method of assessing the suitability or non-suitability of a reading passage for the individual subject was somewhat rough and ready. For reasons of practicability, the investigator was obliged to make a guess at the subject's ability to comprehension. A few minutes conversation prior to the testing served as a guide to the guess. The fallibility of this method was reflected on more than one occasion, by the need for making a switch in the type of passage presented, as when one subject was found to stumble unduly while reading, and perhaps another waltzed through the set task with consummate ease. Absolute precision, however, is unnecessary in this selection.

To avoid the distorting effects of familiarity with passages, subjects were confronted with different reading passages, but as nearly identical as possible, at almost each stage of the experiment. Here again, absolute precision is superfluous. Subjects read passages in their home language.

The investigator refrained as far as possible from attempting any interpretation of the results throughout the whole period of the investigation. The reason for this was an attempt to exclude any prejudice in counting eye movements.

Finally, subjects were subjected to the final testing a long period after cessation of the treatment. This was to allow for the possibility of any latent accommodation affecting the results. An even more important reason was that though the convergence habit at the end of the therapy is perfect, it is a perfection in potentiality and not in use. Thus the subjects were given some time to make use of this newly acquired habit, and thereby displace the hypothetical retinal rivalry.

IV. RESULTS.

The results obtained in the experimental investigation of eye movements in reading have been listed in tabular form on the following pages.

Five subjects have been tested, two males and three females. [1]

Along the columns and rows are listed the manners of reading, the size of the reading passage, and the number and extent of the eye movements in reading. The changes in the number and extent of the eye movements from one trial to the next are reflected along the rows.

Case A / ....

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1 For further information about these subjects see the Tables in the Appendix.

CASE A.

TABLE 1.

BA - Binocular aloud reading   MA - Monocular aloud reading
BS - Binocular silent reading   MS - Monocular silent reading

Manner of reading	B_A	B_A	B_A	B_A	B_A	B_A	B_A
Number of trial	1	2	3	4	5	6	7
Degrees of convergence (initial-final)	-	-	-	(5-16)	(84-87)	(84-89)	(84-89)
Number of lines	14	14	16	16	16	10	14
Number of words	171	164	162	162	162	112	164
Number of letters	695	715	790	790	790	550	715
Total number eye movements	152	134	162	120	116	88	119
Number regressive eye movements	76	67	81	12	16	10	9
Average number regressive movements per line	5.43	4.79	5.06	0.75	1.00	0.63	0.64
Average number progressive movements per line	5.43	4.79	5.06	6.75	6.25	7.80	7.85
Average total number movements per line	10.86	9.57	10.13	7.50	7.25	8.80	8.50
Average number letters per progressive movement	9.15	10.67	9.75	7.32	7.90	7.05	6.50
Average number words per progressive movement	2.25	2.45	2.00	1.50	1.62	1.44	1.49

B_S	B_S	B_S	B_S	M_A	M_A	M_A	M_A	M_S	M_S	M_S	M_S
1	2	3	4	1	2	3	4	1	2	3	4
(5-16)	(84-87)	(84-89)	(84-89)	(5-16)	(84-87)	(84-89)	(84-89)	(5-16)	(84-87)	(84-89)	(84-89)
16	16	10	14	16	16	10	14	16	16	10	14
162	162	112	164	162	162	112	164	162	162	112	164
790	790	550	715	790	790	550	715	790	790	550	715
103	100	67	97	84	94	66	113	73	71	64	90
8	3	2	1	10	4	6	9	4	1	2	0
0.50	0.19	0.13	0.07	0.63	0.25	0.38	0.64	0.25	0.63	0.13	0.00
5.94	6.06	6.50	6.86	4.63	5.63	6.00	7.43	4.31	4.38	6.20	6.43
6.44	6.25	6.70	6.93	5.25	5.88	6.60	8.07	4.56	4.44	6.40	6.43
8.32	8.14	8.46	7.45	10.68	8.78	9.17	6.88	11.45	11.29	8.87	7.94
1.71	1.67	1.72	1.81	2.19	1.80	1.87	1.58	2.34	2.31	1.81	1.82

CASE B.

TABLE 1.

BA - Binocular aloud reading MA - Monocular aloud reading
BS - Binocular silent reading MS - Monocular silent reading

Manner of reading	B_A	B_A	B_A	B_A
Number of trial	1	2	3	4
Degrees of convergence (initial - final)	(8-24)	(8-29)	(10-42)	(65-81)
Number of lines	10	10	10	10
Number of words	107	105	105	105
Number of letters	513	536	536	536
Total number eye movements	88	92	104	75
Number regressive eye movements	7	6	8	2
Average number regressive movements per line	0.70	0.60	0.80	0.20
Average number progressive movements per line	8.10	8.60	9.60	7.30
Average total number movements per line	8.80	9.20	10.40	7.50
Average number letters per progressive movement	6.33	6.23	5.58	7.34
Average number words per progressive movement	1.32	1.22	1.09	1.44

B_S	B_S	B_S	B_S	M_A	M_A	M_A	M_A M_S	M_S	M_S
1	2	3	4	1	2	3	1	2	3
(8-24)	(8-29)	(10-42)	(65-81)	(8-29)	(10-42)	(65-81)	(8-29)	(10-42)	(65-81)
10	10	10	10	10	10	10	10	10	10
107	105	105	105	105	105	105	105	105	105
513	536	536	536	536	536	536	536	536	536
85	66	85	65	90	95	82	64	73	57
6	6	4	2	5	6	6	2	4	2
0.60	0.60	0.40	0.20	0.50	0.60	0.60	0.20	0.40	0.20
7.90	6.00	8.10	6.30	8.50	8.90	7.60	6.20	6.90	5.50
8.50	6.60	8.50	6.50	9.00	9.50	8.20	6.40	7.30	5.70
6.49	8.93	6.62	8.51	6.31	6.02	7.05	8.65	7.77	9.75
1.35	1.75	1.296	1.67	1.24	1.18	1.38	1.69	1.52	1.91

CASE C.

TABLE 1.

B_A - Binocular aloud reading M_A - Monocular aloud reading

B_S - Binocular silent reading M_S - Monocular silent reading

Manner of reading	B_A	B_A	B_S	B_S	M_A	M_A	M_S	M_S
Number of trial	1	2	1	2	1	2	1	2
Degrees of Convergence (initial - final)	(5-8)	(50-75)	(5-8)	(50-75)	(5-8)	(50-75)	(5-8)	(50-75)
Number of lines	16	16	16	16	16	16	16	16
Number of words	162	162	162	162	162	162	162	162
Number of letters	790	790	790	790	790	790	790	790
Total number eye movements	94	78	104	97	97	81	87	86
Number regressive eye movements	10	2	4	1	10	1	3	2
Average number regressive movements per line	0.63	0.13	0.25	0.06	0.63	0.06	0.19	0.13
Average number progressive movements per line	5.25	4.75	6.25	6.00	5.44	5.00	5.25	5.25
Average total number movements per line	5.88	4.88	6.50	6.06	6.06	5.06	5.44	5.38
Average number letters per progressive movement	9.41	10.40	7.90	8.23	9.08	9.88	9.41	9.41
Average number words per progressive movement	1.93	2.13	1.62	1.69	1.86	2.03	1.93	1.93

CASE D.

TABLE 1.

B_A - Binocular aloud reading M_A - Monocular aloud reading
B_S - Binocular silent reading M_S - Monocular silent reading

Manner of reading	B_A	B_A	B_S	B_S	M_A	M_A	M_S	M_S
Number of trial	1	2	1	2	1	2	1	2
Degrees of Convergence (initial - final)	(1-21)	(35-56)	(1-21)	(35-56)	(1-21)	(35-56)	(1-21)	(35-56
Number of lines	14	14	14	14	14	14	14	14
Number of words	164	164	164	164	164	164	164	164
Number of letters	715	715	715	715	715	715	715	715
Total number eye movements	92	83	106	78	105	84	109	80
Number regressive eye movements	8	1	8	1	11	3	9	0
Average number regressive movements per line	0.57	0.07	0.57	0.07	0.79	0.21	0.64	0.00
Average number progressive movements per line	6.00	5.86	7.00	5.50	6.71	5.79	7.14	5.71
Average total number movements per line	6.57	5.93	7.57	5.57	7.50	6.00	7.79	5.71
Average number letters per progressive movement	8.51	8.72	7.30	9.29	7.61	8.83	7.15	8.94
Average number words per progressive movement	1.95	2.00	1.67	2.13	1.75	2.02	1.64	2.05

CASE E.

TABLE 1.

B_A - Binocular aloud reading M_A - Monocular aloud reading
B_S - Binocular silent reading M_S - Monocular silent reading

Manner of reading	B_A	B_A	B_S	B_S
Number of trial	1	2	1	2
Degrees of Convergence (initial - final)	(65-92)	(65-92)	(65-92)	(65-92)
Number of lines	10	10	10	10
Number of words	102	107	102	107
Number of letters	527	513	527	513
Total number eye movements	52	52	62	64
Number regressive eye movements	0.00	0.00	0.00	0.00
Average number regressive movements per line	0.00	0.00	0.00	0.00
Average number progressive movements per line	5.20	5.20	6.20	6.40
Average total number movements per line	5.20	5.20	6.20	6.40
Average number letters per progressive movement	10.14	9.87	8.50	8.02
Average number words per progressive movement	1.96	2.06	1.65	1.67

V. DISCUSSION OF RESULTS.

For the purpose of convenience in making comparisons the method of tabulating the results was to treat each of the four manners of reading in isolation. The results of each from trial to trial are recorded along the rows.

The first 3 columns in Case A represent the results obtained in binocular aloud reading before any treatment was begun on this patient. Unfortunately, the experimenter had not yet at the time of these three tests, decided upon the plan of having subjects read passages in four manners. Nevertheless, these three trials are of use in developing the theory.

The third row in Tables 2 of cases A, B, C, D and E indicate the degrees of convergence, initially and finally, attained by the subjects. The reading tests were applied to the subjects in all cases, a few minutes prior to the treatment session on that day of the trial. The convergence figures are thus the figures obtained at the therapy session on the day prior to the test trial. Initial convergence represents the degree of prism through which the subject was able to converge at the beginning of a

treatment / ....

treatment session, and final convergence represents the degree of convergence at the end of that treatment session.

Consider Table 2, Case A. The results of this subject's binocular aloud reading, BA, indicate that the average number of regressive movements per line have decreased from a relatively high level at the first three trials, to a relatively low level for the last four trials, though with some variation from the fourth to the seventh trial.

Surprise may be evinced at the rather abrupt decrease in the average number of regressive eye movements from the third to the fourth trial of binocular aloud reading. There is some justification for doubting the validity of the investigator's work at this stage. Even assuming the hypothesis prompting this work is valid, figures so magnificently in line with the theory are liable to query, since the convergence habit at the fourth trial was still far from perfectly developed. There is, however, a perfectly reasonable explanation for this.

The investigator admits to having committed an almost fatal error in technique in testing this patient; an error which was not repeated in the testing of other subjects.

The first three tests of eye movements to which this patient was subjected, were conducted before the patient was treated for eyestrain. The results obtained from reading a passage binocularly aloud were in complete conformity with the hypothesis as previously stated, namely that eyestrain is due to retinal alternation. This subject proved in fact to be an extreme case of retinal alternation in which the expectation is that for every progressive movement the eyes make, there will be a corresponding regressive movement of the dual eye.

Now, this subject had in the first place agreed to being tested, in order that an analysis of the eye movements might resolve a source of worry to him, namely his great difficulty in reading at a normal speed.

The investigator erred in discussing the results obtained with the patient. In this discussion, the patient, a student with at least average intelligence, readily appreciated the significance of this abnormally high number of regressive movements. The sudden decrease in the average number of regressive movements per line may thus be attributed to a conscious inhibition of the regressive movements on the part of the subject.

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On the other hand, the increase in the average number of progressive movements per line with binocular aloud reading seems to offer no reasonable explanation, and appears to contradict the hypothesis. It may be that the conscious inhibition of regressive movements led the subject to adopt another mechanism in fixating, namely the use of only one eye for long periods of time.

It is not necessary to discard all the results obtained in later tests of this patient. The results will be accepted as modified by this hypothetical inhibition, and discussed in this new light. A more decisive confirmation or rejection of the hypothesis of retinal rivalry will, however, be sought in the records of the other subjects.

The facts are that the average total number of movements per line have decreased from an average of approximately 10·19 for the first three trials, to 8·50 at the seventh and final trial, with some variations in between.

The average number of regressive movements per line in binocular silent reading, Bs, have decreased from ·50 at the first trial when the deduced inhibition was operative, to ·071 at the final trial. These figures cannot be discarded as completely invalid, since all four trials were subject to the same inhibition effect, and yet there was a decrease in regressive movements on the average. This rather suspect confirmation of the hypothesis is badly offset by the relatively greater increase in the average number of progressive movements per line. As a consequence thereof, there is an increase in the average total number of movements per line for binocular silent reading.

The results obtained with monocular silent and aloud reading, Ms and Ma respectively, taken on the whole, do little to confirm the hypothesis. If anything, they serve to contradict the hypothesis.

This case has produced upsetting though not unexpected results. At one stage the hypothesis appears to be confirmed, yet at the very next stage, we are faced with incompatible results. At this stage of the proceedings, the argument is still very much in the air.

Consider next Case B, Table 2. At the very first trial, only eye movements in binocular aloud and silent reading were observed.

In Case B, the average number of regressive movements per line, decreased with binocular aloud reading, Ba, from ·70 at the first trial to ·20 at the fourth and final trial with some variations in between. Likewise, the

average /

average number of progressive movements per line have decreased significantly from the first to the fourth trial, in binocular aloud reading. The average total number of movements per line have been affected in the same direction.

Binocular silent reading has produced similar significant decreases from the first trial when the convergence habit was quite imperfect, till the final trial, at which stage convergence was perfectly developed. As a consequence of the decreased number of progressive movements on the average, the average number of words and letters per progressive movement has increased.

The figures for monocular aloud reading are both satisfactory and unsatisfactory. As expected, there is little change in the average number of regressive movements per line. The decrease in the average number progressive movements per line from 8·50 at the first test to 7·60 at the final trial is inexplicable on this hypothesis. The decrease in the average total number of movements per line because of the decrease in progressive movements on the average, has likewise no apparent explanation. This hypothesis offers no expectation of any change in monocular reading, as regards the number and extent of eye movements.

In monocular silent reading, there was little change in the average number of regressive movements per line, which remained at a relatively low level throughout. Again there is an unexpected decrease in the average number of progressive eye movements per line from 6•20 through a rise to 6•90 and finally to 5•50. This decrease has affected the average total number of movements to a similar rise and final fall.

In general, here is much in the material provided by Case B which favours the hypothesis. This Case incidentally is the only one in which Afrikaans was used as a medium for reading.

The third case, i.e. Case C, also appears to confirm the hypothesis. From •625 at the first trial, the average number of regressive movements per line has decreased to •125 at the second and final trial with binocular aloud reading. Furthermore, the average number of progressive and total eye movements per line, reflect noticeable decreases in binocular aloud reading, from 5•25 to 4•75 in the former, and 5•88 to 4•88 in the latter instance. So too, the average number of words and letters per progressive movement have increased significantly.

Binocular / ....

Binocular silent reading has also yielded fairly significant decreases in the average number progressive, regressive and total movements per line. The consequent increase in the average number of words and letters per progressive movement, bear testimony to the wider extent of the dual eye movements, now that convergence has finally been established at a very high level.

The results with monocular silent vision are very satisfactory. There has been little if any change all round.

Case D also is a confirmation of the hypothesis. The results from the first trial to the second trial which was conducted even when the treatment was not completed, have changed in a way deducible from the hypothesis. Both binocular aloud and silent reading have yielded decreases in the average number progressive, regressive and combined total eye movements. The similar decreases obtained with monocular silent and aloud reading again lend themselves to no ready explanation, not that any explanation is necessary.

Approaching this problem from the other end, let us consider the figures recorded in Table 2, Case E. We ignore, for the present, the row indicating the degrees of convergence at the two test trials.

The average total number of eye movements both for binocular aloud and silent reading, as compared with other eyestrain patients, is at a relatively low level. This patient had only one test session in which two passages were read. Throughout both passages there was not a single regressive movement.

The average total number of movements per line for Case A was 10•19 on the average for the first three trials with binocular aloud reading. The corresponding figure for Case B for the first trial was 8•80, for Case C, the figure was 5•88 and for Case D, 6•57. Case E, however, averages to only 5•2 for the two test passages on the one trial session.

For binocular silent reading, the average total number of movements per line are 6•46 on the averaged first three trials for Case A, 8•50 for Case B, 6•50 for Case C, and for Case D, the corresponding figure is 7•57. Case A averages to only 6•30 for the two test passages.

The figures for the average total number of movements per line for the final trial when the convergence habit is perfect or at least at a very high level, and

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when the subjects have been supposedly cured of eyestrain are Case A= 8.50, Case B = 7·50, and Case C = 4·88. Even Case D, in which convergence has been established only at fifty six degrees (56°) of prism, has a figure of 5·93 for binocular aloud reading.

The figures for binocular silent reading are 6·93, 6·50, 6.06 and 5·57 respectively.

Assume for the moment that the hypothesis under investigation is factual, and that the same test precautions have been observed in this case E as in the other cases. In the light of the above figures, we may then deduce that Case E is a subject with a high degree of convergence, and hence very unlikely to be an eyestrain sufferer, since there is no need to have to resort to retinal alternation.

In point of fact, Case E is an ex-eyestrain patient and at the time of testing the convergence habit had been finally established at ninety two degrees (92°) of prism.

Conclusions / ....

VI. CONCLUSIONS.

In an investigation of this nature, it would be foolhardy to attempt any dogmatic conclusions. In a previous chapter it was pointed out that the technique employed in the experimental department of this investigation was not completely satisfactory. More important still, the size of the test sample, dictated though it was by circumstances, is insufficient to allow conclusions with absolute certainty. The formulation of any hard and fast principles would necessitate a sample of a great many more cases than was used in this investigation.

Human, sampling and measurement error are factors which must be taken into account. Consequently, the conclusions drawn can only be a matter of probability and not of certainty.

Nowhere in the investigation has there been any serious contradiction to the hypothesis that eyestrain is due specifically to the fact that the two eyes are not working together in perfect harmony, but alternate in use, depending on which eye is dominant at any point of time. Thus for reading and other near work which demands the fixation of objects on lines or words of print, the eyes have to work overtime as they alternate

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in fixating the visual stimuli, and this results in a strained condition of the eyes.

Rather has the general trend of the investigation been such as to substantiate this above hypothesis. The probability is therefore fairly large that eyestrain is in fact due to retinal rivalry of the two eyes.

One thing is fairly certain, and that is that at the least, retinal rivalry is responsible for eyestrain in some, if not all, cases.

The strained condition is due not so much to the striving, whether conscious or unconscious, of the subject to converge on an object, but to the abnormal demands made upon the organism by the development of the faulty mechanism which supplants the convergence habit for the most part. The eyestrain patient develops this alternating retinal habit as the only alternative to the correct habit of vinocular bifoveal vision, which is at all acceptable. This alternative habit is abnormal in the respect that it necessitates a greater expenditure of energy than when the two eyes work together as a single organ.

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We may deduce that people who do not use near vision much, are not very liable to eyestrain. On the other hand, architects, draughtsmen and others in whom near vision is exercised nearly all day, will be more liable to eyestrain if the convergence habit is not fully established.

Since retinal rivalry has its roots in asthenovergence, then with the correction of this deficiency in vision, the mechanism of alternating retinae will be broken down. In its place is established the more acceptable convergence habit. The extinction of the old retinal rivalry habit must take place alongside the reinforcement of the new convergence habit. No longer have the eyes to perform so much work, and since they are no longer overtaxed, the strain dissipates with time.

The less the rate of retinal rivalry, the less probability there is of eyestrain, i.e. the slower the onset of the eyestrain condition.

The only way in which retinal rivalry can be inhibited without correcting convergence, and still having fairly clear vision is to abolish the use of one eye entirely. The result of this will lead to partial or complete loss of sight in one or other eye, i.e. amblyopia.

The kinetic treatment devised by Doctor Stutterheim for increasing the patient's range of convergence is fundamentally sound. The drawbacks to this therapy are the great expense and lengthy period of treatment involved. There is a possible alternative technique as yet untested in practice, but with a high probability of success in theory.

The suggestion is that the eyestrain patient be fitted out with a binocular or monocular prism system which must be worn over the eyes. The prisms must be sixty five degrees (65°) or more in strength. At first everything will appear double to the patient. If, however, the patient engage in ordinary everyday activities as much as possible such as walking, writing and other manipulatory activities, then in the course of time the visual field will return to normal. This is in accordance with the behaviour theory. The adoption of appropriate movements to visual stimulation will lead the disrupted perception of the visual field into a normal perception. With perception back to normal, the patient will be able to converge through a greater angle than before, when the prisms are eventually removed. The perceptual change may be hastened if the patient engage in rotatory movements of the eyes while the prisms are being worn.

The /

The practicability of this scheme depends upon whether prisms can be ground so as to eliminate or at least make negligible any visual distortion. Also, the prisms will have to be comparatively inexpensive to manufacture. In addition, the length of time it takes before the patient learns to overcome this double perception must not be too long.

The former two conditions could conceivably be satisfied. The third condition is in the absence of any experimental investigation, as yet unpredictable. Of course, one must not overlook the possibility that the removal of the prism system may lead to a second disruption of the visual field. This also will however be corrected with the passage of time, in accordance with the laws of behaviour.

One objection may be that during treatment the patient will be unable to pursue normal everyday activities to the fullest extent. Work and social activities may have to be neglected. The only answer to this is that when a patient has 'flu or some such affliction, he goes to bed, and vocational and social activities are likewise curtailed.

One final deduction may be drawn from the hypothesis of retinal rivalry. It is unlikely that birds and reptiles are eyestrain sufferers, for they have their eyes nearly rigidly fixed in the head.

VII. SUMMARY

In the introduction to this thesis is contained a statement of the aims of this investigation, followed by an attempt to justify such a research into the problem of eyestrain. In the analysis of the problem has been included a definition of eyestrain, its symptoms and causes. The physiology of vision and certain related physiological aspects of eyestrain have been discussed, to prepare the reader for a fuller understanding of the problem as later analysed.

The Review of Literature offers some idea of a few previously held theories and facts about the problem, with some criticism of the aforesaid theories.

The object of the thesis was to test the hypothesis that eyestrain is essentially muscle fatigue due to retinal alternation. This retinal alternation is a substitute mechanism adopted by the eyestrain patient as a result of an inability to converge the eyes in response to distances and positions of visually presented stimulus objects.

A number of subjects chosen at random were subjected to experiments in which the number and extent of their eye movements were measured and calculated, to test the hypothesis. The eye movements were observed by the reflection of the eyes in a plane glass mirror.

The results, thus obtained, appear to confirm in part at least the hypothesis of retinal alternation.

Appendix / ....

APPENDIX.

The tables that are listed here, give some further information about the subjects tested in the previous investigation. Each table reflects the sex, occupation and approximate age of each subject in turn.

The first column of each of these tables is a record of the dates of the subject's therapy session. The second column represents the patient's degree of initial convergence on the aforesaid days of treatment, i.e. the degree of prism through which the patient was able to converge at the commencement of each of these treatment sessions. The corresponding figures along the rows for the degree of final convergence represents the strength of the convergence habit at the end of each therapy period.

Two interesting facts emerge from a study of these tables of daily progress during treatment. The first is the great variability in the results of treatment from day to day. The degrees of convergence may rise gradually one day, remain steady the next, and suddenly increase by leaps and bounds the following day, or even decrease.

The / ....

The second point is that a sudden increase seems to occur mainly when there is a lapse of a number of days from one trial to the next.

Both the above facts are not inconsistent with the Behaviour Theory.

Case A / ....

CASE A.

TABLE 1.

Sex: Male.
Occupation: Student.
Home Language: English.
Age: 22 years.

Date of Trial	Degrees of Initial Prism Convergence	Degrees of Final Prism Convergence
June 4	1	8
" 5	2	13
" 6	5	16
" 7	8	24
" 8	10	32
" 11	18	39
" 18	15	46
" 20	20	52
" 22	30	55
" 25	35	61
July 16	35	62
" 18	35	66
" 19	50	68
" 20	45	70
" 23	50	73
" 25	65	78
" 26	75	80
" 27	75	81
" 30	75	82
" 31	84	84
August 1	84	87
" 5	84	89

CASE B.

TABLE 1.

Sex : Female.
Occupation : Cheque Machiner
Home Language : Afrikaans
Age : 21 years.

Date of Trial		Degrees of Initial Prism Convergence	Degrees of Final Prism Convergence
May	14	8	13
"	15	5	21
"	16	8	24
"	17	8	29
"	18	8	32
"	21	10	37
"	23	10	40
"	25	10	42
"	28	19	43
"	29	10	42
June	1	19	44
"	4	15	48
"	7	25	51
"	11	30	54
"	12	35	58
"	15	35	61
"	18	35	62
"	19	43	63
"	21	45	66
"	22	50	68
"	25	50	73
July	16	50	73
"	19	65	75
"	20	65	78
"	23	65	81

CASE C.

TABLE 1.

Sex : Male.
Occupation : Student.
Home Language : English.
Age : 18 years.

Date of Trial		Degrees of Initial Prism Convergence	Degrees of Final Prism Convergence
June	14	1	8
"	20	6	16
"	21	8	22
August	1	8	17
"	2	9	26
"	8	15	28
"	9	20	36
"	13	20	39
"	23	30	55
"	30	30	55
September	12	30	61
"	13	43	65
"	14	50	66
"	18	45	63
"	20	55	68
"	24	50	56
"	25	50	75
October	9	60	76

CASE D.

TABLE 1.

Sex : Female.
Occupation : Scholar.
Home Language : English.
Age : 14 years.

Date of Trial	Degrees of Initial Prism Convergence	Degrees of Final Prism Convergence
August 8	1	8
" 10	1	13
" 13	1	18
" 15	8	21
" 22	8	24
" 24	10	26
" 27	10	28
" 29	10	31
" 31	10	34
September 3	10	35
" 5	10	32
" 7	10	31
" 10	1	21
" 12	10	23
" 14	10	26
" 17	10	31
" 19	18	34
" 21	15	38
" 26	15	40
" 28	15	45
October 3	30	47
" 5	20	53
" 11	35	56

CASE E.

TABLE 1.

ex : Female.
ccupation : Student.
ome Language : English.
ge : 19 years.

Date of Trial		Degrees of Initial Prism Convergence	Degrees of Final Prism Convergence
April	2	8	13
"	4	8	18
"	5	10	26
"	7	15	33
"	10	15	40
"	11	25	44
"	12	30	48
"	13	30	52
"	16	30	57
"	17	35	58
"	23	35	68
"	24	50	73
"	25	50	76
"	26	50	78
"	27	50	78
"	30	50	81
May	1	65	83
"	4	65	83
"	7	65	85
"	8	65	84
"	9	65	84
"	10	65	87
"	11	65	92

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