NON-VISUAL VARIABLES IN BINOCULAR PERFORMANCE

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DECLARATION

I declare that the material presented in this thesis has not been accepted for a degree at any other university.

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D. Humphriss

ACKNOWLEDGEMENTS

This thesis describes the organisation and execution of a programme of multi-disciplinary research which is described in nine chapters, of which only one directly concerns my own profession, optometry. Some of the work discussed, such as encephalography and the evolution of the ape-man, was not known to me in any detail at the beginning of the research fifteen years ago, so that my understanding of much of the material discussed in the thesis has depended on the continued patient assistance and advice of South African experts.

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Being a cross-discipline programme of research, the chapters had to be submitted to several readers in widely different academic spheres, resulting in repeated requests for the re-writing of many parts of the thesis. This re-typing has been done without complaint by my secretary Mrs. Edna Jooste.

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The analysis of the results of the research work in which small pilot samples were submitted to a large testing programme is always difficult and Mr M. Muller of his department gave me invaluable advice on the methods to be used to reduce the batteries and finally to analyse the results of a larger sample.

ABSTRACT

Clinical workers in binocular vision, known as orthoptists, have noticed variations in the binocular performance of patients which appear to have no relation to their visual state. Similarly there are some binocular tests, in particular stereoscopic tests, which cannot be performed by normal students of the Optometry School.

An initial reading of the literature on binocular vision indicated that it can be divided into two parts, that concerning the mechanism which produces one visual percept from two visual inputs to the two separate eyes, and the mechanism which produces stereopsis, by evaluating the angular differences between the two retinal images and interpreting them as a sense of depth.

It was decided to concentrate on the haploscopic aspect of binocular vision, and to search for non-visual variables which determined the operation of this function.

A detailed reading of the literature brought to light several sets of experimental results showing marked variability between normal subjects on the same test. Some of the operators commented on these, but did not look for their origin.

The neurological and neuro-anatomical literature indicated that the production of the single visual percept was an on-going process which became more complex as it was passed to higher neurological levels until the final process was controlled by the cortex of the parietal lobe.

This suggestion was confirmed by an E.E.G. programme carried out by the writer.

The existence of neurological activity in the parietal cortex involving the inhibition processes which remove an unwanted diplopic image from visual perception suggested very strongly that psychological variables would be found here.

This survey of the literature also indicated that no previous work had been done in this field and new tests had to be devised to isolate and measure the non-visual variables. This programme was undertaken by the writer who had done previous research in orthoptics and in optometry.

These tests produced 20 scores, some of which suggested the psychological variable with which the optometric scores might correlate significantly.

The nature of these scores was described to a cross-discipline project team whose members designed a battery of tests, one psychological and the other neuro-psychological.

The psychological battery was based on the assumption that the variable appeared to relate to some sort of psychological rigidity, but that as this was not certain, certain other tests such as motivation, frustration and suggestion must be adequately covered.

The neuro-psychological battery assumed that the binocular variables must be measurable in the activity of the central nervous system, and might appear as the muscular control of movement, or in the speed of perception. A battery of tests, including the E.E.G., was designed to measure these functions.

The total testing programme was now very large, and was given to two pilot samples. The battery was reduced in size by a study of the

correlations, and by the use of cluster analysis. A study of the selected correlations between the binocular and the psychological scores indicated a relationship between the psychological results and some of the binocular tests.

A reduced battery of both tests was given to a larger sample and a factor analysis of the result selected perseveration as the major psychological variable in binocular performance.

During the course of the research work some very valuable discoveries were made for clinical optometry. The possible value of the results to psychology and the avenues of future research opened up by the programme of research are discussed.

GLOSSARY OF ABBREVIATIONS, TERMS AND WORDS

Agnosia	A total loss of sensory perception.
Alpha Rhythm	Rhythmic electrical potential changes in the cerebral cortex varying from 8 to 13 cycles per second.
Ambliopia	Loss of visual resolution without discoverable cause
Aniseikonia	A marked difference in size of the retinal images
Apraxia	Inability to carry out an intended movement without pathology of the muscles involved.
Arboreal	Living in trees.
Australo-pithecus	The Southern ape; the name given to the S. African ape-man
Authoritarian	A personality type related to Fascism
Canthus	The nasal or temporal angle between the eyelids
Choroid	The middle layer of the eyeball, consisting largely of blood vessels.
Chiasma	The junction and partial decussation of the optic nerves.
C.F.F.	Critical fusion frequency.
Ciliary	Pertaining to the ciliary body
Colliculus	A relay centre in the dorsal mid-brain
Commisural Fibres	Fibres connecting one hemisphere of the brain to the opposite hemisphere
Conjunctive movements	Movements of the two eyes which are paired
Controlls	For Binocular controlls see markers
Cytoarchitecture	The cellular construction of the cortex of the brain in terms of its surface areas.
Cybernetics	The study of remote control
Cyclo-phoria	The tendency of the eye to rotate in its socket
Cyclo-vergence	The actual turning of the eye about an antero-postero axis.
Decussation	A crossing over of nervous fibres, as in an x
Dendrites	Extensions from a nervous cell which produce contact with other cells.

Dioptre	A measure of curvature, one dioptre having a radius of one metre. Optically the power of a lens, which having a power of one dioptre will focus parallel light to a distance of one metre.
Diplopia	Double vision resulting from the two eyes not being directed to the same stimulus point.
Dorsal	Towards the back.
Dysfunction	Partially correct functioning.
EEG	Electro-encephalogram.
Eideticism	Very vivid imagery.
Endocast	A cast of the interior of the skull.
Encephalisation	The development and evolution of the higher levels of the brain.
Esophoria	The tendency of the eyes to converge.
Exophoria	The tendency of the eyes to diverge.
Extort	The rotation of the upper part of the eye outwards.
Factor analysis	A statistical method whereby a common cause to varying behaviour can be isolated.
Farad	A unit of electrical capacity.
Fissure	A deep groove in the brain dividing it into lobes.
Foramen (Optical)	The apperture where the optic nerve leaves the orbit to travel through the brain.
Fundus	The interior back of the eye as seen through the pupil with an ophthalmoscope.
Fusional lock	An identical stimulus offered to both eyes which causes them to lock onto it in binocular vision.
F.R.Fusional Reserve	The amount the eyes can move away from the binocular fixation point with accommodation held constant.
Galvanic	A direct electric current.
Ganglion cells (Retinal)	The second relay of the visual impulse between the rods and cones and the lateral geniculate bodies.
Geniculate Bodies	The lower visual centres in the thalamus.
Gyrus	A fold of the surface of the brain
Haploscope	From the Greek Haplos, single. An involved stereoscope used for investigating binocular vision.
Heterophoria	The tendency of an eye to move away from a common fixation point.

Heuristic	Having a common imagination.
Horopter	The locus of stimulus points in space giving a uniplopic response.
Hyperbola	A curve formed by the section of a right circular cone when the cutting plane makes a greater angle with the base than the cone sides make to each other.
Innervation	The electrical changes in a nerve which result in sensory or muscular response.
Intort	To rotate the upper parts of the eyeball towards each other.
Isomorphic	Having a similar organic structure.
Labile	Easily moved or charged.
Lepidoptera	The moths and butterflies.
Limbus	The circle where the cornea joins the sclera.
Macula	A small area of the retina subtending an angle of about 2 degrees from the fovea centralis which appears like a yellow spot after death.
Markers	Also called controlls. A method of marking a contour in a stimulus to be fused binocularly with a similar stimulus so that the contour can be shown to be present in binocular vision, and not to have been suppressed.
Modality	An aspect of sense experience belonging to a particular specific sense.
Micronystagmus	Small jerky movements of the eyes.
Mutation	A genetic change producing an inheritable difference in a species.
Myelinated	Having an insulated sheath.
Nasion	The bridge of the nose
Nativistic	Having innate ideas.
Neuro-psychology	That branch of psychology relating behaviour to neuro-anatomy, physiology, and pathology.
Ndabele	An African tribe speaking a language similar to Zulu and living North of Pretoria.
N.F.R.	Negative fusional reserve.
One-tailed test	A test whose results are all in the predicted direction.
Ontology	The study of the development of the foetus.

Optokinetic nystagmus	The jerky movements of the eyes resulting from watching the vertical lines on a revolving drum.
Orbicularis	The muscle which surrounds the eye and closes the lids together.
Orthoptics	The science of the investigation and treatment of abnormalities of binocular vision.
Perseveration	Continuing a behaviour which should have ceased.
P.F.R.	Positive Fusional Reserve.
Phylogenetic	Relating to the order of evolution.
Primary-secondary	A classification of behaviour similar to introversion-extroversion.
Proconsul	A type of prehistoric ape thought to be the ancestor of the man-ape.
Pseudo-stereopsis	The reversal of stereopsis, by reversing the stimulae to the two eyes.
Retinal Disparity	Failure of the retinal images of one object to fall on corresponding elements.
Retinal Rivalry	The condition induced when two totally different stimulae fall on corresponding retinal points.
S	The subject of an experiment.
Saccadic Movement	A small abrupt movement of the eye.
Sclera	The outer coat, or white of the eye
Scotoma	A blind area due to non-reception by the retina or non-transmission by the nervous system.
Septum	In orthoptics, a device so placed that part of an image is occluded from one eye only.
Silurian	A system of rock formation in pre-history
Stereopsis	The production of the visual sense of depth resulting from slight angular differences between the two retinal images.
Stereogram	A two-dimensional stimulus from which a third dimension is seen by binocular viewing.
Strabismus	The medical term for a squint.
Subliminal	Nervous activity below the level which produces awareness of a stimulation.

Suture	A join of tissue effected by surgery.
Synoptophore	The trade name for the most commonly used haploscope
Tachistoscope	An instrument for presenting a stimulus for a very brief period of time.
Tarsoid	Related to the Tarsier, an animal similar to the Lemur.
Teleostereopsis	An artificial increase of visual sense of depth
Toroid	A geometric surface having maximum and minimum curvatures at right angles to each other.
Tortion	In orthoptics, the rotation of the eye around the antero-postero axis.
Transection	A large surgical cut through an organ of the body.
V.F.R.	Vertical fusional reserve.
Visual Acuity	The standard test for visual acuity is the reading of letters at a distance of 6 metres. If the letters whose parts subtend an angle of 1 minute at the centre of rotation of the eye can be read the visual acuity is normal and is recorded as 6/6. If the patient has a lowered acuity and can only read larger letters, these are recorded as, say, 6/12 which means that the patient reads at a distance of 6 metres letters which a normal patient would read at 12 metres.

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CHAPTER 1

THE CONTENT AND PURPOSE OF THE THESIS

Over two thousand years ago, a Greek, Empedocles of Aregente noted that 'we see singly with two eyes' and asked how it came about.

Despite most extensive research, today's scientists cannot answer the ancient Greek. A vast amount of knowledge has been accumulated on the subject, but still no reply can be given because, among many other unknowns, we do not know exactly how the cells of the cerebral cortex code and process the innervations arriving from the ganglion cells of the two retinae.

While it might seem that the answer to the ancient Greek must lie in the field of neuro-physiology, it is a prime purpose of this research to show that the process of producing one visual percept from two retinal inputs is so complicated that variables are present which, at this stage of our knowledge, cannot be accounted for through visual physiology, because the variables are psychological.

It was the very complexity of the role of this psychological influence on binocular visual performance which resulted in the research programme being continually discontinued and hence spread over a long period of time.

The final writing of this thesis marks the end of one aspect of a programme of research work which commenced in 1961. The programme was designed to investigate a proposed relationship between binocular performance and psychological rigidity. Optometric and psychological experiments were designed and carried out, and a considerable amount of data collected which suggested that there was a relation between binocular performance and psychological rigidity.

Correlations level were very low and when some of the tests were repeated on a second sample of optometric students opposite signs were found. There was no clear indication as to how the research should be extended and the programme was abandoned.

During the carrying out of the research work, several discoveries were made concerning particularly the inhibition processes in normal binocular vision. These were so important to clinical optometry that the psychological programme was put on one side until 1973, when the work on binocular vision and psychological variables were taken up again and brought to the conclusion given in this thesis.

In the new programme, the proposal was not that there would be a relationship with psychological rigidity, but that there existed non-visual variables in binocular performance and that some of these were to be isolated, measured and related to psychological variables.

An understanding of the complexity of this problem is more complete if the reader can comprehend the extreme intricacy of the act which brings about normal binocular vision.

The Binocular Vision of Modern Man

Most of the brain is involved in the production of one percept from the input of the two retinae. A brief outline of the process is given here. The detail and references are presented later in Chapter Two.

The production of binocular vision begins with the movement of the fovea centralis of each eye towards the retinal image of a common target. When they are within a half a degree of angle of the target, a fusional compulsion takes control, and the two eyes 'latch on' to the target. A separate neurological motor centre, dealing only with binocular movement now takes control, and rotates the images around the visual axes until they are exactly superimposed. The neuro-electrical innervations from the two images are then summated by some central organisation.

This fusing and locking mechanism has considerable flexibility. It has to allow for the movement of the eyes after binocular fixation as they are not stationary. Both eyes tremble, oscillate, wander from the point of fixation and jerk back towards it.

The images can differ in size, outline and illumination by about 10 per cent without any overlap being seen. It is possible to fuse that part of the target which is common to both eyes, and inhibit unilaterally parts which are in conflict, setting up a state of retinal rivalry within a fused single image.

If the two images are so different as to be not fusible, they are evaluated separately. One of the two images is then selected and brought to the conscious level, while the other is suppressed and not seen.

When the images are within the fusible limits, and are united, an analysis is made by the para-striate cortex of the horizontal difference between the two inputs which is interpreted as depth; the ability to form this three-dimensional space is known as stereopsis.

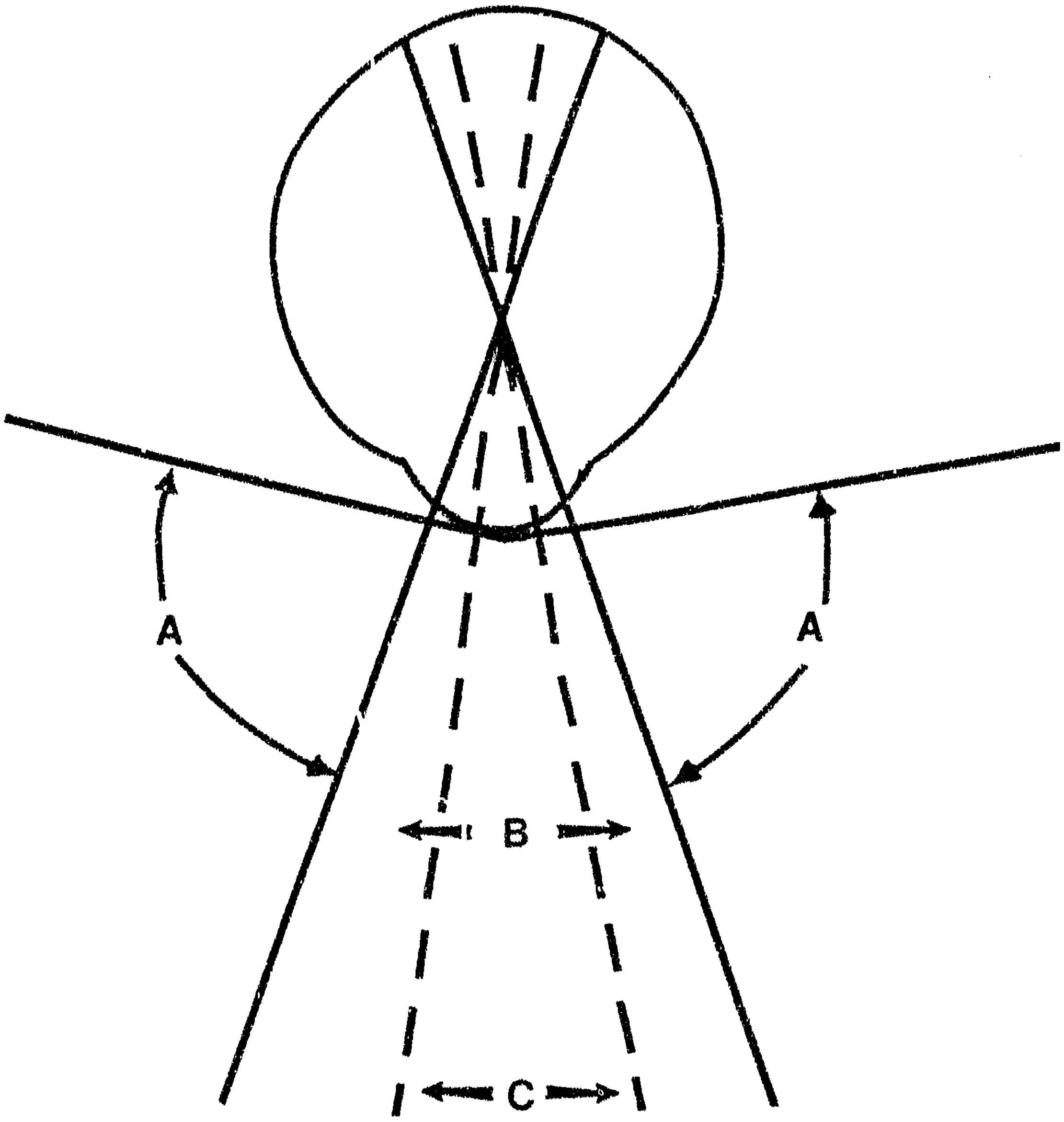
The final result is a panoramic view of 208 lateral degrees. This is only partly binocular, more than two thirds of the field being monocular (Fig. 1.1). There is a central binocular field of 60 degrees and on either side of it are two monocular fields of 74 degrees each. There is no awareness of the edges of the binocular field, nor of any loss at these edges of stereoscopic vision. The depth seen at the periphery is probably due to a right and left image comparison without fusion.

When the viewer looks at a cube of wood held in his left hand, the retinal images are neither the same size nor shape. If a tool is held in the right hand to work on the wood, the hands will occlude part of the tool or the wood from one eye or the other, the area occluded varying from second to second if the cube is rotated for inspection. Yet despite all these obstacles, some sort of neurological averaging computer selects the parts which are fusible from the two eyes and locks the visual axes on to them.

Binocular Vision and Stereopsis

While stereopsis cannot take place until binocular vision has been established, it is a separate and different function. Stereopsis is achieved by a comparison of the retinal disparities between the parts of the right and left retinal images. Kaufman (1965) compared the production of one haploscopic image from two retinal inputs with the production of stereopsis and demonstrated that they are different functions.

Kahneman, Normand and Kubovy (1967) demonstrated that if the left retinal image is delayed and presented more than 100 m secs after the right, stereopsis is not seen, but binocular summation takes place when



HUMAN BINOCULAR VISION

A. Monocular low resolution areas.
B. Binocular field within which stereopsis is possible.
C. Small central field within which objects are recognised as fusible.

FIG. 1.1

the image is delayed up to 300 m secs. From this experiment the authors deduce that binocular vision and stereopsis are produced by different cortical areas.

Regan and Spekriejse (1970) demonstrated a spike wave with a delay of 94 seconds which appeared when stereopsis was seen. The same wave appeared when horizontal disparate targets were fused, but the wave was not seen when the disparity was vertical. This suggests a particular cortical activity when there was fusion of retinal points which were slightly out of horizontal correspondence and which would produce the sensation of three-dimensional depth. The location of the wave in the cortex cannot be deduced from the experiment as the cathodes were placed on the occiput and the ears.

Juliez (1965) has demonstrated that the ability to form a three-dimer [illegible] image does not require recognition of the outline, and that a pictu [illegible] depth, such as a spiral can be created from a binocular presentation of random computer generated dots whose angular disparities produce the third dimensional effect.

Harwerth and Ra [illegible] 1975) have confirmed this by demonstrating that if one eye is so blurred that recognition of pattern is lost, but the retinal image disparity can still be detected, the sense of depth remains. Sperling (1970) advances a theory for binocular vision that there are two neural fields, one course and one fine, in which fusion is a separate state.

Humphriss (1953) describes cases of convergence insufficiency where stereopsis is lost, but recovers after physiological diplopia is re-established. In such cases there is no relation of the amount of the amount of fusion to the amount of stereopsis.

The weight of this evidence suggests that stereopsis, an ability to convert the angular disparities of the right and left retinal images into the perception of depth, is a separate function from binocular fusion following fusion after it has been achieved.

Haploscopic Vision - The Three Processes

For the purpose of this thesis, stereopsis is used only as a means of contrasting monocular depth with binocular depth. The thesis is concerned with the act which precedes stereopsis; that is the alignment of the separate images and their summation into a single visual percept.

The function of producing a single binocular vision can be seen to be controlled by three processes, firstly the motor control consisting of a fusional compulsion and a fusional locking mechanism, secondly an inhibition process which removes from consciousness any image or part of an image which conflicts with the process of unity, and thirdly a fusional process which adds together those parts of the images which are sufficiently similar to be within its unifying abilities.

The medical sciences and the discipline of bio-physics have discovered a considerable amount of data on the processes which bring about single binocular vision.

This information has been presented in Chapter Two. It is not a critical study of the evolution, anatomy and physiology of binocular vision, it is a search for information relating to the subject of this thesis, the non-visual variables in binocular behaviour. Hence any theories advanced by authorities on matters which are not fully understood, such as the evolution of the optic chiasma, are not examined and criticised, but merely put forward as information.

The study begins with the evolution of binocular vision, which is traced from bilateral light reaction, through two eyed vision, to stereopsis and finally to the binocular vision of modern man.

It is demonstrated that the eye reaches its highest performance at the level of the bird. Thereafter, the increased frontality of the orbits and the increased encephalisation of the visual cortex, that is, the making of greater use by the brain of the same information, are the evolving process.

It is concluded that man's binocular vision evolved to its highest level, not with the development of his vision but with the evolution of his intelligence.

The study continues with the anatomy and histology of binocular vision. This is done to make clear the type of electrical picture which is created by the two separate retinae, transmitted to the cortex and analysed ..

The process of combining the two sets of neural impulses appears to be an ongoing one, starting with some simple relationship at the thalamic level in the lateral geniculate body, and going on through increasingly complex stages from the striate cortex to the para-striate and peri-striate cortex and probably being relayed forwards into the association cortex of the parietal lobe.

From area 18 the visual picture is transmitted to many other non-visual parts of the brain, where it is thought to be analysed in terms of safety or danger, and to the frontal lobe for the planning of future action. It is shown subsequently that before unification, the monocular picture can be considerably modified but there is no evidence as to how the final binocular picture is organised.

The physiology of binocular vision is concerned firstly with the motor control which brings the eyes into alignment, maintains that alighment, and secondly with the nature of the central mechanism which summates tne two independent inputs into one conscious image. The bio-physicists have proved that there is an independent motor control over binocular vision, separate from that of the reflex and voluntary control located in areas 17 and 6, the occipital and frontal cortex. This binocular control centre is shown to be in areas 18 and 22 which are more parietal than occipital.

Similarly the summating process does not appear to be a physiological summation, but rather a psychological assembly of pre-conditioned monocular data.

The conclusion supports a principle now established in neuro-histology, that there are not areas of motor cortex adjoining areas of sensory cortex, but there is a transition of one to the other, the best example being the cortex on both banks of the fissure of Rolando.

Similarly, the cortex giving rise to the fusion process and the motor control bringing the images into alignment inter play in an area of cortex at or near the angular gyrus. This is association cortex outside the visual area, apparently the centre for the controlling neurology of the end processes in binocular unity.

A study of the psychology of binocular vision is concerned with the process of inhibition and the suppression of an image before fusion.

When the brain has to deal with two retinal inputs which differ slightly or considerably, then it can inhibit parts of each image, or it can totally inhibit one image. This process of inhibition is done on a selection basis which is entirely psychological. It relates to the subject's previous experience and to the prejudices which have formed from it. The area of brain which deals with this probably varies with the type of choice which has to be made before one image is inhibited.

The involvement of forward association cortex in binocular vision is supported by a research programme reported in Chapter Three in which the process of inhibition was located in the parieto-temporal cortex.

Further support for the proposal that the unification process is in the association cortex may be found in a study of the pathology of binocular vision, and in evidence from the breakdown of such functions as convergence. In a study of 100 cases of inadequate convergence, Humphriss and Burrow (1969) found that there were more cases due to psychological trauma than to neuro-pathology.

In addition to the evidence that the neurology of binocular vision is such that there are likely to be non-visual variables in binocular performance, several experimentors have noted variations between the results of binocular experiments on subjects screened as visual normal, that is, they had uncovered a non-visual variable. This comment is supported by clinical workers who have reported the highly variable performance of their patients which does not relate correctly to their visual condition.

The Programme of Research

It was clear from this data that two research programmes were required. The first would isolate and measure the non-visual variables, and the second would relate them to known psychological traits and hence show something of their nature.

When the work was first initiated the approach made to the problem was firstly to isolate the non-visual variables. This was done by studying the conditions under which the variables appear in clinical practice using as subjects largely students and institute staff. These subjects were carefully screened and those tested binocularly were all completely normal visually but found some binocular tests difficult to perform.

Numerous pilot experiments were carried out and several sensory variables were isolated which affected binocular performance and which were non-visual in origin.

Binocular variations which could be measured visually were known, but the consulting room tests were insufficiently accurate for statistical analysis, mostly because they had poor end points. These tests were improved until satisfactory tests re-test correlations were established.

The programme resulted in the isolation of three groups of non-visual variables, two of which were sensory, one related to the function of the suppression of an unwanted image. or part of an image, and one which related to the flexibility of the fusional lock, once fusion had been established. The third group related to the motor control which maintained the eyes in a position where unification could take place.

These results were put before a project committee of the National Institute of Personnel Research consisting of the heads of the departments of experimental psychology, neuro-psychology and psychometrics and two optometrists, the writer and the head of the school of optometry in Johannesburg.

As a result of their deliberations a battery of psychological tests was set up in an attempt to find scores which would correlate significantly with the binocular battery. This battery was based on six proposals, each linking binocular vision with psychological or physiological behaviour.

These proposals were :

(a) That it was known that binocular scores could be improved by suggestion and motivation. Their increase by this means might correlate significantly with scores of suggestion and motivation.

(b) That the ocular rotation resulting from muscular movement should correlate with scores of physical strength or the ability to maintain it.

(c) That a state of psychological tension produces convergence and reduces divergence. This state can be measured in an EEG score as tension reduces alpha amplitude and index.

(d) That the binocular scores would relate to EEG scores. It was thought that the response scores and some element of central excitability of the nervous system would relate to flexibility in behaviour.

(e) That the binocular behaviour would relate to other visual measurements such as c.f.f. and after image duration, and possibly to the acuity of other senses such as hearing.

(f) That the binocular scores would relate to scores of psychological flexibility-rigidity.

Based on these proposals two batteries of tests were designed. The final programme produced 20 binocular scores, 20 neuro-psychological scores and 60 psychological scores.

A carefully screened pilot sample of 23 male optometry students performed all the tests and from the results a 100 x 100 correlation matrix was computed.

A study of these correlations showed that there appeared to be a relation between the EEG scores and the binocular scores. The binocular tests and a self rating test of rigidity of temperament given to the optometry students was repeated on a staff sample of 37, all of whom had recently had an EEG recorded.

Significant correlations were again found with the binocular scores, but not with the same scores which produced significant correlations from the optometry sample. For this reason, and because an EEG programme is very time-consuming, the EEG programme was discontinued.

A further study of the binocular scores suggested that a significant non-visual variable could be seen in the matrix. The binocular battery and the self rating tests were given to a sample of 48 university students. The correlations from this sample supported the existence of a non-visual factor in the binocular test results, but did not confirm its relation to temperamental rigidity.

The generation of Cattell clusters from the 100 x 100 matrix produced one cluster containing the binocular scores thought to represent rigidity in binocular vision, tests of perseveration and two of the temperamental rigidity scores.

These tests were given to a further sample of university students and the results of a sample of 87 were factor analysed. Two factors were extracted, one of them, perseveration, was shown to be the major non-visual variable responsible for differences in binocular behaviour. The other factor, temperamental rigidity, only related to the binocular scores at a non-significant level.

The results of the whole programme and their benefits for psychology and optometry are discussed in the last chapter.

CHAPTER 2

A REVIEW OF THE LITERATURE ON THE EVOLUTION, ANATOMY, PHYSIOLOGY, PATHOLOGY AND PSYCHOLOGY OF BINOCULAR VISION

The Evolution of Binocular Vision

The evolution of binocular vision can be traced through three stages, and a fourth may be deduced (Fig. 2.1). At the lowest level, the animal can react to a difference in the amount of light received on opposite sides of the body.

Bilateral Light Reaction

This bilateral reaction to light is demonstrated in the earthworm, Lumbricus Terrestis, which moves away from the light to a damper and hence safer environment. Barucha Reid (1961) suggests that this is due to a negative light reaction, producing a greater output from one half of the supra-oesophageal ganglion.

Spooner (1957) states that the worm Planaria gonocephela has two eye spots on either side of the head from which light sensitive cells are connected by nerve fibres to a central nucleus. These worms act similarly to the earthworm turning away from the higher illumination.

Directionally selective neurones have been found in the prothoracid ganglion and the optic lobes of the hawk moth (Collett and Blest, 1966). These binocular units specialise as movement detectors and show discrimination along a horizontal axis.

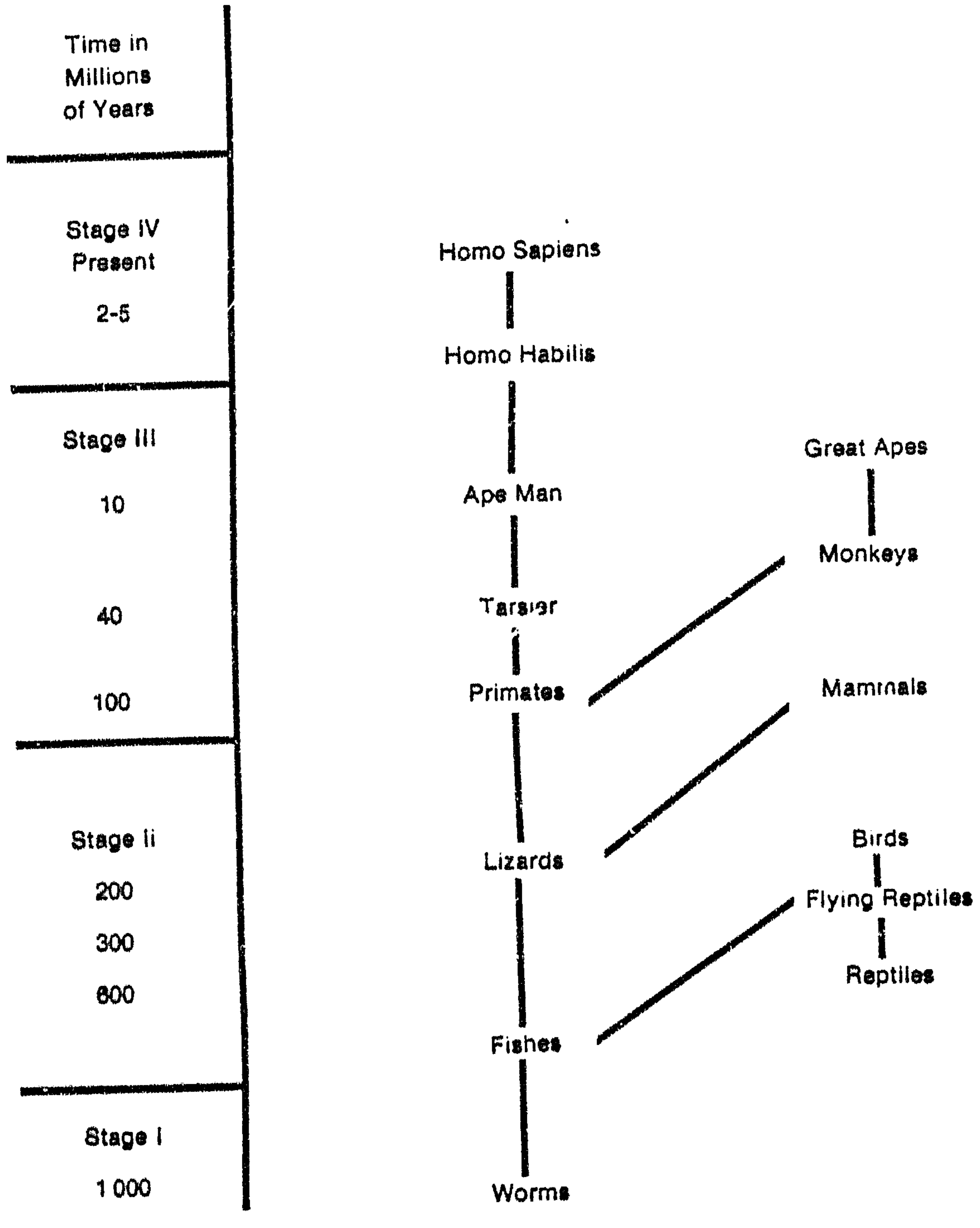


FIG. 2.1

The Evolution of Binocular Vision.
The explanation of the stages of
binocular vision is given on
the following page.

Fig. 2.1 - Explanation of Diagram

Time in Millions of Years	
Stage I 1200	Worms. Had an ability to respond to the amount of light falling on either side of the body.
Stage II 1000	Fishes. Had a crude eye giving crude triangulation and hence a sense of distance and direction.
600	Reptiles. Had an eye with a controlled movement making more accurate triangulation possible and hence the catching of flies with the tongue.
500	Birds. The flying reptiles evolved into the birds with a highly advanced eye,making very accurate triangulation possible. In the predator birds the orbits have become more frontal,further improving this ability.
200	Lizards. The lizards evolved along a separate branch from the birds. One further branch evolved to the great apes, the other to the primates and to man.
Stage III	
70	Primates. The tree shrew had a flexibility of grasp.
40	Tarsier. The orbits have become more frontal and the thumb has become in apposition to the fingers.
30	Monkeys. The upright stance had freed the hands to develop, and binocular convergence allowed them to inspect accurately what they had.
20	Great Apes. These animals which evolved separately from man had stereoscopic vision.
Stage IV	Probably had a further improvement in convergence.
10	Ape-Man. Had an ability to inhibit the vision of one eye when it interfered with what the animal wishes to see with the other eye.
2-5	Homo Habilis. Had developed the precision and power grip and was probably able to inhibit the vision of one eye when it interfered with what the animal wished to see with the other eye.
0,5 - Present	Homo Sapiens. Full binocular vision.

Two-eyed Triangulation

After the development of a crude eye, the position of an object in space could be determined by triangulation. The distance between the eyes is the base of the triangle. The angle of the line of sight from one eye to the object is known by the position of its image on the retina. These three lines form a triangle, and the larger the angle between the base and the lines of sight, the greater is the distance from it.

At the level of the fishes, triangulation had become essential to survival, so much so that the flat bottom fishes have a binocular field vertically. Triangulation from two-eyed vision is shown to be advanced in the fresh water fishes to the extent that it could be used, not only to place the body so that an object to be eaten fell on the line straight ahead, but the exact distance to the eye can be computed. Luling (1963) has demonstrated that the Archer fish which can spurt water and knock an insect off a twig into the river, cannot do so accurately when one cornea is damaged by a parasite which attacks them.

Barlow (1975) has demonstrated a similar inability in frogs to catch flies if the fibres of one optic nerve are damaged.

Triangulation improved further with the evolution of the eye itself, the retina becoming more sensitive, the outer coat stronger, so that muscles could move the eye efficiently, and a lens which focused the eye of the amphibian under water later gave man the ability to concentrate on a near image for a long period of time (Walls, 1963). The more accurate process of triangulation made it possible for predator birds to locate a small animal in three ways :

(a) By an asymmetry of the position of the images on the two retinae they learn that a stationary object is to the right or left of the line ahead.

(b) By the rate of change of the position of the two images they learn that in relation to the viewer, the object is moving away from or towards them.

(c) They learn in what direction and with what speed it is moving.

This information is clearly vital for survival, both in obtaining food and avoiding attack or collision.

The loss of this ability in a one-eyed bird is demonstrated by Shiffman and Walk (1963) who closed one eye of chickens and showed that they then pecked inaccurately and descended steps with less confidence than the two-eyed birds.

It seems likely that the judgement of depth without stereopsis, which is shown by Charnwood (1954) to be present [illegible] an, is the remaining inheritance of this early evolution of two eyed vision.

The Development of True Binocular Vision

The third stage of evolution towards true binocular vision began when the eyes moved forward from the lateral position of the lower animals towards the orbits of man whose central lines are 22 degrees outwards (Wolff, 1958). This change took place at the same time that paws began to evolve towards hands, so that it was possible for both eyes to fixate a small object held between the fingers (Smith, 1959). It was accompanied by a major change in the neuro-anatomy of the optic chiasma.

Walls) states categorically that in the lower vertibrates all the fibres of the optic nerve cross to the opposite side; Polyak (1957) is more guarded. He demonstrates that the evolution of the chiasma began with complete nerves crossing each other, the right or left nerve being above the other apparently in a random manner. Then the nerve bundles became interlaced, but degeneration studies of the animal at this stage show no interaction of the right and left optic innervations.

After considering comparative anatomical studies he continues:

> Not all optic nerve fibres however terminate in the contralateral half of the cerebum as one would be led to expect from the completeness of the decussation in the chiasma. The exception is two small fibre sheets in the supraoptic areas.
>
> It is possible that an almost complete decussation is found only in species in which vision is completely or largely panoramic. The Barn swallow may conceivably possess a visual system in which a fair portion of the optic nerve fibres recrosses in a supra-chiasmal region to the ipsilateral side effectively creating a condition similar to the partial crossing of advanced animals.

Nobach (1959) in the James Arthur lecture on 'The evolution of the Human Brain' said :

> Further analysis of the development of the chiasma indicates that a close relation exists between the degree of frontality of the eyes and the proportion of uncrossed fibres. In brief the number of uncrossed fibres is related to the size of the field of vision where there is overlap between the two eyes.

He supports this statement with these figures :

> The lower vertebrates have crossed fibres only. In the rat 1/20th of the fibres are uncrossed, in the horse 1/8th, and in the opposum 1/5th, in the dog 1/4, in the cat 1/3rd and in man ½.

There is contention as to why these uncrossed fibres evolved. Walls is of the opinion that right and left conjugate ocular movement cannot be made accurately without uncrossed fibres ending in conjunction with crossed, so that an error in movement could be accurately and quickly corrected.

Mello (1967) has demonstrated that in pigeons, there is a transfer of learning, but only if the targets were geometrically similar. What could be learned and transferred to the ipsilateral hemisphere was therefore very limited in form.

It can be demonstrated in the lower animals that what is learned as a response to a visual stimulus to the right eye, is not learned by the brain serving the left eye, and that the animal does not react if the right eye is covered up and the same visual stimulus presented to the left eye. This lack of learning can be produced in the cat, the monkey and the dog by transaction of the chiasma and the corpus callosum, suggesting that the purpose of the uncrossed fibres is to store learned visual perception on both sides of the brain so that the animal can react to it, irrespective of which eye receives the stimulus (Sperry, 1963).

Whatever the reason for this evolutionary change, the end result was that in man, the vision received from the right nasal and the left temporal fields are both transmitted to the left striate cortex, so the brain receives two half pictures of the visual world.

The Evolution of the Visual Cortex

There is very little improvement in the eye itself between the stage of the higher mammal and modern man. It was shown by Mann (1928) that once the modern eye had evolved, it is the better brain that produced the evolutionary advance rather than the improved individual eyes. The evidence she advances is that the eyes of the carnivores and the birds are in some respects superior to man. It was the improved brain of man which made more use of the same visual information transmitted to it, so that those animals whose orbits moved forwards provided the brain with the type of information which it could process with greater efficiency into the construction of visual space. The changes in the brain which took place with advancing binocular vision are given in detail by Prince (1949). He illustrated this change by comparing the tarsier with a lower mammal, the tree shrew, whose eyes look more outwards than forwards, and which has no visual association cortex; and with the baboon which he considers has stereoscopic vision and has a further visual association, for example, of the cortex. He shows that as the eyes moved toward each other when the position of the orbit became more forward, a greater area of cortex was necessary to correlate one eye to the other, and that this development took place at the same time as the co-operation between hand and eye lead to skill with the hands.

The general tendency for visual reactions to move slowly to higher cortical levels is demonstrated from the level of the rat where there is a definite tendency to shift the emphasis from the mid-brain where it is dominant in the infra-mammalian vertebrates of the forebrain (Polyak, 1957).

Comparing the monocular and binocular control of horizontal mystagmus in cats and rabbits, Braun and Gault (1969) have been able to demonstrate that the binocular function of a cat is superior to that in rabbits.

If the neuro-histology of the lateral geniculate body of the cat is compared with that of the monkey, the latter can be seen to be able to pass forward the retinal picture with greater detail than is possible for the cat (Glees and Clarke, 1941).

In the monkey there is an increase in the area of visual sensory cortex containing the white line of Genari, and the gorilla, orang-outang and chimpanzee, have a greater area of visual association cortex than the baboon. The man-ape with a brain about one-third the size of modern man, had an additional association area not found in the great apes which probably associated his vision with his manual ability.

Jones (1948) also states that the development of frontality of the eyes is related to the evolution from paws to hands, and confirms that this is a major determination in the evolution of the brain. He shows that when a definite area of the brain is the seat of a well defined sensation or sensibility, the motor centre that governs the movements of the parts most intimately related to that sensibility, will be in close proximity to that area of the brain in which th [illegible]ory centre lies.

Jones continues the argument that when the hand is ac[illegible] a tactile organ, it is probable that a hand-tactile area will be developed in cortex beyond that devoted to snout touch, with a corresponding motor area in proximity to it. The development of the hand as a tactile organ will be correlated with an increased power of vision and an increased visual area in the brain cortex, since the hands are used for bringing objects into closer proximity to the eyes so that a clearer impression of them may be gained.

He goes on to say that if you add to this fact the very reasonable assumption that visual impressions and tactile impression from the hands will be simultaneously correlated, then this association will give rise to associations of touch and sight that were previously tactile-olfactory sensations.

Advancing Man

The continued advance in tool-making is demonstrated by Tobias (1964) who proposed the acceptance of a new type of early man Homo habilis. This name is taken from the Latin meaning able or handy. The bones of the hand suggest that Homo habilis had acquired the precision and the power grip (Napier, 1962) and his culture shows him to be a more advanced tool-maker than the ape-man. This evidence supports the theory that man evolved because he was able to make his tools, some of which served as weapons of attack or defence. The need for improved binocular vision as man evolves is noted by many authorities in the field. Magoun, Darling and Prost (1960) state that as long as an animal needed to run on its front legs, the development of its front paws was restricted to the branch clinging fingers of the tarsier. Upright stance freed the hands from locomotion and provided the circumstances where a more efficient binocular vision was required to guide them.

Proof that it was early man's ability above his other assets which allowed him to survive is shown in a recent study by Tobias (1975). Fossils unearthed along the whole Eastern and Central length of the African Continent show that two types of early man,one known as the robust, represented by Australopithecus robustos and Australopithecus boisei, and the other the gracile Australopithecus africanus lived alongside each other for some two million years. Gracile man survived because he could use his hands to carry out the commands of his wits. Robust man who relied on his strength died out, and gracile man evolved to Homo habilis then to Homo erectus and finally to Homo sapiens.

The increase in the size of the brain from Australopithecus to Homo erectus, is given by Tobias (1964) in the following table :

	Total brain volume	Parietal brain volume
Australopithecus africanus. Man-ape	520 cc	294 cc
Homo habilis. Handy man	573 cc	364 cc
Homo erectus. Pekin man	1030 cc	470 cc

From Man to Ape

The fourth stage of binocular evolution may be deduced from the changes in behaviour from man-ape towards man. It is generally agreed by the authorities that this took place because man was a tool-maker (Darlington, 1969; Clarke, 1970).

The authorities are virtually unanimous that these higher levels of binocular vision became possible because of the improved association of learned hand movements with improved binocular vision, and the same authorities place the cortical control of this function in the parietal lobe of the brain.

Conclusions

The study of the evolution of binocular vision shows that an advanced eye had evolved at the level where there was two-eyed vision but not binocular vision. The changes which produced binocular vision were the increased frontality of the eyes, the development of uncrossed fibres in the optic chiasma, and a considerable enlargement of the parts of the brain dealing with the visual input.

The study shows that stereoscopic vision is present in the monkeys so that the fine control of binocular movement must have existed at this stage.

That these stages of evolution can still be traced in modern man is suggested by the work of Braddick (1970) who demonstrated that there is an advancing coding system parallel with advancing binocular vision, so that binocular interaction depends on shape as well as on disparity. He writes that his experiments:

> demonstrate that a considerable amount of processing is performed on the message from each eye independently. Neural re-coding takes place, but not before there is any binocular interaction. Binocular interaction occurs at a number of different levels in the visual pathway and that in at least some levels there is a parallel processing both in two monocular channels and in a combined channel.

A highly selective function of inhibition in binocular vision was described in terms of a man working on a cube of wood held in his hands. It seems likely that this function was the last to evolve and developed as man advanced from Homo habilis to Homo sapiens.

This is an important conclusion for this thesis because it means that the later stages of the evolution of man's binocular vision took place, not parallel with the evolution of his vision, but with the development of his intelligence.

This being so, it would be expected that there would be non-visual variables in binocular vision which would relate to the personality or temperament of the subject.

The Anatomy and Neuro-histology of Binocular Vision

For the benefit of the reader who is not familiar with the surface anatomy of the human brain, the fissures, sulci and gyri mentioned in the text are depicted in Figs. 2.2 and 2.3. The functional anatomy of the surface area is drawn in Fig. 2.4.

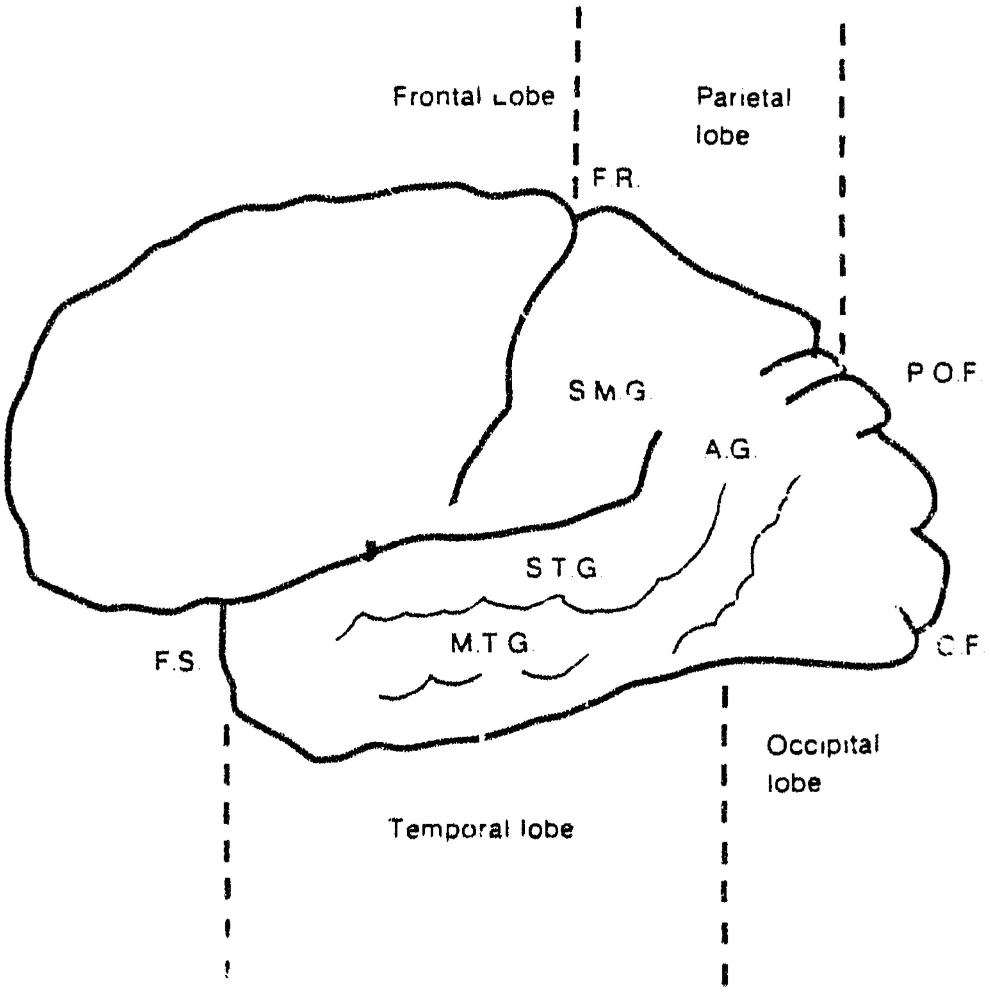
The Gross Anatomy

The two eyes may be likened in many ways to two small television cameras which take moving pictures by a process of scanning, and transmitting the result of the scanning in the form of a series of electrical pulses to the receiving set, the brain.

The eyeball which may be compared to the body of the camera consists of three layers: the outer coat, the sclera and cornea which is tough and withstands the internal ocular pressure averaging 15 mm of mercury. The middle layer which consists of the choroid, ciliary body and iris is a vascular structure. Adherent to its inner surface is the internal coat, the retina whose first layer is made up of pigment cells which absorb the light focused upon them by the optical system.

The optical system has two lenses, one is the cornea which is continuous with the sclera and has a dioptric power of 44 dioptres.

Left Lateral Surface of the Human Brain

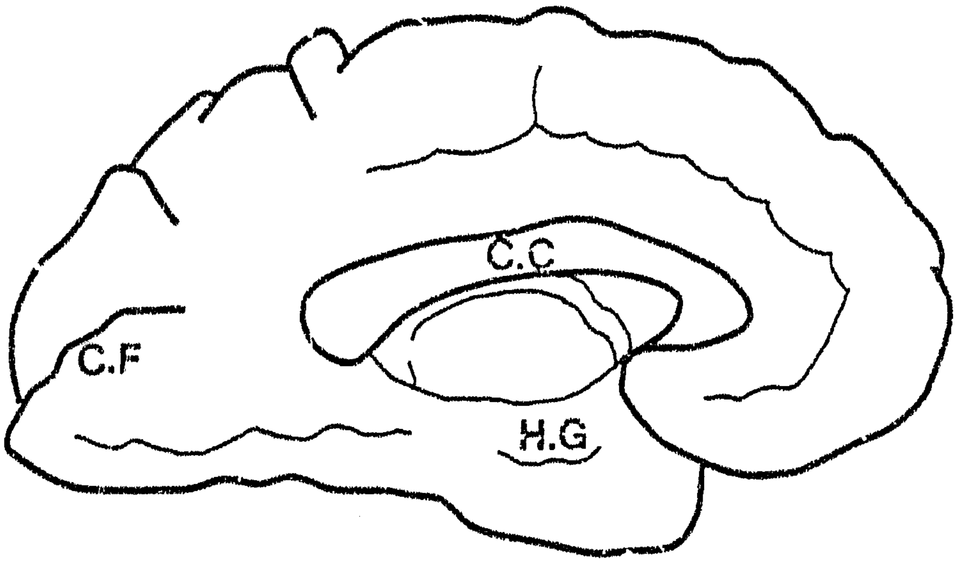


F.R.	Fissure of Rolando
S.M.G. ,	Supra-marginal gyrus
P.O.F.	Parieto-occipital Fissure
A.G.	Angular gyrus
F.S.	Fissure of Sylvius
C.F.	Calcarine fissure
S.T.G.	Supra-teinporal gyrus
M.T.G	Middle temporal gyrus

The supra temporal sulcus lies between the supra temporal and the middle temporal gyri.

The middle temporal sulcus lies below them

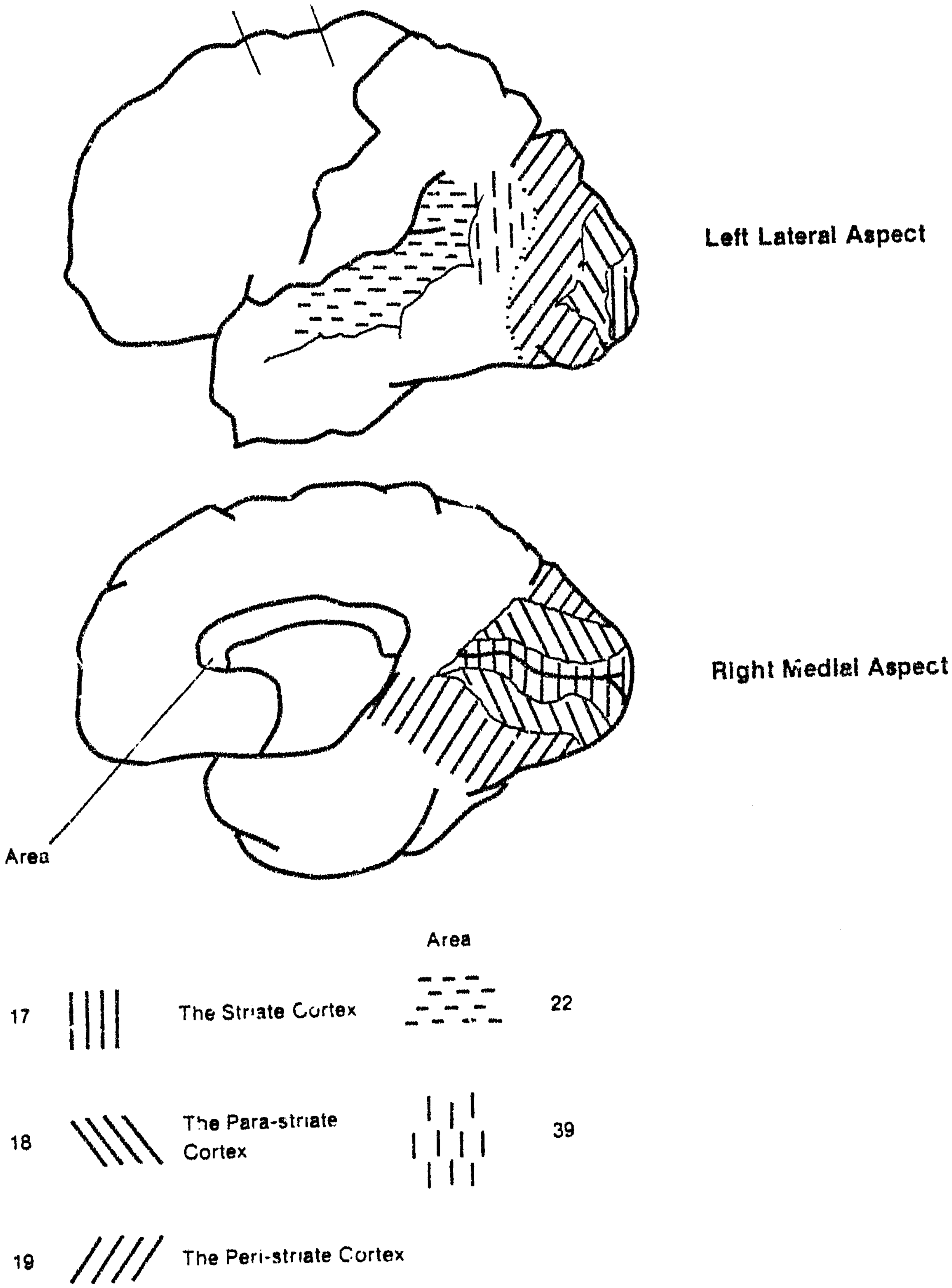
FIG. 2.2



C.C	Corpus Callosum.
C.F.	Calcarine Fissure.
H.G.	Hippocampal Gyrus.

FIG. 2.3

The Left Medial Surface of the Human Brain



Brodman's Cytoarchitectural Map of the Human Brain

FIG. 2.4

The other suspended inside the eye is an adjustable lens, the chrystalline lens, with a dioptric power which can be varied from 16 to 30 diopters in the young.

The clarity, size and shape of the retinal image undergoes considerable alteration if there is any error in the size, shape or chemical constituents of the eye. An error of length of the eye of one millimetre will blur the visual acuity from 6/6 to 6/60. Similarly a minute error in the curvature of the cornea will distort the image beyond recognition.

In contrast to these monocular errors in the formation of the image the matrix of cones which converts it into a neuro-electrical picture, is remarkably regular (Polyak, 1941).

The ocular anatomy therefore shows that the two images are not usually of exactly the same size, shape nor clarity, and that they are formed on matrices of rods and cones which are not identical in the two eyes.

These images, when converted to electrical energy would require to be adapted to each other in the visual cortex before they could be unified into one visual percept.

The sensory perceptor, the retina, is a thin transparent membrane lining the posterior hemisphere of the eye, and lying loosely against the choroid. Some 1 250 000 nerve fibres run from the 132 000 000 individual light sensitive cells to leave the eye in a bundle at the optic disc.

The two optic nerves travel posteriorly and medially and leave the orbit through the optic foramen. They unite in the optic chiasma which is just anterior to the pituitary gland. Here the fibres undergo partial decussation, the fibres from the left nasal half of the retina crossing over and running with the temporal fibres of the right eye to form the right optic tract, the right nasal and the left temporal fibres forming the left optic tract. The tracts now carry fibres representing the two halves of the field of vision. These fibres run parallel with each other, but make no contact.

After leaving the chiasma, the tracts move laterally and posteriorly passing round the cerebral peduncle to enter the lateral geniculate bodies (L.G.B.). These bodies are part of the thalamus, and fibres from the right and left retinae become associated here.

The actual purpose of the lateral geniculate relay is not known. The bodies in the higher mammals have a well defined six layer structure, and the crossed fibres terminate on laminae 1, 4 and 6, and the uncrossed in 2, 3 and 5 (Le Gros Clarke, 1941).

It is known that the layers respond to different signals from the retina, the on signal, the off signal and the on-off signal (De Valois et al., 1958).

From this point onwards it is not known what happens to the original innervation from the ganglion cells. Brodal (1969),who considers the anatomy from the point of view of clinical neurology, states that the innervation may be inhibited by the output of efferent fibres coming into the L.G.B.

From the time that a single innervation reaches the cortex the original innervation may affect, or is affected by, as many as 5 000 neurons

The optic tract continues posteriorly as the geniculo-calcarine pathway, the fibres ending in layer 4 of the striate cortex. The density of the fibres here is such that they can be seen by the human eye and are called the white line of Gennari.

The course of the fibres from the retina to this cortex has been plotted by the anatomists and it has been shown that the retina is represented on a point to point basis here (Weale, 1960), but a study of battle wounds to the geniculate-calcarine tract (Pollock et al, 1957) shows that point to point representation is far too simple an explanation. According to the point to point theory, the wound should produce a blind area proportional to the damage inflicted without affecting the adjoining areas, but this is not so. If the normal field is tested tachistoscopically for recognition of the position of the letter C, the threshold is raised. Battersby et al. (1960) also argue that the point to point representation of the retina in the cortex is not satisfactory.

Bailey and von Bonin (1951) made an estimate of the number of fibres, and the number of ganglion and stellate cells in the striate cortex, and found them to be the same. This suggests that the two half pictures formed in the striate cortex are pulsed forwards, both intact to a higher level of cortex.

It would also seem necessary before the two retinal images are united, that the brain was able to appreciate the whole retinal image and this would require commissural fibres to the opposite side. There are no commissural fibres between the right and left striate cortex, so that the image must remain as two half images.

Blakemore (1969) advances evidence that the creation of binocular vision from binocular activated cells requires impulses to be passed across commissural fibres. As these do not exist in the striated cortex, he argues that binocular vision must be a result of a more forward neural activity.

In all of the cerebral cortex, excepting the area dealing with the sense of smell, the neuro-anatomy can be subdivided into six layers. These vary in their content in different parts of the brain, particularly if the function of the cortex is largely the reception of sensory information or the transmission to the mid-brain of motor instructions.

Brodal (1969) p.644, reproduces a diagram of von Economo in which an area of parietal cortex is drawn. This area includes the association cortex in which learning is known to take place and includes the binocular areas of Brodman, numbers 22 and 19. It extends from the intra-parietal sulcus to the superior temporal sulcus and includes the posterior inferior temporal gyrus.

Conclusions from the Anatomy

The ocular anatomy suggests that it is not possible for two human eyes to form two identical images, and that the irregular matrix of rods and cones which converts the image to neuro-electrical energy must send to the brain two slightly different images. The neuro-anatomy indicate that these two electrical pictures are transmitted to the cerebral cortex in complete integrity, though they may be both modified and interpreted at the thalamic level by the lateral geniculate bodies. The fact that the

L.G.B. is part of the thalamus suggests that it might carry out the estimation of distance based on the observation of diplopia, using the method of triangulation, observed in the lower mammals. Having done this, the two neural pictures could be passed on with complete integrity for more sophisticated analysis at a higher neural level.

Although it is only here that non-visual variables would be expected to be found, Douthwaite (1978) states that the visual system is influenced by psychological factors which arise in the visual pathways to the visual cortex.

Despite this opinion, it is unlikely that the perception of our binocular vision is markedly affected at this level, or in area 17 because of the lack of commissural fibres between the striate cortex of the right and left hemispheres. Although this could be finalised in area 18, there is no anatomical evidence that it takes place here or more anteriorly. Evidence from the neurology and psychology of binocular vision and from the EEG research described in Chapter 3, suggests that the final analysis and composition of the binocular percept is a function of cortex forward of the visual areas, involving the inferior parietal and posterior temporal cortex.

The anatomical evidence that the function producing binocular vision requires a degree of flexibility in analysing dynamic images, indicates that whatever variable results in rigidity in the central nervous system as shown in such behaviour as the perseveration of the authoritarian personality, is likely to be present in binocular behaviour and could be isolated and measured.

The Physiology of Binocular Vision

The Process of Unification and Summation

A major change in thinking concerning binocular summation came about with the discovery (Bishop et al., 1962) that there are cells in the lateral geniculate body (L.G.B.) and the striate cortex which only respond to binocular input. The lowest level phylogenetically in which these cells have been found is in the opposum.

Goodwin and Hill (1968) demonstrated that in the opposum a marsupial, considered to be halfway between the reptiles and the mammals, 20 per cent of the cells of the superior colliculus are binocularly stimulated.

In 1962 Bishop et al., using micro-electrodes inserted stereotactically into the L.G.B. of the anaesthetised cat,located the existence of cells which are important functionally to binocular vision.

In 1963 Hubel demonstrated that the cat's L.G.B. had a small number of cells with binocular representation, and that these are different in nature from the binocular cells in the visual cortex. Sukuzi and Kato (1966) produced evidence that the L.G.B. mediates inhibition in the post-synaptic component of its response if the other optic nerve is stimulated with a conditioning volley.

Eisman, Hansen and Burke (1967) demonstrated the same small integrative effect in the cat's L.G.B. when the animal was alert, the mass of the incoming information being passed on intact.

Barlow, Blakemore and Pettigrew (1967) confirmed this with two targets finding a maximum cell response in the striate cortex when the targets were placed symmetrically.

Henry, Bishop and Coombs (1969) demonstrated the existence of cells in the striate cortex originally thought to be monocular directional sensitive cells, but found to be binocularly stimulated. Hubel and Weisel (1968b) confirmed the existence of these cells with the study of kittens with one eye sutured for the first 37 days of life. They also demonstrated (1968a) a majority of the cells in the striate cortex of the Macaque monkey to be monocularly driven. Their number in area 17 was greater than that of the cat, but similar for area 18. They also found various differences in response in the various layers of the striate cortex, and make the interesting comment that the cells of the Macaque cortex which are driven binocularly are in layer 2 and the upper two-thirds of layer 3, while the cells in layer 4 only responded to a monocular input. They also note that the cells which respond binocularly exhibit a marked ocular dominance.

Marg (1970) has recorded the binocular activity of cells in the human cortex using embedded micro-electrodes, and states that the responses are very similar to those of the monkey.

Perry, Childers and McCoy (1968) took binocular recordings from four occipital areas and showed a large variation in the summation resulting from their binocular input varying from a minimum of eight per cent to a maximum of 43 per cent. They also found marked difference between observers.

From this evidence it may be assumed that binocular vision is the result of the activity of specialised cells in the L.G.B. and the occipital cortex which respond to a binocular input. Their output is maximum where there is agreement in size, type and position of two targets, and their activity is inhibited when the retinal image of one eye is not consistent with that of the other eye.

This conclusion is supported by the finding of Burns and Pritchard (1968) who considered their experiments on monkeys and write:

> The visual system maintains binocular fusion by continually hunting for those directions that provide the greatest cortical response combined with the smallest area of visual cortex excited.

The Location of the Binocular Visual Cortex

The experiments of Pasik and Pasik (1964) on optokinetic nystagmus with monkeys had suggested that binocular vision was only created through the sub-cortical commissures subserving this area. If this is so then binocular vision cannot be produced by area 17 as there are no commissural fibres between the striate cortex of the two hemispheres.

The function of stereopsis has been located in area 18. Baugh (1970) established that monkeys respond to stereoscopic targets and Hubel and Wiesel (1970) located the cells in area 18 which respond to this input.

Duke Elder (1949) put forward evidence for an area slightly anterior and inferior to the angular gyrus where convergence may be initiated. This is supported by the discovery of cortex involving Bradman's areas 22 and 19 which, when stimulated in the Macaque resulted in convergence, accommodation and pupillary reaction (Jampel, 1959). It seems likely that from area 17 onwards there is movement control which increases in sophistication as the location is more anterior. Foerster produced ocular movements in man from area 18 and Penfield, in association with Boldrey, obtained ocular movement in the posterior parietal regions, but only by using higher intensity currents, an indication that the function is complex.

This would support the requirements of stereopsis in terms of movement, that the eyes and the cortical analysing system must be able to align the eyes to an accuracy of about 1 minute of angle and that there is some relation between the analysis of stereoscopic disparity and flexibility of convergence.

The Behavioural Evidence as to the Nature of Summation

Half a century ago experimenters in this field disagreed as to whether there is, or is not, binocular summation of the retinal inputs. The reason for this disagreement is twofold. If the target area stimulated, is large, the lowering of thresholds is very small, and Pirenne (1943) and many others argued that this amount of increase is not greater than chance, due to the use of two detectors rather than one.

This argument was advanced despite experiments which showed that if the two stimuli were not on corresponding points, increase in detection due to chance could be measured.

With improved methods the evidence from human experiments in favour of summation has increased until it is now irrefutable. It can be summarised under the types of stimulation demonstrating summation. These are:

(a) The visual threshold of light.
(b) The recognition of form.
(c) Binocular brightness.
(d) Pupillary reaction.
(e) Response time.
(f) Critical fusion frequency.

The research work on summation carried out prior to 1935 is collated and criticised by Dorothy Shaad (1935). She demonstrated that there were 10 researchers or pairs of researchers whose work demonstrated summation and six who denied it.

She was followed by Crozier and Holway (1938-9), Forbes and Mote (1956) and Zigler (1958), all of whom demonstrated both summation and something of the conditions producing it.

Summation of Light

Given improved computer programmes, the probability of a lowered threshold when seeing one stimulus with two eyes has been calculated with greater accuracy, and it has been shown by Matin (1962) and Ronchi

Gloria (1965) that the increase recorded is greater than that computed as due to chance.

Matin (1962) also showed that when the interval between the time of presentation is nil, maximum summation takes place and that summation decreases as the time between presentation to the two eyes increases.

More recently Thom and Boynton (1974) have again shown that summation does not take place if non-corresponding points are stimulated, and they regard the summation which takes place when the stimuli are in precise correspondence as physiological. Zigler (1958) demonstrated a similar lowering of the threshold for scotopic para-foveal stimulation.

Considering all the evidence it is now clear that central neural summation of the bilateral retinal inputs does take place for light provided that :

(a) The stimuli are presented at the same time.
(b) That they are approximately equal in size and illumination.
(c) That they are presented to corresponding retinal areas.

It is however, questionable if the summation can be called physiological. The amount of increase of the binocular percept over the monocular is extremely small (Wolf and Zigler, 1963). This is not the final common path of Sherrington. It is nearer the summation of percepts of the same target by different senses and might as reasonably be called a psychological assembly as a neural summation.

Form

The threshold for form perception is lower in binocular than monocular vision (Shaad, 1935). Humphriss and Wortley (1971) found a slightly superior binocular visual acuity over a monocular acuity in three groups of South Africans, Bantu, Bushmen and persons of European descent. Erikson and Greenspon (1968) found binocular summation for form perception provided that there is retinal correspondence of the presentation and the exposure is brief.

Binocular Brightness

Fechner noticed that under some conditions brightness was lower binocularly. This was explained by Teller and Galanto (1967) who demonstrated that this binolular lowering of brightness takes place if the illumination entering one eye is 12 per cent lower than the other, and that what has to be within the 12 per cent agreement, is the light after it has been moderated by contrast.

Engel (1967) was able to find a mathematical function for brightness summation, which was the vector sum of the uniocular brightness response, and the special cross correlation of the uniocular test fields.

In addition to the brightness summation it has been observed that there is a greater pupillary reaction to binocular stimulation than to monocular (Thompson, 1947) and after images are seen more quickly and last longer when stimulation is binocular.

Response Time

Gilliland and Haines (1975) show a reduction in response time to a target presented binocularly over one presented to the monocular dominant or non-dominant eye. This reduction in response time takes place over the retina from 60 degrees nasally to 90 degrees temporally.

Summation in Critical Fusion Frequency (C.F.F.)

The slight superiority of binocular vision over monocular can be demonstrated precisely with C.F.F. results. Ireland (1950) repeated the experiments of Sherrington and showed that there is a fall in threshold binocularly over monocularly, but there is a rise in threshold if the flashes are out of phase. His results with two subjects were :

	Subject I	Subject II
Dominant eye	29,8	31,2 per second
Non-dominant eye	29,9	31,0
Binocular in phase	31,5	32,8
Binocular out of phase	28,9	29,4

These figures are typical of the very small improvement in binocular over monocular vision.

An unexplained aspect of binocular vision is a difference between the accuracy of recognition in the the two fields, depending on which eye sees the target. Corbalis (1964) demonstrated that letter recognition in binocular vision is more accurate in the left field for letters presented to the left eye, and the right field for letters presented to the right eye.

The behavioural evidence concerning binocular summation supports the neurological evidence, that summation is at a maximum when there is agreement between the targets and that corresponding retinal points must be stimulated.

The behavioural evidence shows that the threshold for binocular vision is lower in every aspect of vision provided that the above conditions exist.

Again it remains questionable if the very small improvement of binocular over monocular vision could correctly be called physiological summation. It has been shown to be due to the activity of binocularly activated cells and it seems that the improved binocular thresholds are not the result of neural summation. It is more likely to be due to the activity of special cells whose sensitivity is, for some unknown reason, very slightly more efficient than the monocular cells.

Behavioural Evidence as to the Nature of Binocular Fusion

Non-Visual Differences in Binocular Tests

Several researchers in binocular vision have commented on the variability in their results, and one or two have mentioned psychological conditions which they relate to the variation. Ogle (1950) states that the shape of the horopter is partly determined by the degree of eideticism of the viewer. Lyons (1966) also mentions the wide differences between observers in horopter measurements. Levigne (1953) observed but did not demonstrate a relation between intelligence and the establishment of an abnormal retinal correspondence. Humphriss (1961) established a relationship between retinal inhibition in a state of retinal rivalry and the age of the subject. The graph relating these two functions does not appear to be that of maturation or senescence, and the writer suggests that it is due to a loss of lability which occurs as the child becomes experienced.

Binocular Fusion

When two eyes approach what appears to be a common target diplopia results so that the two retinal images may be compared. Winkelman (1953) has shown that if one of the two images is recognised as not to be fusible with the other, then the movement towards the target is reversed, and the images are separated.

If the images are fusible, then any error in alignment is corrected, and as their proximity increases there is a compulsive movement which increases in speed as the images approach the fovea until they jump into precise alignment and summation takes place.

When fusion is achieved a locking mechanism is created which holds the fixation of the two eyes to precisely corresponding points on the retina, a right-left relationship which is very rigid (Flom and Ker, 1967).

The strength of the fusional lock varies considerably with the type and size of target. As the target is moved away from the fovea centralis, fusion weakens, but its depreciation is not proportional to the fall off of the visual acuity (Ludvigh, McKinnon and Zaityett, 1965). Their results showed a marked difference in the results of their three subjects.

It has been demonstrated that the greatest strength of fusion is achieved if there is a common fixational point and a peripheral fusional lock. There is also some relation to the amount of contour visible in the viewing central area and that the greater the amount of contour, the greater the fusional lock, but no mathematical relationship between the two has been established.

The fusional lock is not affected by the observer's interpretation of the target (McLoughlin and Rifkin, 1965) but there is a stronger lock for a target which can be interpreted as a complete Gestalt than a target of the same amount of contour which is a nameless shape (Cowan and Bliss, 1967).

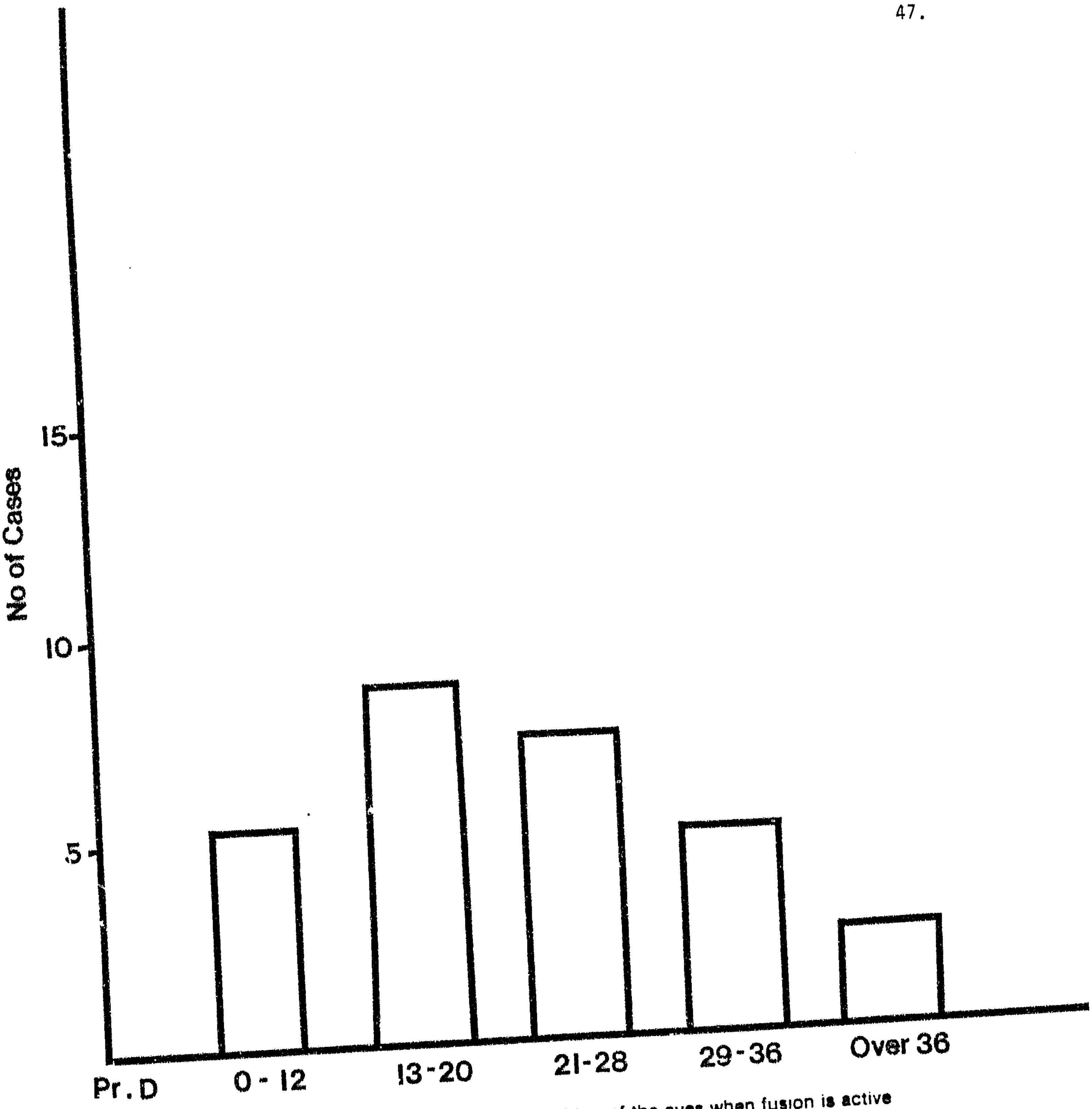
The strength of the fusional lock varies considerably between normal subjects (Mitchell and Francis, 1961). Ogle divided his subjects into tight and loose fusers; Bennet et al. (1958) demonstrated that the act of fusion was neurologically slow, they also divided their subjects into fast and slow fusers. Brecher, Hartman and Leonard (1955) showed a slowing of the fusional act with very low blood alcohol levels. The seeing of two diplopic moons by persons who are slightly drunk indicates that the fusional function is not very stable.

Measuring the Fusional Lock

The strength of this lock can be measured in a variety of ways (see Chapter 5), the distribution being very similar to that of an intelligence quotient (Fig. 2.5).

A very different distribution is found if the position of non-fusion of the eyes is measured. This can be done by placing before one eye a device which so distorts the image that it is not fusible with the other. The eye then deviates slightly from the position of fixation of the other eye. The amount of deviation can be measured with a Moddox rod, which distorts a spot of light into a long thin line. For ease of comparing the position of the line with the white spot, the streak is usually coloured red (Borish, 1970a).

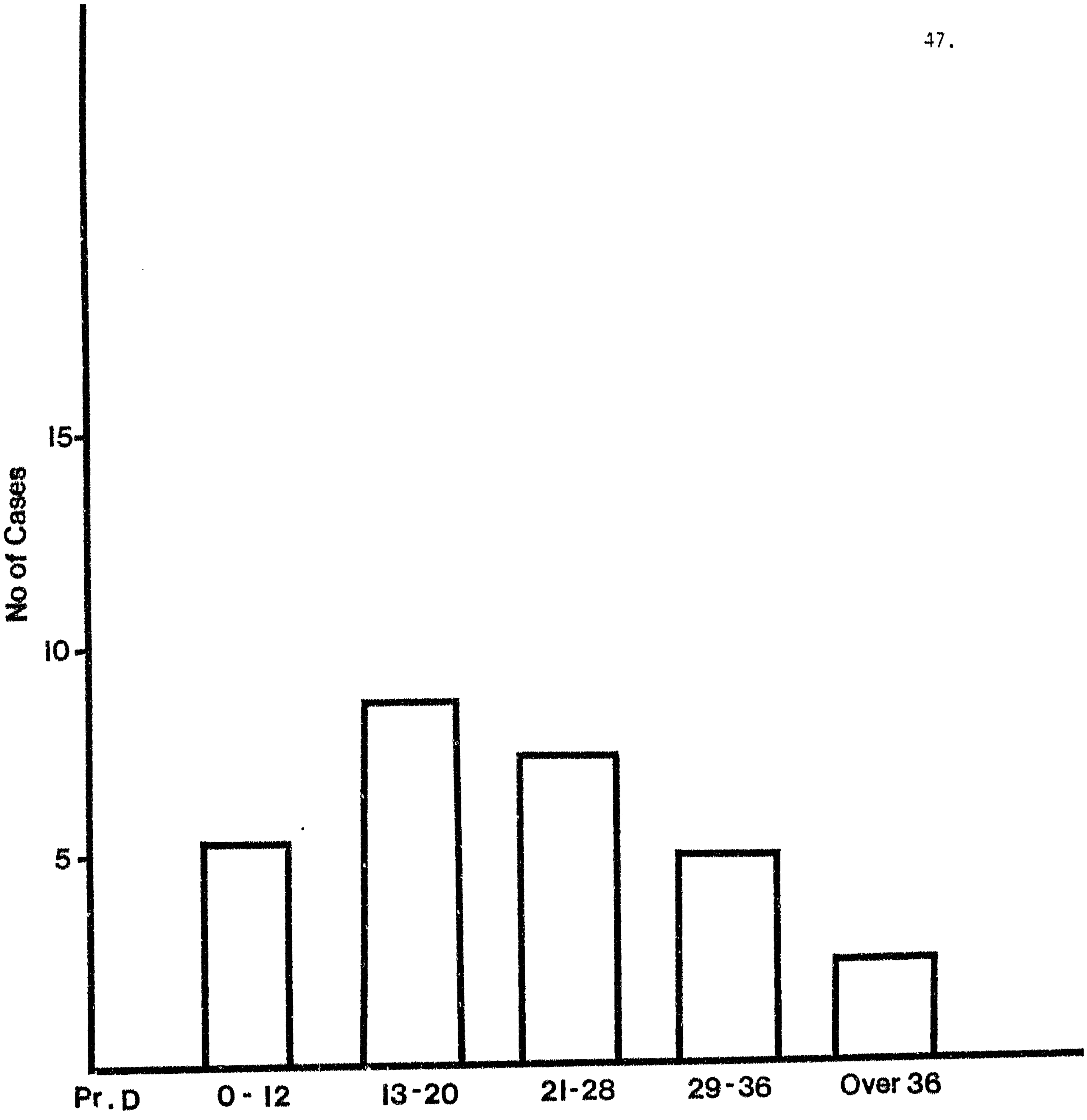
The deviated eye is then kept in position by the normal tonus of the six ocular muscles and the position may be regarded as physiological as the subject cannot control its relation to the vertical, nor cause it to move in divergence. A few subjects can converge voluntarily and cause the line to move away from the spot, but this can be prevented by an instruction to them to relax and not make any such effort.



Distribution of the position of the eyes when fusion is active and the eye is forced to move by the displacement of the target by a rotary prism.

Pr.D. Angular deviation in prism dioptres.
N.35 Mean P.F.R. 22.0 Pr.D.

FIG. 2.5



Distribution of the position of the eyes when fusion is active and the eye is forced to move by the displacement of the target by a rotary prism.

Pr.D. Angular deviation in prism dioptres.
N.35 Mean P.F.R. 22.0 Pr.D.

FIG. 2.5

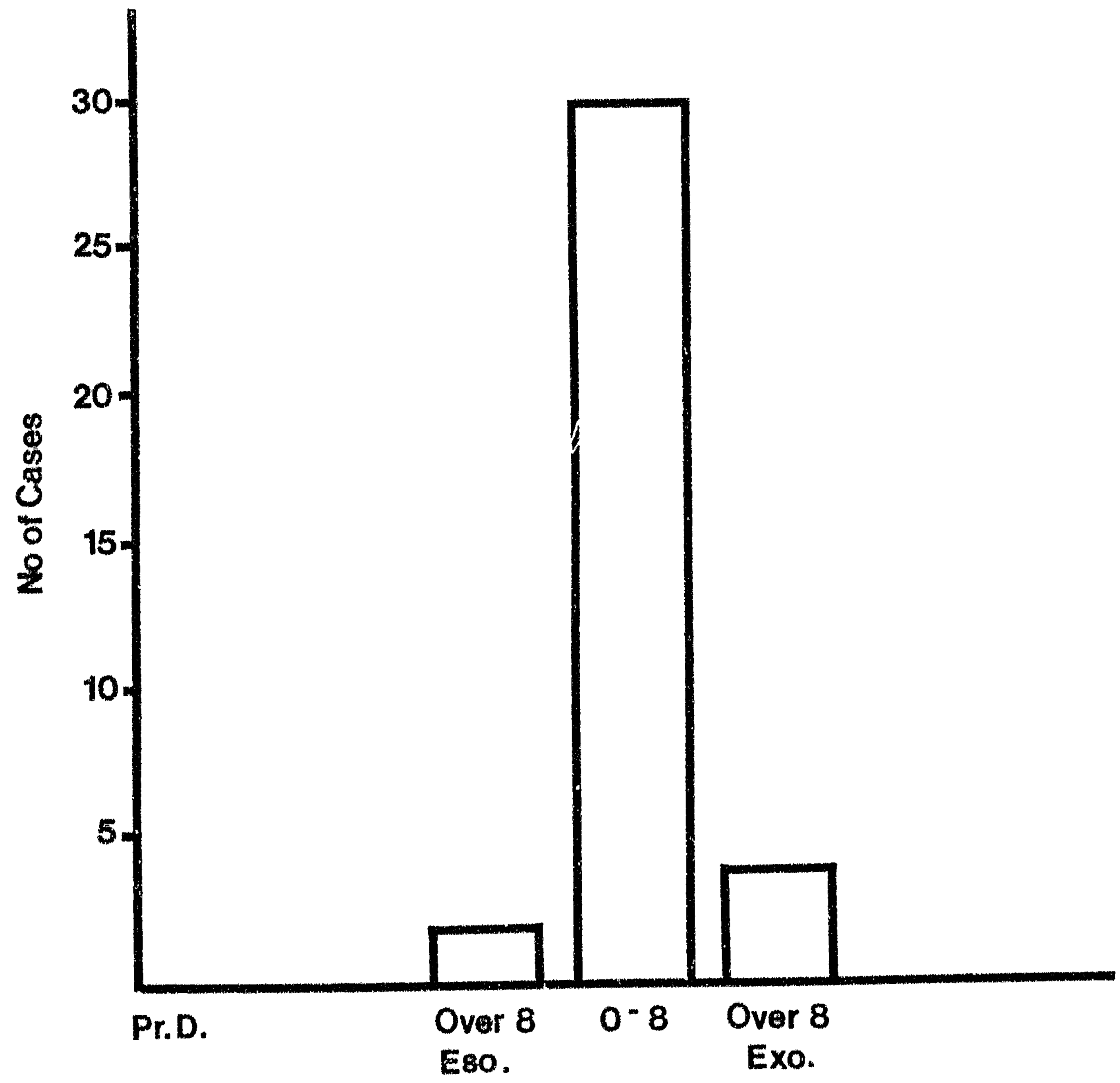
The distribution of the deviation of a right eye to the right (esophoria) or left (exophoria) from the spot can then be measured and plotted (Fig. 2.6). The test can be repeated with subject fixating a spot of light at a distance of 33 cms. The accommodation is then active and convergence is innervated by the output of the third cranial nucleus. As the convergence-accommodation neural linkage has some degree of flexibility, it might be expected that the distribution of the error in position of the non-fixing eye under these circumstances would be greater, but this is not so, in the great majority of patients very little convergence is recorded (Fig. 2.7). The distribution is similar to that of many physiological functions, that is, the standard deviation is very small.

Retinal Disparity

There is an aspect of peripheral vision which demonstrates a flexibility which varies between individuals. It is known as retinal disparity or retinal slip.

If a fused picture of a square and two central dots is created from two squares and one dot slightly above centre and one slightly below it, and if a base of prism is placed before one eye, forcing it to converge slightly in the interest of retaining fusion, then the marks separate and assume a slightly divergent position.

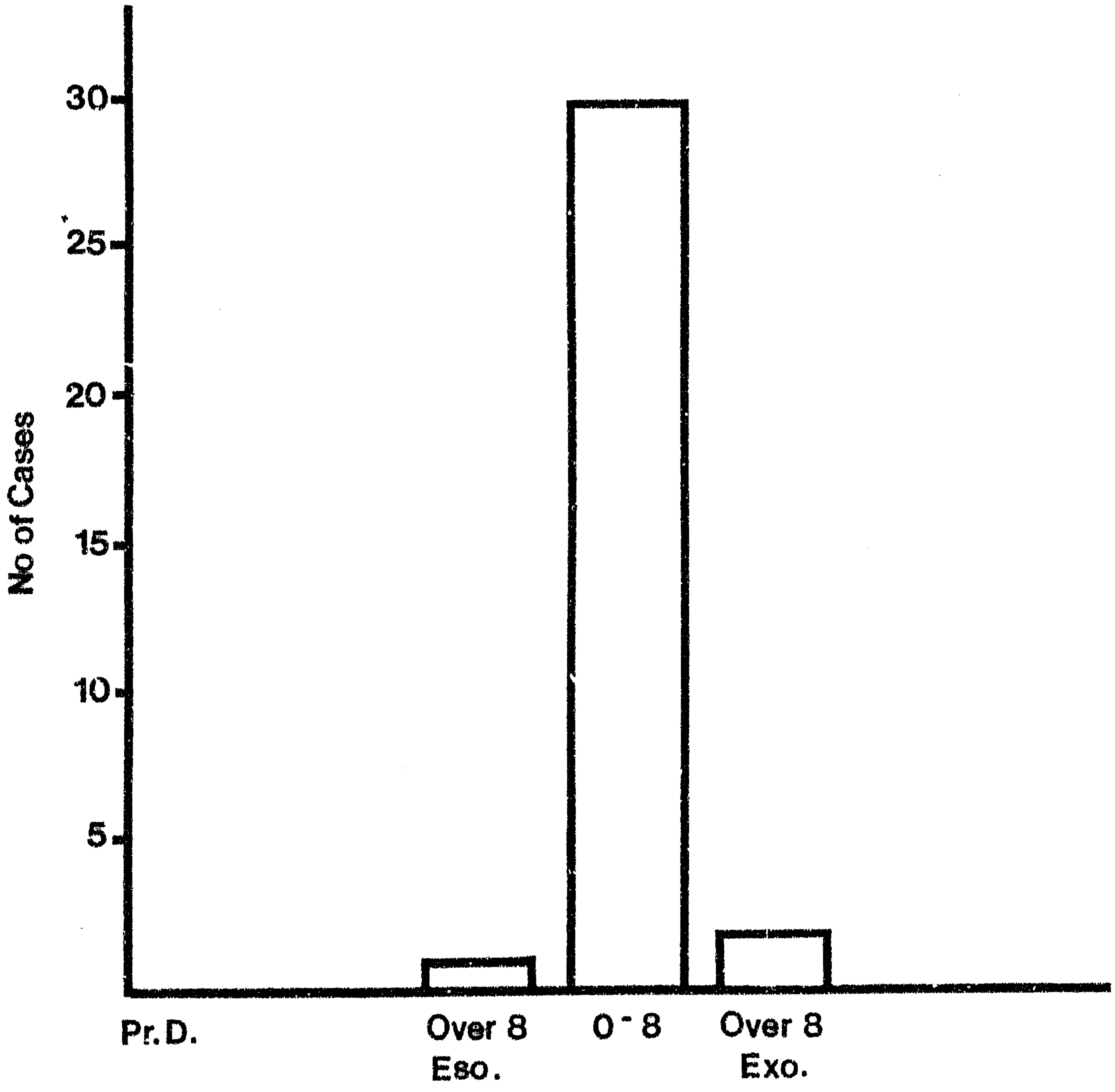
It would be thought that the vertical edges of the square should now demonstrate a slight diplopia, but this is not so. They remain fused (Borish, 1970b).



Distribution of the position of the eye when fusion is destroyed and the position is maintained by muscular tonus.

To the L (ESO) Esophoria, a tendency to turn inwards.
Exophoria, a tendency to turn outwards.
Pr.D. Deviation in prism dioptres.
N.35 Mean position 0.35 Pr.D Exophoria.

FIG. 2.6



Distribution of the position of the eyes when fusion is destroyed, accommodation is active, and the position is maintained by muscular tonus.

Esophoria.	A tendency to turn inwards.
Exophoria.	A tendency to turn outwards.
Pr D.	Deviation in Prism Dioptres.
N.35	Mean position 0.735 Pr.D. Exophoria.

FIG. 2.7

This flexibility in fusion, also demonstrated in the distance between the horopters measured with the target moving inwards and outwards, is known as Panum's area (Mitchell, 1966; Fender and Julesz, 1967).

This area of binocular flexibility is not the same for distance and near viewing (Richards, 1971) and there are considerable differences between subjects, particularly at the near distance.

Solomon (1973) states that these differences can be explained by the tortion of the eyes in near vision.

Extensive research has been done clinically on the relation of the stress placed on the ocular muscles and the amount and type of disparity demonstrated (Ogle, 1950 ; Carter, 1964 and Lyons, 1966) and instruments have been devised which are claimed by their inventors to measure the amount of relieving prism required by a patient who demonstrates this stress.

One of the instruments devised by Mallet (Lyons, 1966) was used on a large group of optometry students to see if its variability was repeatable and if it was sufficiently reliable to use statistically in this study. The results were not favourable. The majority of the students with measurable heterophorias recorded nil disparity, and none of those who gave positive results repeated them when re-tested four days later. For this reason retinal disparity was not used in the design of the optometry battery of tests

Conclusion

The summary of the anatomical evidence was that some sort of flexibility in binocular fusion had to exist because the anatomy of the eye was such that the two retinal images could not be exactly the same.

The physiology shows that such a flexibility does exist, and that in summating the two inputs a very small lowering of the monocular threshold results. This is not consistent with a common end path, but more with an assembly of psychological data. The degree of flexibility is shown to be similar in all aspects of fusion, and the experiments described show that it can be measured.

Binocular Movement

The Neural Control of Movement

Bio-physicists researching in the field of cybernetics have become interested in ocular movement because the eyes respond to a central innervating mechanism which represents a type of remote control. These systems can be identified by their variation, that is, in the way in which the moving mechanism behaves in relation to the controlling centre. There is a lag before movement takes place, a variation in the degree of accuracy of line up, a difference in the speed of movement achieved, a tendency to oscillate at the end point of movement, and a damping system to prevent this.

If this data can be established, then the researcher in cybernetics can identify the type of remote control system used. That this analysis will apply to ocular movement is suggested by Robinson (1968) who comments on the similarity to a large gun moved by remote control instruments, and by Childress and Jones (1967), two electrical engineers, who note the large amount of damping in ocular movement.

An analysis of the responses showed that there were three separate controls. One dealing with reflex movement was coarse and fast, the second controlling voluntary movement, was slower and a little more accurate, and the third, much slower but very accurate, dealt only with binocular movement.

This discovery is consistent with the neuro-anatomy. The pyramidal cells of Meynert have dendrites which are innervated by 30 retinal ganglion cells. The outgoing efferent fibres are large and heavily myelinated, and link the occipital lobe directly with the midbrain. This is ideal neurology for crude fast reaction to visual stimuli (Wolff, 1958b).

The second control must be in the frontal eyefields which are concerned with voluntary movement, so that if the left hemisphere is stimulated, both eyes turn to the right (Crosby and Henderson, 1952).

Evidence already presented suggests that the site of the third control is in areas 18, 19 and 22 with a particular concentration in the angular and marginal gyri. The areas appear to interact and there is not yet any clear evidence as to precisely the function of any of them.

The binocular innervating systems produce two types of binocular movement, paired conjugate movements, where the eyes move in the same direction, and vergence movements when they move in opposite directions.

Movement in search of a target is achieved through a series of jumpy or nystagmic movements until fixation is achieved, when the eyes drift away and are brought back towards it by a flick. Pickwell (1972) established that the initial flick is generally greater in the dominant eye. There is evidence of a binocular controlling centre in the amount of agreement between the right and left eyes when making these movements.

Nachmias (1961) found that the saccadic movements were correlated, but the drifts were not. He observed considerable difference between observers in the drifting behaviour. Carifa and Hebbard (1967) recorded physiological nystagmus binocularly and their records show that the saccades occur simultaneously in each eye, usually in the same direction and with similar magnitudes. They also recorded a micronystagmus which is not binocularly co-ordinated except when the tremor exceeds 36 seconds of arc in magnitude, which is rare.

Hebbard (1964) called these tremors, and measured them as having a movement of 10-14 seconds of angle and a frequency of 85 per second. He measured the saccades of 5-6 minutes of angle at a frequency of 1-2 per second. St. Cyr and Fender (1969) summarised the evidence concerning conjugate binocular movements, plotted the right against the left eye movements and produced a scattergram showing a high positive correlation between the right and left correcting flicks which are binocularly innervated. There was more scatter in the plot of the drifts.

The time difference between the right and left eye movements was measured by Less (1970) who demonstrated that the binocular innervating centre can detect a time difference of 25 minutes per second.

Although the saccades of the right and left eyes have some agreement, the amount by which they vary should produce a type of diplopic confusion, the eyes being sensitive to much smaller angles than the movement differences. This, and possibly the avoidance of a field of vision moving in the opposite direction to that of the eyes is avoided by totally suppressing the vision during the saccades (Latour, 1960). Starr, Angel and Yeates (1969 showed that the suppression did not take place during smooth movements, such as following or tracking.

Vergence Movements

The search for a target through vergence movements is also achieved through right and left saccades. Alpern and Wolter (1956) show that in this binocular search for a near target, one eye makes a saccade in an incorrect direction. Alpern (1957) confirmed this behaviour and found very different responses between observers. The controlling mechanism acts as though a conjugate movement were required, and when it is discovered that this is not so, the system switches to vergence control (Tamler, Jampolshy and Mang, 1958).

Rashbass and Westheimer (1961) demonstrate that the amount of movement is proportional to the magnitude of the disparity in position of the two eyes to the target. The correcting movement can be altered while it is being performed by a target change in disparity. The eye responds to this in 160 movements per second but takes 800 movements per second to complete a vergence movement.

They also demonstrate that the time lost in correcting the directional error of the first saccade partly accounts for the slowness of convergence movement.

Krauskopf, Cornsweet and Riggs (1960) deduced from their analysis of vergence movement that there is a movement centre which is aware of the extent and direction of the errors of binocular fixation and innervates the saccadic corrections, not towards the fovea, but towards the mean position of error of the two eyes. These correcting saccades were found to correlate with each other, 0,40 indicating the existence of a binocularly innervating centre for vergence movements. The marked difference in vergence movement behaviour between subjects was noted by Huang and Smith (1970) who detected eye movements in photosensitive electric cells activated by light reflected from the scleral corneal margin. The subjects were five young females.

The input from the cells was fed into an averaging computer which calculated the difference in time and distance between the saccadic eye movements of the right and left eyes. One observer produced almost exact agreement between the right and left saccades, the other four girls showed variation in magnitude, form and time between the right and left eyes.

Convergence and Divergence

There is not agreement as to whether there are two different control systems for convergence and divergence, although it is agreed that both systems vary from the control of conjugate movements.

Clinically it is known that patients suffering from general or ocular tension are esophoric (have a tendency to converge) while those who have a debilitating disease are exophoric.

Wertheim and Mitchell (1956) found that fusional movements of convergence were faster than those of divergence (relaxation of convergence). They also found that the eye movements are directed by a binocular centre.

Boubicr (1964) repeated the investigation and found that conjunctive movements were twice as fast as convergence and this was faster than divergence. She also found that the eyes remain fixated for as long as two or more reaction times, and she argues that having made a fixation, the brain needs time to consider its next movement.

It was believed for many decades that Perlio's nucleus, a medial part of the third cranial nucleus, was a centre for convergence. A lengthy neuro-anotomical and physiological investigation by Warwick (1955) disproves this. Warwick shows that there is no nucleus in the mid-brain controlling convergence as these nuclei have no integrative ability. He demonstrates that the mid-brain nuclei only carry out the orders of a higher centre.

Convergence may be produced by stimulating accommodation, and accommodation always accompanies forced convergence. The amount of convergence induced is a linear function (Flom, 1955 and 1960; Wallis, 1966) which is very constant for the individual, but the slope of the graph varies between individuals and suggests a neurological difference.

There is no evidence as to the type of control which results in fusional compulsion. When the two eyes are each within one half a degree of the target, a fusional compulsion takes control and an abrupt movement into precise alignment is made (Lange, 1953).

Cycloversion

There is an objection to the use of convergence and divergence as a test of fusional strength because the measurement is complicated by the convergence-accommodation linkage. Thus the experimenter does not know if he is measuring the strength of fusion or the flexibility of the mid-brain linkage.

This objection does not apply to cycloversion which is a rotational vergence when the eyes rotate in opposite directions to each other. This effect can be achieved by fusing two vertical lines in a haploscope and rotating them in opposite directions when the eyes make the same movement in the interest of fusion and retaining single binocular vision.

There might be two explanations of this unity. The eyes might rotate in their sockets, or the images might rotate in the cortex. Which of these two did in fact occur was the subject of debate for almost a century. The cyclo-rotational movements of the eye were first reported by Nagel in 1861. Helmholtz reported the ability to retain a fused image which was rotated by viewing through a rotating prism, and Hering queries the validity of the experiment in 1869. The first demonstration that cyclofusional movements do take place was made in the classical experiments of Hofman and Bielchowsky who rotated cards of print which had drawn on them two parallel lines, one seen by each eye. Later Brecher, using a telescope to watch markings on the iris,measured the actual movement of the eye and confirmed that the eye does rotate in its socket from five to eight degrees.

Verhoeff refuted this and insisted up to 1930 that the rotation is in the cortex and not in the eye itself, but in 1934 he repeated Hofman and Bielschowsky's experiments and agreed that these movements do take place.

Ogle and Ellerbrock (1946) summing up the experiments in Germany and America, say:

> no longer is there any question that cyclo-fusional movements can be enforced, and these movements fall into the category of reflex movements, characterised by Hofman as psycho-optical reflexes in that they depend on the attention of the observer, and yet, when that attention is given they act as reflex movements, and can be neither induced nor suppressed spontaneously.

In 1950 Moses marked the limbus with ink dots and measured the tortion on oblique gaze. He found these amounts of tortion :

5	15	25	35	45	Obliquity of gaze
6m	1	2 49	5 40	9 44	Degrees of tortion

He found that the angle of the after image agreed with the demonstrated tortion.

Ellerbrock (1954) describes a refined method of inducing cyclovergence movements and comments that some of his subjects fused two black threads into a Y. A similar result was found in the experiments described in this thesis, and this perception is interesting because it demonstrates the ability of the cortex to change the shape of a simple stimulus, as it is apparent that two straight threads cannot be seen as a Y.

A possible explanation of this perception might be found in the work of Thorn and Boynton (1974) who demonstrated that adjoining areas of vision are affected by the disparity.

Ogle and Ellerbrock also consider cyclo-vergence movements in terms of spectacle wearers whose astigmatic prescriptions tilt the retina images away from each other. The authors show that in persons who have worn an oblique astigmatic correction for many years, a cyclo-vergence movement is still made to adjust the position of the image towards that of the other eye. Their results suggest that cyclofusion movements occur much more freely, readily and frequently than is generally recognised. It may in fact be inferred from their experiments, that in man, cyclofusional movements take place constantly during the normal process of seeing.

Pascal (1955) states that there is cyclo-vergence in opposite directions in convergence. Fixing at 8 cm each eye has incyclo-vergence of 4 degrees. In oblique positions of the eye, the eye may be extorted, but on convergence of the other eye it intorts. Belcher (1964) makes the very interesting point that in reading, the eyes look downwards and inwards and tortion is required in opposite directions. This may well be a reason why man developed the oblique muscles whose major action is tortion when looking inwards. These muscles, the superior obliques, are intorters and depressors, and it may be that the separate nerve supply to this muscle (the fourth cranial nerve) resulted from the need to adjust the position of the two eyes to each other in the convergent looking down position.

Allen (1967) again surveys the literature on cyclophoria. He placed a horizontal thread on the anaesthetised cornea and measured its rotation when the other eye converged. From 17 subjects in the primary position he recorded rotations from 0,0 degrees to 3,6 degrees. He shows that there is an increasing cyclo-vergence with elevation and depression, and with convergence reaching a maximum excyclo-vergence of 13,0 degrees at 30 degrees of convergence with 40 degrees of depression.

More recently Kertesz and Jones (1969) demonstrated that the cyclo-vergence does in fact consist of two parts, a movement of the eye and a movement in the cortex, that is within Panum's area.

According to Fells (1975) the muscles which are largely responsible for the rotation which aligns the retinal horizontal with the terrestrial horizontal are the superior obliques. This may be why they have a separate nucleus to innervate them and a rather complex action through a pulley.

Summary

The physiology of binocular vision may be summarised as follows :

The process of unification and the analysis of diplopic differences is probably performed by binocularly activated cells in the L.G.B. and the cortex of areas 18, 19 and 22.

This conclusion is consistent with a large amount of behavioural evidence concerning binocular summation.

The evidence as to the control of binocular movement may be summarised as follows :

(1) There is a separate neurological control for binocular movement.

(2) This control is situated forward of the striate cortex and is located in areas 18, 19 and 22. It is probable that these three areas carry out different functions.

(3) The controlling cortex is aware of the differences in binocular fixation and corrects these by making movements of the two eyes individually towards the position of mean error between the two eyes.

Both in the process of unification and the control of binocular movement, the behavioural research shows [illegible] able difference in the results of tests done by subjects who a[illegible]ly normal. In the two fields, the existence of non-visual variables in binocular performance is clearly established.

The Nature of Visual Inhibition

Suppression

If a pencil is held 10 cms above a page of reading matter in line with the nose and the centre of the page and the text is read, persons with normal binocular vision do not find any parts of the word occluded by the pencil. When the pencil is before the right eye, the image of the pencil is inhibited and the word is seen by the left eye. As the eyes scan along the line of words the image of the pencil produced by the left eye is now inhibited, and the words are read from the right retinal image. When the pencil is removed, binocular vision for all the words results (Giles, 1943 a) .

If a plus three sphere is held before the left eye and a distant chart of letters is viewed, no letters are legible by the left fogged eye. This blur can easily be inhibited and the letters read by the right eye. If however, the plus lens is moved in a slow circular movement, the centre of the chart tends to disappear and the moving blur is seen (Humphriss, 1937).

A patient who is astigmatic in one eye only and does not wear glasses has a similar binocular condition, except that one retinal image is permanently blurred. On optomteric examination a lowered visual acuity is often found in the astigmatic eye, and on the haploscope a central permanent scotoma can be plotted. This area of central retina is now permanently inhibited. Patients suffering from this permanent suppression can draw a picture showing the blank central area (Humphriss, 1937).

Examination of the nature of this scotoma shows that it is not absolute but relative. Vision of light and of movement is not lost, perception of pattern is lost (Fox and Check, 1966a).

All of these conditions fall under the heading of suppression or inhibition and they are frequently used during this thesis. In order to differentiate between the irreversible inhibition of the temporary inhibition, the former is called suppression (its clinical name is suppression ambliopia), and the latter function, suspension.

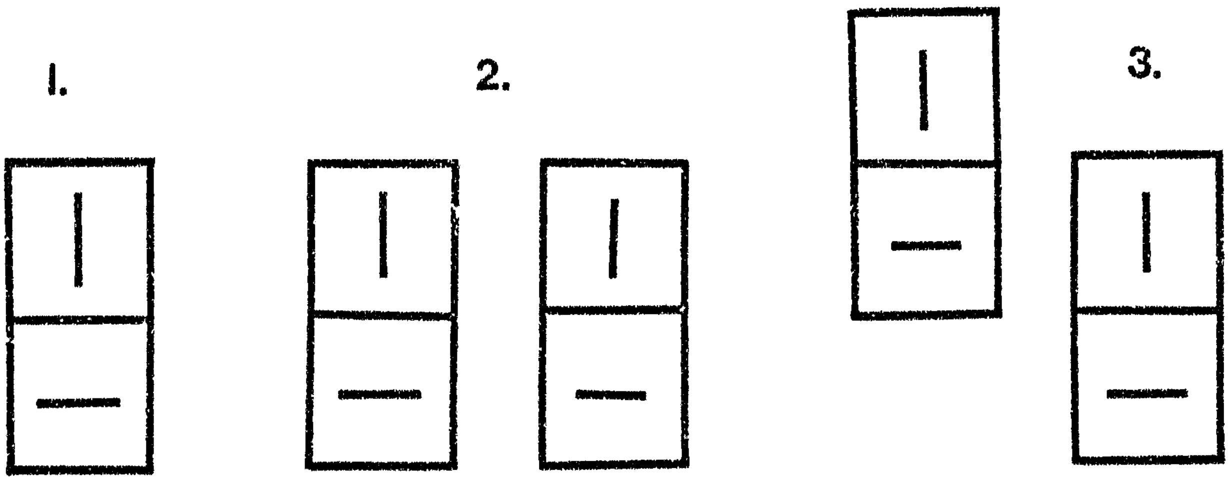
Visual Suspension

Humphriss (1937) investigated the factors that cause one of two non-fusible images to be not suspended, and found that:
subject can see either image, be it stationary or moving, by trying to see it or by thinking hard of it. If subject relaxes and does not try to see either image, then the moving image is seen. Similar inhibition of a stationary target was found by Grindley and Townsend (1965), and Fox and Check (1968) demonstrated that if one eye is suspended and a target moves in that field, then it takes the subject longer to record the movement than if the target is moved before a non-suspended eye.

Humphriss also demonstrated that if one image is clearer than the other, then the clear image is seen. The weakest factor in bringing one image to consciousness is brightness. The clarity reaction dominating a blurred brighter image was used in the design of a retinal rivalry test used in the experimental work.

During our experiments on the effects of blurring one eye of a normal subject, we began to suspect that the fovea centralis responds to very small differences in right-left clarity, and as this might have a most important clinical application in optometry, an experiment was set up to investigate the reaction. Our first difficulty was to design a test in which a subject could react to right and left differences at a level of near maximum acuity, that is 6/6 (20/20). Attempts to make photographic slides were not a success. Good results were eventually achieved by using a chart 6 metres away from the observer in which a small illuminated chart was seen which was partly monocular and partly binocular When we had demonstrated on a pilot group that the observer could detect changes at the level of 6/9 acuity the following experiment was performed:

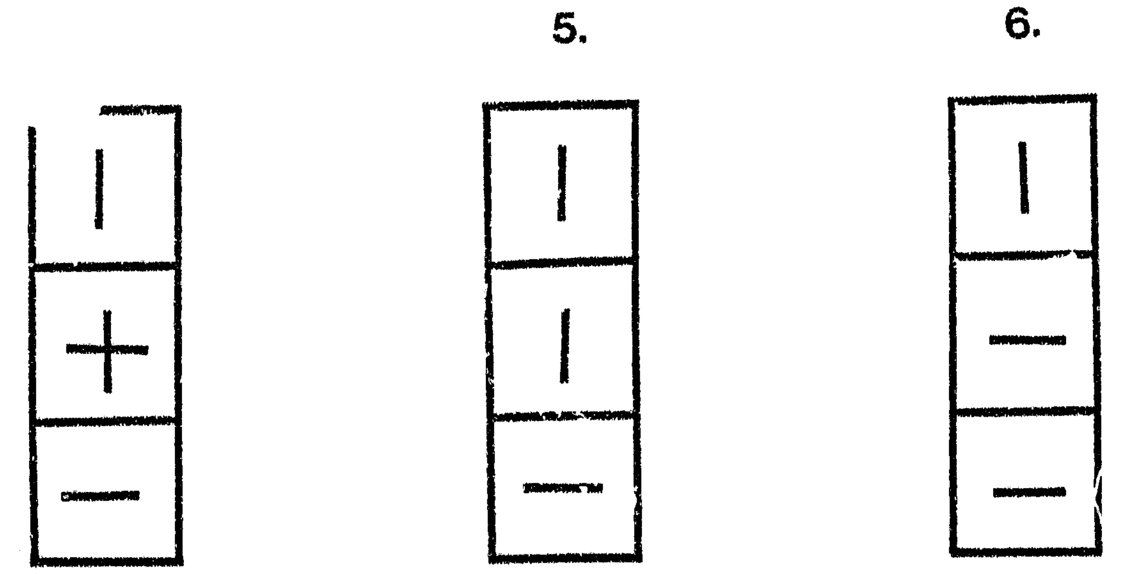
Method : A vertical rectangle 24 mm high by 12 mm wide was drawn and bisected. In the upper square was a vertical line equal in acuity to 6/9 and in the lower a similar but horizontal line (Fig. 2.8). The target was mounted on a dark brown sheet of masonite and fixed to the wall behind the subject's head. It was illuminated by a projector using a rectangular strip of light slightly larger than th target. The room was otherwise in darkness. The advantage of this type of illumination was that when a doubling prism was used, only the small illuminated chart was seen in diplopia, the level of illumination in the room being insufficient for subject to appreciate the diplopia there. The target was seen by the subject through a mirror placed 2,7 m before them, the target on the wall being 3,3 m from the mirror. The subject was shielded from the illuminating projector. A refractor head was positioned comfortably before the subject and a base in prism was introduced until the rectangle doubled horizontally. A vertical prism was introduced before the second eye which lifted the rectangle by half its height. The base-out prism was then reduced until the two half rectangles fused.



seen by
both eyes

Separated by base
in prism

R image lifted by
base down prism



base in prism removed
R and L images are
fused

Target seen with
plus 0.75 D sph
before R eye

Target seen with
plus 0.75 before
left eye

The appearance of the target used to demonstrate central retinal suspension

FIG. 2.8

The four steps are illustrated in Fig.2.8.

What is now seen is a rectangle consisting of three squares. The upper square is seen by the right e, the lower square by the left eye. The central square is seen binocularly and therefore contains a cross of which the vertical part is seen only by the right eye and the horizontal by the left eye.

Subjects. The subjects were seven members of the staff of European origin, and 14 similar patients selected from the practice as visually normal. Subject was to look at the target and describe it. Plus sphere in 0,25 D steps was introduced before the dominant eye until a change was noticed. The plus was then reduced in the same steps back to normal. The procedure was then repeated on the non-dominant eye.

Results. The result varied between the young and the older subjects. Some young children reported that when the first 0,25 lens was introduced before the right eye, the vertical line in the centre square disappeared.

Most of the patients below 20 years of age reported that the line had vanished when the 0,50 fogging lens was placed before the right eye.

All subjects reported that the line had vanished when the lens was increased to the 0,75 D sphere.

When the plus lens was removed, the oss was seen again in the central square.

No subject reported the disappearance of a part of the rectangle, only of the line inside it.

Conclusion. The visual cortex dealing with binocular vision can inhibit any part of an image, however small, which interferes with binocular clarity. This process of inhibition is slightly affected by the age of the subject, the older subject requiring a little more blur to the image before it is inhibited.

The results in this experiment were confirmed in a further experiment. The same subjects were used.

Method. The subjects were seated before a synoptophore which was adjusted to their comfortable position of binocular vision, and the two slides (Fig. 2.9) were put into the instrument. One eye was then increasingly fogged with plus sphere taken from a trial case and placed in the auxilliary lens holders before the eye pieces. The subjects were asked to count the number of dots they could see.

Result. As the fogging increased all subjects counted a lesser number of dots, the smaller dots in the centre having vanished.

The conclusion from the experiment is that if the vision of one eye interferes with what the observer wishes to see, an area of vision equal to the interfering area is suspended. This suspension is discontinued as soon as it is not necessary. When the suspension operates, it is as though a very small central area of retina, probably not more than a half a degree in subtention at the centre of rotation has been occluded. The author referred to its use in the consulting room as 'The Psychological septum' (Humphriss, 1962).

Binocular Refraction

This was an exciting discovery for a clinical optometrist. It

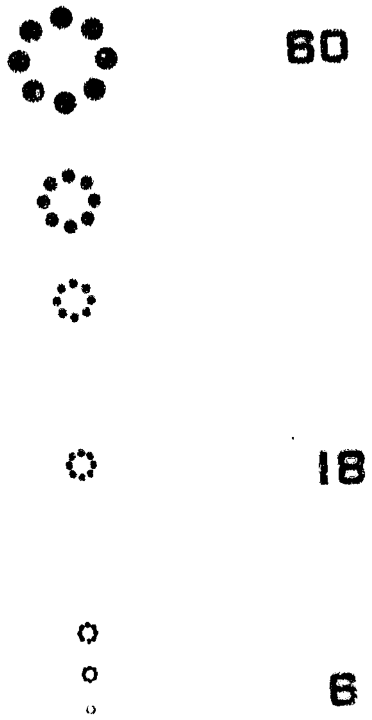


FIG. 2.9

Target for the second experiment. Slides used to demonstrate central retinal inhibition.

made clear that if one eye of a patient is fogged with a plus 0,75 sphere, a very small area of central retina, probably not more than one half of a degree of the fovea centralis, is suspended. Binocular vision is otherwise normal. The optometrist can therefore refract the unfogged eye as though the other eye were occluded.

A research programme was instituted to find out the ideal viewing conditions for this refractive technique, and after some two years of research a complete binocular refractive technique was developed. This is now taught and used all over the world.

Peripheral Suspension

Suspension also takes place in the peripheral retina. If you sit with your left shoulder towards a well sighted window and study the wall paper at eye level, you are not aware of the peripheral images of the nose, seen to the left from the right eye, and to the right from the left eye (Brock, 1964).

If you now close the right eye and look to the right, the well-illuminated outline of a pink nose is clear. If the left eye is closed and you look to the left, a dark outline of the nose is now seen.

If in either of these positions both eyes are opened, the image of the nose slowly vanishes, beginning with the centre of the nose and spreading until the actual outline is the last to go. It is thought that a similar inhibition is the cause of the drop in visual acuity and the concentric reduction in the field of vision found in hysterical ambliopia.

The area of cortex which carries out this inhibition is not known. Berman and Levi (1975) using a visually evoked response from area 17 of the cortex found that there was no loss of visual acuity or field of vision there, indicating that the inhibition takes place forward of the cortex. That the evoked potention represents the state of suspension was demonstrated by McKay (1968) who measured the potential of an evoked response from a normal eye and repeated it when a contrasting form was presented to the non-tested eye. He showed that the potential falls when the contrasting target is seen.

This evidence is of particular interest when taken with the findings of the E.E.G. research which locates forward in the brain an area which appears to deal with suppression in binocular vision.

Retinal Rivalry

The image seen in a state of retinal rivalry has interested optometrists, neuro-psychologists, and psychologists for many years. The optometrists have been concerned because the condition they have to treat, suppression ambliopia, is one in which a permanent inhibition has resulted from a state of irreversible retinal rivalry. The conditions under which the image is seen are therefore the best to induce a return of vision after the cause of the rivalry has been removed (Humphriss, 1937).

A practical method of treating suppression ambliopia based on this principle was developed by the author and is described by Giles (1943b) in his book 'The Practice of Orthoptics'.

The neuro-psychologists have shown that the alpha rhythm in the E.E.G. agrees exactly with the percept seen by the subject. While the experimenters can locate the rhythm of the image seen, they are unable to find the unseen image and are hence unable to say where it is stored or how it is inhibited.

Lansing (1964) examined the E.E.G.'s of subjects whose right eye was stimulated by a white flickering light, and the left by a pattern of red light. He found that the stimulus seen agreed with the E.E.G. pattern recorded. He was unable to explain the mechanism of whereabouts of the response to the input not seen.

Psychologists have been interested in retinal rivalry because the picture seen is determined by the state of mind of the subject (Engel, 1956). If one of the two pictures is familiar to the subject then this will be seen. Bagby (1957) contrasted familiar scenery with an unfamiliar view and demonstrated that all his subjects saw the familiar scene. Goryo (1969) working in Japan, showed that if the targets were presented to both eyes at the beginning of the test, the picture seen in the rivalry situation was that seen more times previously.

Similar results were found in binaural hearing experiments when contrasting sounds were presented to the separate right and left ears, subjects always hearing their own names (Neisser, 1966).

If the visual contrast is between a pleasant or preferred picture or an unpleasant or disliked picture, the former is seen.

Pettigrew, Allport and Barnett (1958),using a haploscope and portraits from the South African identity documents demonstrated that when viewing two of four race groups, each sa his own race. Further, that those politically prejudiced to the right would not see a mixture of two races, but saw one or the other, while the coloured people (half castes) always saw the mixture.

A similar result was obtained by Davis (1959) in America when a picture of a negro kissing a white woman would not be seen.

If one of the pictures presented, matches the state of mind of subject, then this is seen. Van der Castle (1960) demonstrated that if words are presented in a rivalry state, an aggressive person will see words suggestive of aggression. Shelley and Toch (1962) used this reaction to select criminals who were responding to rehabilitation programmes. Those responding saw a non-violent picture, those not responding saw the violent picture. The same technique using photographs of mothers and fathers with stern and pleasant features was used by Purcell and Edward (1966) to demonstrate difference in reaction between asthmatic and non-asthmatic boys.

Kaushall (1975) investigated hemispherical dominance in rivalry situations and concluded from his results that the left hemisphere is dominant for rivalry, the right dominant for brightness and the uncrossed fibres dominant over the crossed.

Lack (1971) investigating the function of accommodation in retinal rivalry concludes that the control is central and not ocular.

These reactions in a state of retinal rivalry are further evidence that after the two retinal half images have reached area 18 of the human cortex, they are assembled into one picture which can be recognised and then pulsed in their entirety down into the hippocampus for assessment (Arnold, 1960). After this assessment is made, one is allowed to come into consciousness and the other is totally inhibited.

This evidence is only marginally interesting to the thesis but it does indicate the extremely complex task which is carried out by area 18 whose behaviour must be in part responsible for the results obtained in the experimental work.

Intra-cranial Pathology

The area of cortex which processes binocular vision can be located, and something of its nature discovered from loss of function resulting from tumours in the occipital and parietal lobes.

Damage to any part of the brain interferes with the normal saccadic movements of the eyes, to such an extent that Rodin (1964) considers the change to be diagnostic of brain damage. He comments that it is most marked with damage in the parietal lobe and considers that the defect results from lack of inhibition of movement.

Damage to the para-striate cortex suggests that in addition to its sensory function, it is also an opto-motor centre. Carmichael, Dix and Hallhike (1954) investigated 73 patients with cerebral lesions and conclude that Brodman's area 18 is an opto-motor area. They write:

> Optokinetic nystagmus is normally exercised through independent nervous mechanisms situated in the supramarginal and angular gyri. The optokinetic responses to the left and right are subserved primarily by anatomically separate reflex pathways within the brain stem. Each of these pathways is under the modifying influence of a centre in the supramarginal and angular gyri of a particular cerebral hemisphere, thus the right hemisphere facilitates optokinetic nystagmus to the left and inhibits it to the right.

This conclusion is supported by Hecaen and de Ajuriaguerra (1954). Writing on optokinetic nystagmus, they say:

> The conclusions arrived at by various authors, particularly Fox, allows us to retain the idea that lesions of the posterior parts of the hemisphere (chiefly the supramarginal and angular gyri) have a disturbing effect on optokinetic nystagmus.

The evidence from this pathology is that there is an area of brain which is parieto-temporal whose function is to retain exact and prolonged binocular fixational attention.

There is very little evidence of the effect of pathology on the fusional process. Blakemore (1970) describes the case of a fourteen year old boy who had his chiasma sectioned traumatically and who retained fusional movements. This suggests that one image was transferred to the opposite hemisphere through the corpus callosum for comparison with its fellow.

Mitchell and Blakemore (1970) show that binocular depth perception at the midline was lost in a 16 year old male who had his corpus collosum sectioned to prevent the spread of epilepsy. These two taken together support the thinking that right-left comparison is made in area 18 via the corpus callosum.

Some neurologists have located the visual functions to a particular area of post-tempero-parietal cortex. Gowers (1887) believed that the angular gyrus in each hemisphere constituted a higher visual centre, especially concerned with the visual fields of the other eye. He describes a crossed ambliopia, a loss of peripheral visual function in the opposite side to the parietal lesion. A comment by Denny-Brown and Chambers (1958) might support this view. They note that a patient with a parietal lesion, when looking at a line, bisects it at the point of fixation, not being aware of the visual reception of the stimulus from the line of the affected side. Riddock (1917) quotes cases of loss of three-dimensional vision, resulting from wounds in the tempero-parietal area. Ettlinger, Warrington and Zangwill (1957) found that a visual spatial agnosia is related to tumours of the supra-marginal angular gyri and the posterior portion of the first temporal convolution. McFie and Zangwill (1960) found that in seven cases of posterior parietal lesions in the left cerebral hemisphere, there were constructional apraxia defects. In the right hemisphere they found an impairment of spacial estimation.

These cases of loss of function related to binocular vision support the evidence from the evolution of the brain that adjoining areas, one of which is motor and one sensory, tend to evolve together.

Damage to the parieto-temporal cortex not only interferes with binocular movement, but it also damages the ability of the brain to assemble sensory inputs concerned with binocular vision. The area is clearly shown to be cortex, which being so far forward in relation to the striate cortex, must be one of the final areas concerned with binocular vision, if not the actual area where the previously processed retinal input is finally assembled.

It was to examine this hypothesis that the E.E.G. programme of research described in the next chapter, was undertaken.

Conclusions

The nature of binocular vision has to be considered as three interacting functions, the control of movement which makes fusion possible, the process of fusion, and the process of inhibition when fusion is not possible.

The existence of a separate motor control of binocular movements suggests that this evolved because of the need to converge and observe with greater accuracy including stereopsis, what was held in the hand.

The physiology places this function partly in the parietal association cortex.

It appears from the histology that fusion results from the activity of special binocular neurones. These have only been traced as far forward as area 18. The behavioural evidence shows a flexibility in this function, suggesting that the images, within known limits, can be adapted cortically to each other. This function appears more psychological than physiological. Its flexibility can be measured and was the basis of one of the experiments set up to isolate and measure a non-visual variable.

Binocular vision is seen to be an on-going process in which the reactions to the bi-retinal input are probably handled more physiologically than psychologically in the lateral geniculate bodies and the occipital cortex.

From area 18 forwards the two electrical pictures undergo considerable monocular modification or inhibition, and a final assembly of the two into one visual percept is probably made in the parietal cortex. Evidence supporting this conclusion and its significance is given in Chapter 3.

CHAPTER 3

THE EEG RESEARCH

The Purpose of the Research

It is basic to this thesis that the function of creating one visual percept from two retinal inputs is dependent on three processes, the motor alignment of the eyes, the central organisation which summates the two inputs and the process of inhibition which removes parts of images which are not fusible.

Data was presented in Chapter 2 showing that the first two functions are controlled from Brodman's areas 18, 19 and probably 22 of the cerebral cortex.

The selection of one image which is in a state of total rivalry with that of the other eye and has to be inhibited is shown to be possibly a function of the hippocampus.

The literature does not indicate in any way how the function of suppression of one image takes place when the two eyes are not accurately aligned to the same point of the target, such as in saccadic movements, or in a child with a squint. In this situation, both retinal images are the same, and hence no process of psychological selection is required, the identical images are in a state of diplopia.

The EEG programme was undertaken in the hope that it would throw some light on the process of non-fusion, as in a child with a squint for no visual reason, or the process of suspension of an image required for normal single vision.

The physiological significance of the EEG is described by

Nelson (1968). In order to make clear the significance of the findings of bursts and runs of theta and delta frequencies in these cases the normal EEG of children is described.

The Normal EEG

The development of the EEG from birth to maturity appears as a steady increase in frequency in the waves recorded. Below the age of three years delta rhythm with frequencies of 3.5 hz and under are mostly found. Up to the age of eight, theta rhythm with a frequency of 4-7 hz dominates the record, and its amount may be used as an index of maturation. The alpha rhythm, with a frequency of 8-13 hz then becomes dominant when the eyes are closed.

A small amount of beta rhythm of frequency 14-30 hz is present in the normal adult EEG. The voltage is lower than that of the alpha wave and it does not block with mental activity and imagination.

Murdoch (1974) reviews the experimental evidence showing the increased frequency with chronological age in great detail. The figures given in Table 3.1 which are extracted from his data, show the change of frequency in the developing child.

Table 3.1

EEG frequencies found with increasing age

Authority	Date	Age of Children	Frequency Hz.
Berger	1932	0-35 days	1-6
Walter	1950	0-1 year	1-3
Henry	1944	0-2 years	4-6
Walter	1950	2-5 years	4-7
Walter	1960	Above 6	8-13
Lindsey	1936	8-10	8-13

During this period of development the EEG will demonstrate its dominant frequency, but there will be irregular and usually bilateral appearance of the lower frequencies.

In [illegible] normal EEG, the rhythms which are recorded from electrodes placed symmetrically in pairs either side of the head, appear with such remarkable similarity that a change in the wave which is unilateral is always an indication of abnormality. This, and the appearance of the delta, theta and beta frequencies, in an amount larger than normal, and EEG waves which instead of having a sine wave form are spiked in shape, are abnormalities which were found in the recordings of patients with abnormal binocular vision.

Suppression Ambliopia

Suppression ambliopia has been described in Chapter 2 of this thesis as a binocular state wherein one eye has a central scotoma, which is only present when the other eye is seeing. This occurs when fusion of the two eyes is not possible such as in a squint, or when the two retinal images are so dissimilar as to be not fusible, then the central retinal input of one eye is firstly suspended and later permanently inhibited.

The EEG of patients suffering from this condition was investigated by Dyer and Bierman (1950, 1952) working in America. They demonstrated spikes and bursts of high voltage delta and theta waves in the parietal and occipital cortex. They showed the highest incidence in 39 children between five and 12 years of age 32 having abnormal EEGs. Of all their cases of abnormal binocular vision [illegible] per cent had abnormal EEG recordings.

Parsons-Smith (1953) working in London demonstrated abnormal EEG waves in the records of children with suppression ambliopia. Of 50 cases he showed that 12 had normal EEGs, eight had spike waves, 21 had high frequency waves of 18-22 hz, and also waves with a frequency varying from two to seven hz. Two cases only are mentioned as showing waves with a frequency of 5.5 hz per second in the parietal lobe.

Dyer and Bierman and Parsons-Smith were interested in the abnormality from a clinical point of view, from a research approach it seemed possible that an indication of the location of the function of suppression might be found if the appearance of the abnormality could be related to a particular pair of electrodes.

It was also believed that these results might be of clinical diagnostic value to the orthoptic therapist, and this justified the experiment ethically.

Cases of abnormal binocular vision were chosen from the author's practice. Those selected had no motor abnormality such as squint, and no abnormality of fixation. The cases were screened by an ophthalmologist as free from ocular pathology, and there was no medical history of cranial trauma or pathology. The recordings were made on a Gallileo E.8 B machine.

The purpose of the EEG was explained to the patient or their parents, and in no case was the recording declined. An examination of these first EEGs showed that they had one abnormality in common, bursts or runs of high voltage delta and theta waves, mostly localised but sometimes diffuse.

The nature of these abnormal recordings may be seen by comparing the EEGs of a normal child with that of a child presenting suppression ambliopia (Figs. 3.1 to 3.4).

The first EEG (Fig. 3.1) was recorded from a healthy youth of 18 years. This shows a normal alpha of frequency 10 hz. The almost exact symmetry between the right and left recordings from the parietal lobe should be noted. The EEG in Fig. 3.2 shows the same recording from a female aged 20 with abnormal binocular vision. The abnormality is bilateral and consists of delta high voltage waves.

The next EEG (Fig. 3.3)shows a recording from a normal child aged nine where the cortex is not yet mature in electrical terms. The underlined parts of channels 3 and 7 show some theta waves and some bilateral differences.

The EEG in Fig. 3.4 shows the same recording from a boy aged 10 with abnormal binocular vision. Channel 3 shows slow waves with high voltage which do not appear as clearly in channel 7.

The recording of these delta and theta high voltage waves in the cases of binocular abnormality raises the possibility of a maturation defect involving mostly the parieto-temporal cortex.

Having found this abnormality in five records of cases where visual inhibition was thought to be the cause of the low visual acuity, the sample was extended to include cases where the cause was known, but not the same. The final sample included the following :

Cases where there was full visual acuity in both eyes, some fusion, but for reasons not known there was occasional suppression. These were mostly found clinically through subnormal convergence.

Cases where the visual acuity was subnormal due to a high monocular refraction error.

Cases of strabismus, of non-paralytic origin.

Cases of strabismus of paralytic origin.

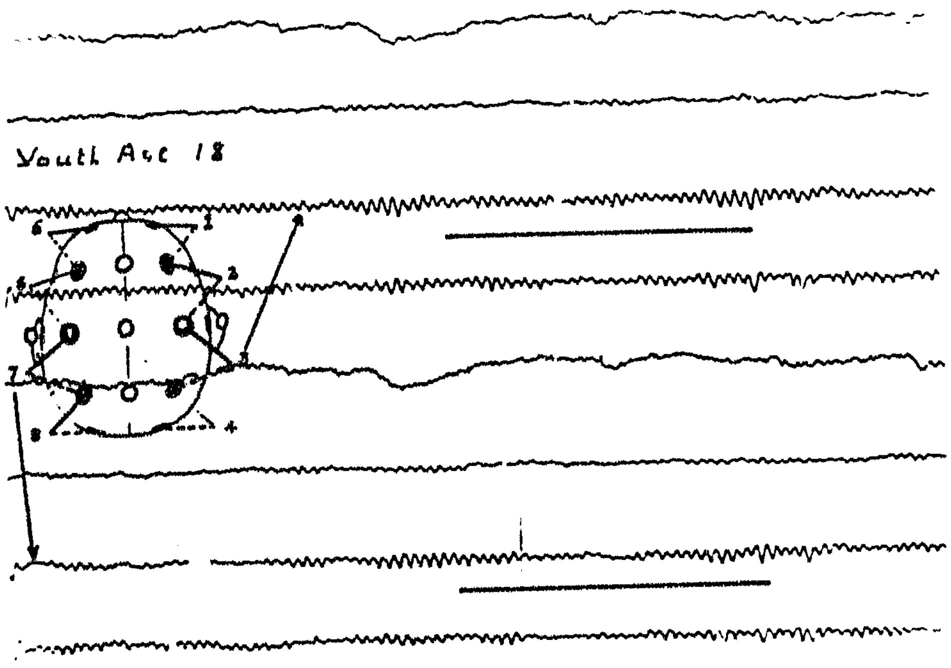


FIG. 3.1

EEG of a healthy youth aged 18 years

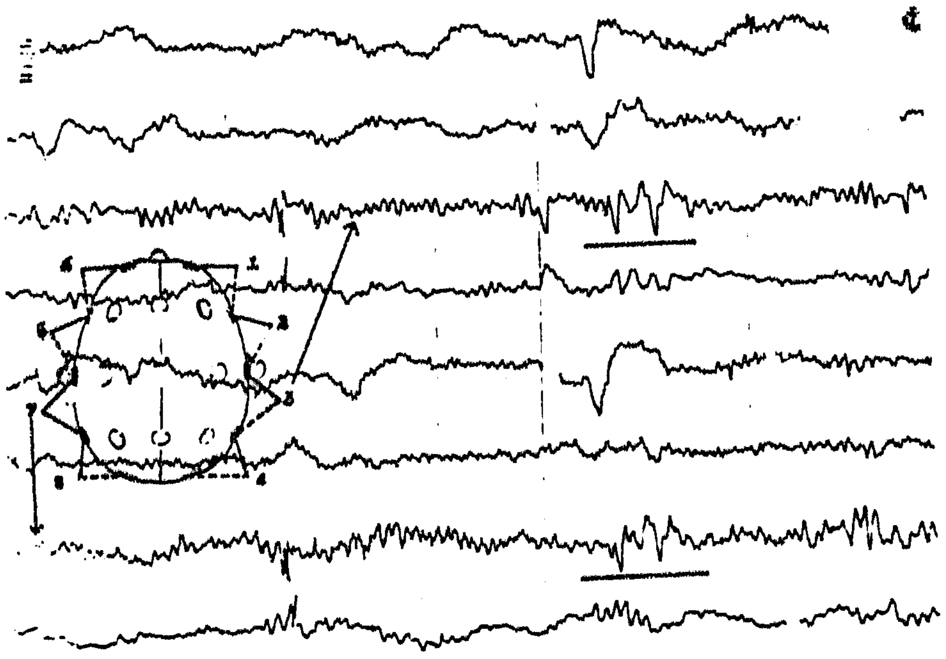


FIG. 3.2

EEG of a female aged 20 years with abnormal binocular vision

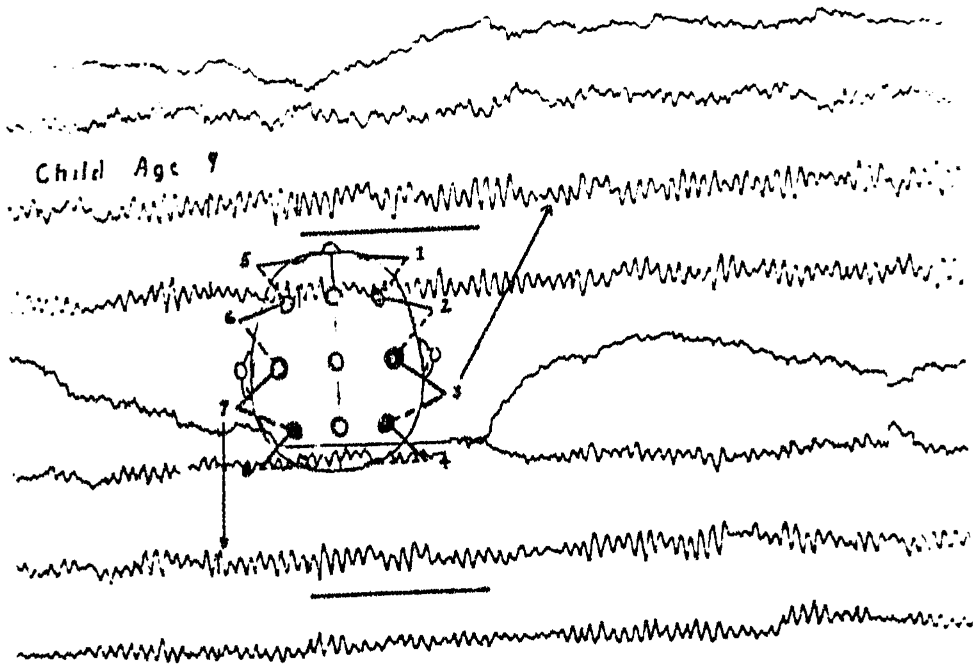


FIG 3.3

EEG of a normal child aged 9 years

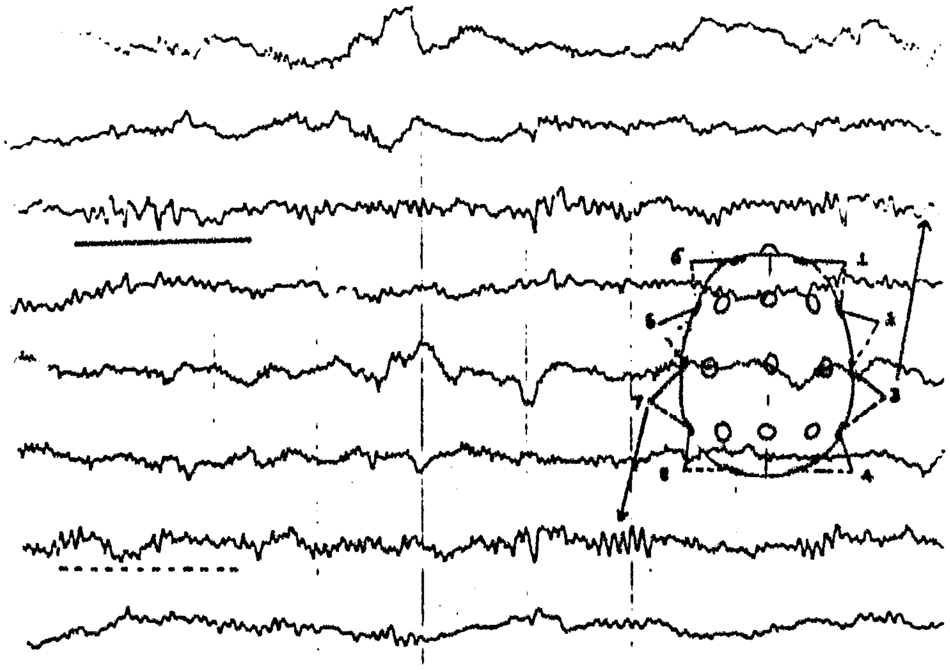


FIG. 3.4

EEG of a boy aged 10 years with abnormal binocular vision

The recording of these delta and theta high voltage waves in the cases of binocular abnormality raises the possibility of a maturation defect involving mostly the parieto-temporal cortex

The Distribution of the Abnormality

Of the 34 cases recorded, two females and two males exhibited spikes in the temporal and parietal cortex, one female aged 20 had a very large amount of beta activity in the parietal cortex.

The location of the high voltage delta and theta waves demonstrated by 29 cases is given in Tables 3.2 and 3.3. As some of these cases demonstrated both delta and the theta waves, the number of cases is greater than 29.

The concentration of abnormality in the tempero-parietal cortex is shown in Figs. 3.5 and 3.6 drawn on the surface of the right and left cortex. The method of scoring was as follows:

If the concentration was in one location only that area of cortex was marked with three dots. If it was spread slightly outside the area, two dots were marked on the main locality and one in the area where fewer bursts or runs were recorded. If the locality spread over the temporal, parietal and occipital cortex, one dot was allocated to each area.

If the locality was shown to be fronto-temporal, or upper parietal, the dot was moved in that direction.

The result shows the concentration in the tempero-parietal cortex.

Table 3.2

Distribution of EEG abnormality by frequency of the abnormal waves.

R. Hemisphere		Left Hemisphere	
Frequency Hz	No. of cases	Frequency Hz	No. of cases
1	2	1	1
2	8	2	6
3	10	3	7
4	10	4	6
5	7	5	5
6	7	6	5
7	2	7	4

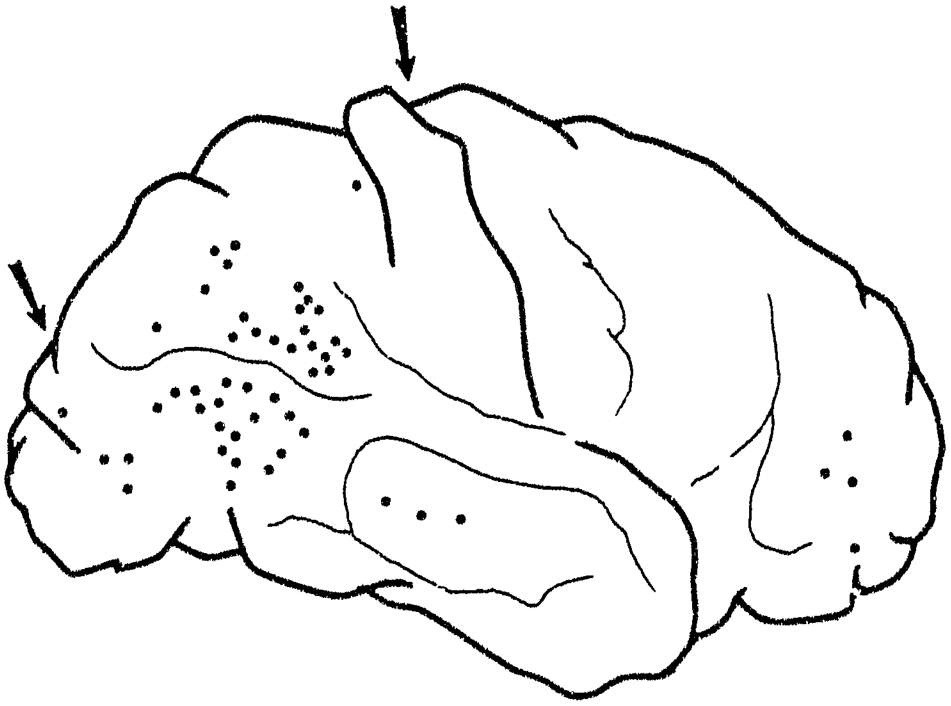
Diffuse, having no laterality

Hz	No. of cases
1	Nil
2	1
3.	3
4	3
5	2
6	3
7	1

Table 3.3

Distribution of EEG Abnormalities

R. Hemisphere		L. Hemisphere	
	No. of cases		No of cases
Parietal	10	Parietal	5
Temporal	14	Temporal	7
Occipital	3	Occipital	3
Diffuse	1	Diffuse	0

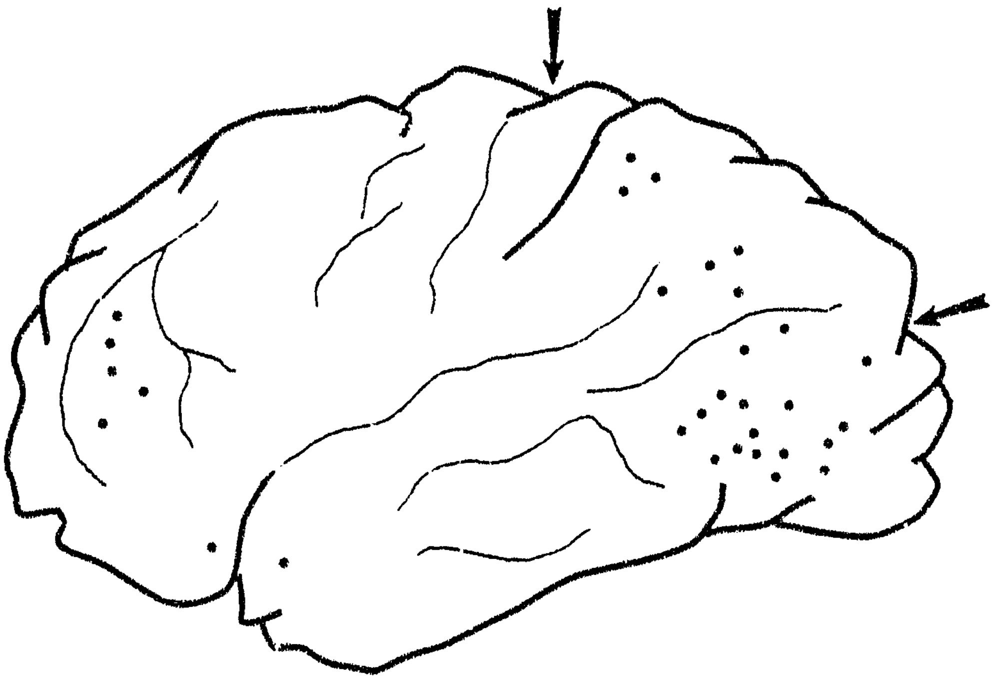


R LATERAL

Distribution of abnormality on the right and left lateral surfaces of the brain.

The arrows mark the margins of the parietal lobe.

FIG. 3.5



L LATERAL

Distribution of abnormality on the right and left lateral surfaces of the brain

The arrows mark the margins of the parietal lobe

FIG 3.6

A comparison was made between the abnormality of the vision and the EEG. A comparison of the laterality is given in Tables 3.4 and 3.5.

Table 3.4

Comparison of Visual and EEG Laterality

Laterality	No. of cases
Both right	7
Both left	3
EEG R. vision left	2
EEG L. vision right	4

Table 3.5

Comparison of laterality where one abnormality was bilateral

Visual abnormality	EEG				
Alternating	R	6	L	4	Diffuse 1
EEG Diffuse	Visual abnormality				
	R	2	L	2	Alternating 1

A scattergram (Fig. 3.7) shows the relation between the amounts of the EEG and visual abnormality. It can be seen to be completely scatter, there being no agreement between these two ratings.

This is consistent with findings in other fields such as recovery from intra-cranial trauma where the improvement of behavioural disturbance bears no relation to the amount of EEG disturbance.

	Low	Medium	High
Slight	●		●
Mild	●●●	●●●	●●●●●
Moderate	●	●●●●	●●●●●
Abnormal	●●●		●●●●
Severely Abnormal			●●

Scattergram relating the amount of abnormality in the Binocular Vision to the amount in the EEG record.

FIG. 3.7

Visual examination of the results showed that there was one type of EEG abnormality and one visual condition common to all 29 cases, that is the high voltage delta and theta activity in the EEG and an inhibition of the vision of one eye to avoid double or blurred vision. In this regard, the similarity of the EEGs of these binocular abnormals to those of minimal cerebral brain dysfunction is discussed later.

Except for the majority of cases which have delta and theta waves and a tendency for them to concentrate in the parietal cortex, there is nothing in common between the EEG record and the disability.

As we had hoped to find some diagnostic value in the EEG's and also to guard against the possibility that the sample was unique, with the kind co-operation of Drs J. Swartz, the senior ophthalmologist at the Children's Hospital, the Superintendent and the Professor of Ophthalmology, Professor Luntz, EEGs were recorded from 18 children with suppression ambliopia. Two of the recordings had no delta and theta activity, but had spikes in the occipital lobe. The 16 cases with slow waves were classified as follows :-

Males 10
Females 6
Frequency 4 demonstrated abnormal delta rhythm
12 demonstrated abnormal theta rhythm
5 cases were rated as abnormal
10 cases were moderately abnormal
1 case was slightly abnormal.

The distribution of the abnormality is shown in Table 3.6 and Figs. 3.8 and 3.9.

Table 3.6

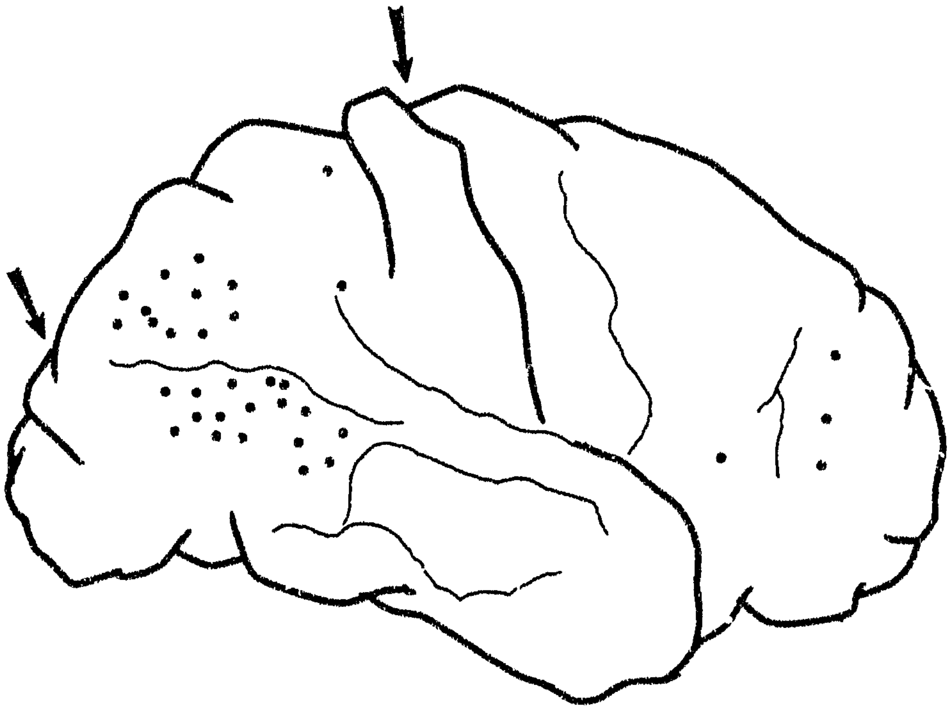
Location of abnormal EEG waves

Parietal	12 cases
Temporal	6
Occipital	5
Bilateral	3
Diffuse	1

The laterality of the EEG abnormality was 9 R
3 L
4 Bilateral

There was no agreement between the data for these children except that the 18 were all cases of suppression ambliopia, and 16 of them demonstrated the same type of low frequency high voltage runs and bursts mostly in the parietal-temporal cortex shown in 29 of the EEGs of the cases from the Benoni practice.

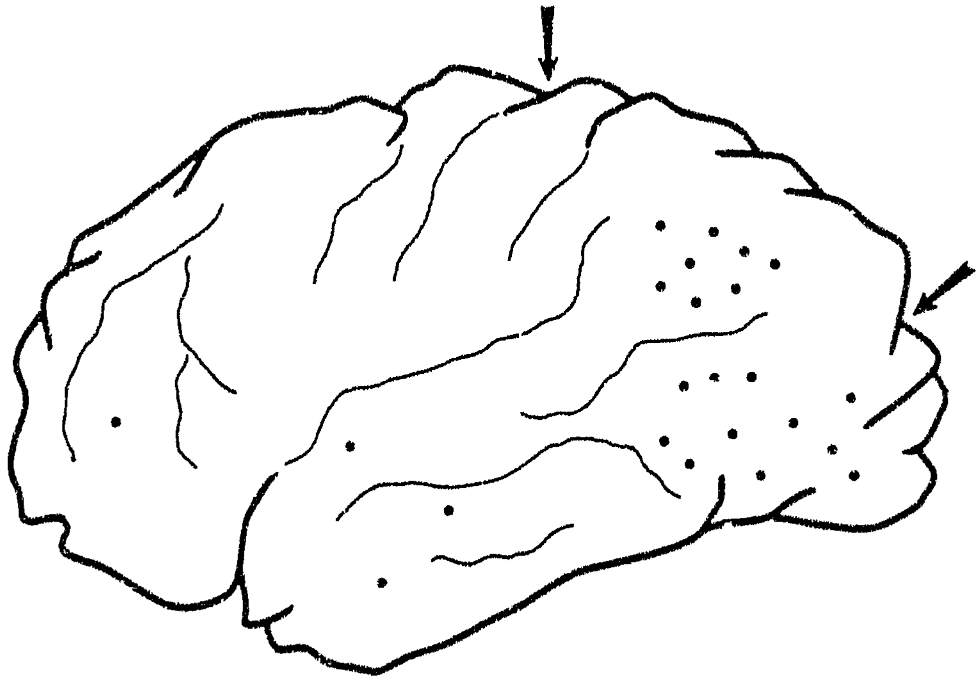
The importance of this research to the thesis is the establishment of a process of inhibition, peculiar to binocular vision which is located well forward of the visual cortex. This cortex is known to contain inhibition bands which affect learning and the significance of the fact is now explored.



R LATERAL

Distribution of abnormality on the lateral surfaces of the brain.
The arrows mark the margins of the parietal lobe.
Sample 16 children from the childrens hospital.

FIG. 3.8



L LATERAL

Distribution of abnormality on the lateral surfaces of the brain.
The arrows mark the margins of the parietal lobe.

FIG. 3.9

Discussion of the Literature and the EEG Research

In Chapter 2 it was shown that areas of the parietal cortex were involved in the production of single binocular vision. These are given in Brodman's areas 18, 19 and 22 and anatomically the marginal and angular gyri are named as being the major areas responsible. These deductions are strongly supported by the EEG research.

An examination of the function of this area of cortex reveals that it is concerned with children who have problems of association.

Tuller and Eames (1966) found a high proportion of delta and theta frequencies in this area in children with reading disability.

Similarly Capute _et al_. (1968) found slow activity in the post-temporal cortex in a greater amount in their sample of children with minimal cerebral dysfunction, than in their control sample of normal children.

Hughes and Myklebust (1971) recorded slow waves in the temporal cortex which were associated with non-verbal deficiencies in learning, and Satterfield _et al_. (1974) found 11 per cent of their children with learning problems had similar slow waves.

Murdoch (1974) compared the EEGs of 35 children at a school for remedial education with the same recordings made eight months later, and showed that as the children improved in their reading, so the EEG changed towards normal.

Comparing this sample with a carefully matched control group he showed a more frequent appearance of abnormalities in the EEGs of his children with minimal cerebral dysfunction than in the records of the normal children (Table 3.7).

Table 3.7

Comparison of the EEGs of normal and learning retarded children

	M.C.D		Control	
	Present	Absent	Present	Absent
Theta	32	3	22	13
Delta	32	3	22	13
Sharp waves and spikes	19	16	7	28

While Murdoch found more spike and sharp waves in reading disabled children than in the control group, there was a greater difference in the amount of low frequency waves most of which were in the parieto-post temporal cortex.

It may be significant that the inability to learn to read is sometimes referred to as a learning block suggesting some function of inhibition during the learning process. In this sense it is similar to suppression ambliopia which is an irreversible visual inhibition in binocular vision located in the same area of cortex.

Conclusions

Considering the whole process of unification of the two retinal inputs, there is evidence that :

(a) The two images are examined individually as to the possibility of fusion, and when not fusible one is inhibited. The process was shown to be largely psychological.

(b) If the images are fusible within certain limits, they are adjusted to each other so that fusion can take place. This process again appears more psychological than physiological.

(c) An individual control mechanism for binocular movements has evolved which is not in the normal movement control area of the occipital or the frontal lobe.

(d) Examination of the binocular as compared with the monocular thresholds indicates that this unification act is more an assembly of sensory data which has been previously processed than a physiological summation.

(e) The cortex carrying out functions (a)-(b) and (c) is not in the occipital lobe, some is far removed, probably in the hippo campus, the balance being carried out in the parietal lobe.

(f) This is association cortex where learning from sensory input takes place. Its well-known function is to associate the inputs from two different senses such as the sight of a hand striking a bell and the sound of the bell. It would be consistent with general neuro-histological function to find that this cortex which carried out this act would also unify the two pre-conditioned retinal images.

The acceptance of these statements is sufficient basis to assume that there will be variables of non-visual origin in binocular behaviour, indeed it was shown in the review of the literature that several experimenters had demonstrated their existence, but did not attempt to explain their origin.

The reader will have noticed that nowhere in the review of the literature is there mention of any relationship between binocular optometric measurements and personality variables.

A few relations have been observed and some measured between binocular functions, such as the seeing of spacial distortion, and psychological rigidity, but a measurement of the binocular function has not been correlated with the psychological behaviour.

The author believes that no such correlations have been established, and that the work presented in this thesis covers a new field of research. Support for this statement is given by Bartley, 1971. In his Charles Prentice invitation lecture to the American Optometric Association, Howard Bartley, a Professor of Psychology, described seventeen areas where both psychology and optometry are involved in the same field of research. Excluding stereopsis, binocular vision is not mentioned.

The writer presented to a project committee of the Institute a summary of the literature and his own personal observation from clinical and research work that there is considerable difference in performance between subjects on most of the aspects of binocular vision, which variability cannot be accounted for by visual differences between the subjects.

The writer pointed out that while there was considerable evidence as to the processes which lead up to unification, there was only a small amount of behavioural evidence as to the nature of the unifying process.

He stressed the difficulty of the research programme, which might require searching the whole field of psychology for significant correlations with binocular vision.

As some of the optometric work had already been done, the writer was able to state that he was certain that the binocular non-visual variables could be isolated and measured, but that only an organisation such as the institute could set up the programme of psychological research which would be required.

The representatives of the institute were unanimous that this was a worthwhile area of research and two programmes were set up, the one to improve the measurement of the non-visual variables, and the other to attempt to discover something of their nature by finding significant psychological correlations with them.

CHAPTER 4

THE DESIGN OF THE BINOCULAR EXPERIMENTS

The design of the binocular battery was determined by two considerations:

1. Previous clinical and experimental knowledge offered five methods of approach to the problem of isolating the non-visual variables.

2. The psychologists requested that the optometrists should design binocular experiments where the function would be frustrated by some factor which could be introduced in such a way that it was a parallel to the frustration tests used to measure aspects of psychological rigidity. It was thought that these scores might correlate significantly with similar tests done monocularly such as the Thurston repeated letter tests. The clinical facts indicating non-visual variables in binocular vision could be divided into four groups. These were:

1) There were established clinical methods for measuring binocular functions. Examination of these methods showed that the end point was often uncertain and the subject's performance varied with the instructions given to him. These methods had to be improved so that they gave reasonable test-retest reliabilities when their scores could be used for statistical analysis.

2) Proposals were advanced that the binocular measurements would vary under certain conditions such as increased motivation, and experiments had to be designed which would test this.

3) There were steroscopic tests which could not be done by some visually normal students. A programme had to be set up to find the variable

in these tests and to establish if it was related to binocular vision or to steroscopic ability.

4) It seemed possible that one of the tests of retinal rivalry could be adapted so that it measured the ease in which a subject went into a rivalry state from a fusional state.

Measuring the Fusional Reserves

Binocular fusion has been described as a process which requires that two, almost identical stimuli be presented to areas of the right and left retinas which are near corresponding. A fusional compulsion then causes the eye to move so that the two images are aligned on corresponding retinal cones and one percept is then formed from the two images. When fusion has taken place, a mechanism comes into being which moves the eye so that fusion is not destroyed, and this elasticity of movement can be measured. It is this control in the interest of retaining single binocular vision that is termed a Fusional Reserve (F.R.). The F.R's are classified in accordance with the direction in which they are measured, in convergence, positive, (P.F.R.) in divergence negative, (N.F.R.) one eye above the other, hypervergence or vertical (V.F.R.), and cyclo-vergence (cyclo-rotation) a rotation of the eye about the optic axis.

When fusion is measured, it is necessary to know that the two images have been fused and one has not been inhibited. This is done by the use of controls. If two letters E are fused, there is no way of knowing if they are fused or one suppressed, but if T E and E N are fused into T E N, then the perception of the T and the N shows that neither eye is suspended and therefore the E's are fused. The E is then referred to as the fusional lock and the outside letters, the controls.

The measurement of the fusional reserves is taken by displacing one image until diplopia results (the break point) and by reducing the displacement until fusion is re-established (the recovery point). In addition in the P.F.R. a point is sometimes reached when the effort of convergence causes accommodation to take place, so that the eye becomes pseudo-myopic and the image becomes blurred. This is known as the blurr point. It is difficult to measure with any degree of accuracy.

It is well-known clinically that the fusional reserves vary considerably between subjects. There may be visual reasons for this, for example, a marked difference between the R and L eye refractive errors brings with it a binocular instability and low fusional reserves, (Gibson, 1955) but low reserves may be recorded from subjects with no visual reason for the subnormal recording.

There are two main factors which govern the amount of fusional reserve in terms of the stimulus, its contrast with its background and its size. If these are raised, the F.R. is raised, if they are reduced the F.R. is reduced.

In terms of the psychological state, it is thought that the P.R.F. is higher in tension states and the N.F.R. higher when the subject is relaxed. It is also thought that all the reserves are higher with motivation, but

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A description of the fusional reserves and their measurement is available in detail in any text book on clinical orthoptics. (Giles 1945. Ch. 10 Lyle and Jackson 1953: Gibson 1955). Unfortunately no standard method of measurement has been agreed upon, and various schools prefer different methodology.

there are no published papers confirming these generally held clinical beliefs.

In addition to these variables, it is known that the F.R.'s fall off if one eye is blurred (Ogle, 1950) and it was thought possible that the amount of fall off might be due to psychological rigidity and not a visual variable. The difficulty in arriving at this figure with an accuracy sufficient to produce significant correlations is the lack of an accurate standard test for the fusional reserves. It was therefore decided to investigate this problem and design an improved test.

Designing a Fusional Test

The principles followed in designing a fusional test which would measure its strength accurately were:

1) Binocular vision requires a fusional lock, some stimulus brightly contrasted with its background, away from the macula, as macular fusion has little strength.

2) A foveal indicator is necessary to show that fusion has broken. When fusion first collapses, one of the two diplopic images must separate by an angular distance of some three Prism Dioptres (Pr.D.) before the diplopia is reported. As the fall off with fogging may be much less than 3 Pr.D. this inaccuracy had to be eliminated.

A binocular lock had already been designed, and was incorporated in a piece of equipment used for investigating the stability of binocular vision called the Turville Infinity Balance Technique (Turville, 1946). This lock consists of a narrow black rectangle about nine inches square on a white background. It was thought that an illuminated square would be better than the black on white and this was designed.

The problem of the foveal indicator was met by shining a bright light along a tube. At the end of the tube was a red celluloid filter.

The apparatus was constructed as Fig. 4.2.

A box was made 2.20 cm square inside measurement. Inside this box a small box was fitted with an outside length of two inches. Inside the larger box, and at the back of the smaller box a 15 watt lamp was mounted. A sheet was fitted over the front of the larger box, and drilled in the centre with a 1 cm hole. In the back of the smaller box a hole was drilled at the middle and a tube press-fitted so that its base was in alignment with the hole in the milk plastic front of the outer box and its end approximately 1cm away from the inner surface of the front. This end of the tube was covered with an Ilford red celluloid filter.

This apparatus provided an illuminated square, of a brightness which was in marked contrast to the darkened room, but not too bright for long observation. The inner area of the illuminated space was absolutely black, and in the middle of this square, a small red light shone brilliantly. This target was viewed through a refractor head with the two rotary prisms in place (Fig. 4.1). Prism was introduced binocularly in equal amounts until fusion collapsed. When this happened, and sometimes before the square was reported as double, two red lights were seen inside the square. The apparatus appeared to meet the requirements in that it provided a fusional lock and a foveal indicator.

When the test was put into use, difficulty was found in measuring the recovery point. This can best be explained by reference to the TE EN test already described. Clinically the slide is most useful, and the type of

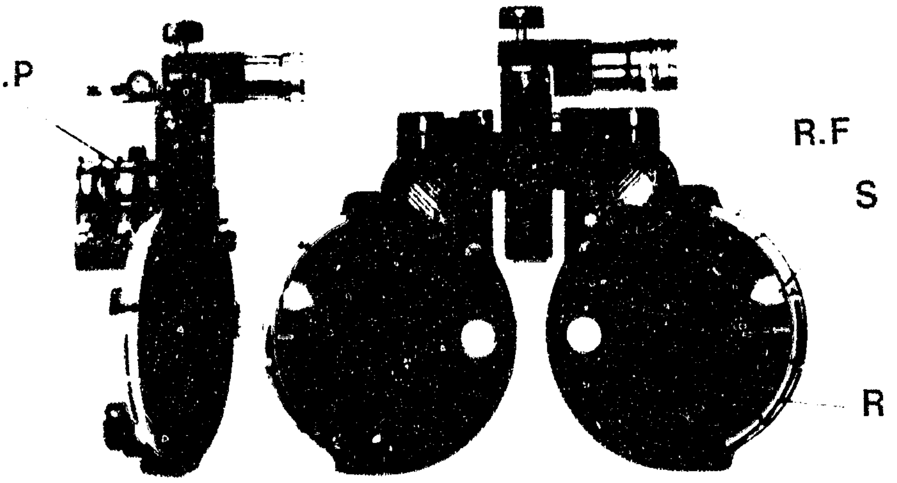


Fig. 4.1 - The refractor head used for the experiments. Plus sphere is introduced in 0.25 D steps by rotating the disc marked R downwards.

The red filter used in the retinal rivalry tests is introduced by moving the selector (S) to the position marked R.F.
The fusional reserves were measured with the rotary prisms marked R.P.

measurements taken, is sufficiently accurate. At the end point of a positive fusional reserve, the eyes diverge and the letters are seen to separate and cross over to form the order E N T E. When the tubes are diverged (towards parallel) to measure the recovery point, the letters E N approach T E and in clinical practice this is done fairly fast, so that the letters cross each other and the E's again fuse to TEN. If the letters are approached slowly, the upright of the N sometimes fuses with the upright of the T and normal recovery does not take place.

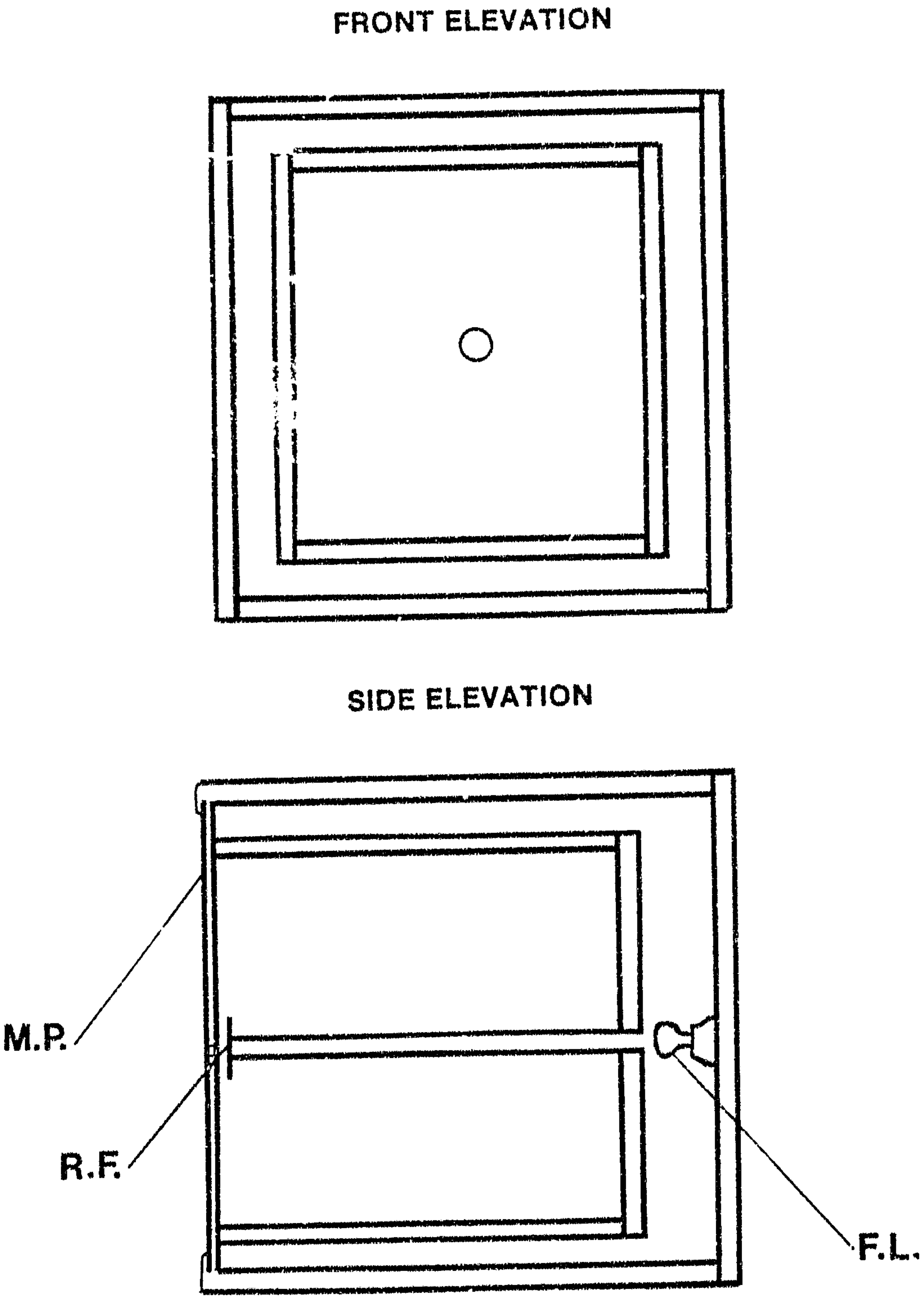
It was discovered that the box sometimes gave the same reaction as the TEN test. When the two images were made to approach each other with a view to effecting recovery, the L side of box (a) fused with the right side of box (b) and prevented refusion (Fig. 4.3).

This was overcome by using a cross as a target. Considerable research and many trial models were made before an acceptable target was designed. Its final design is shown in Fig. 4.4. The rectangles are illuminated through milk plastic, the centre circle through a red filter. The central non-illuminated area was wide enough to allow the centre dot to be seen in diplopia when the cross began to double.

When re-fusion took place the reaction shown in Fig. 4.5 took place. The L horizontal line of cross (d) fused with the R horizontal line of cross (c) giving the result shown.

When measuring the horizontal Fusional Reserves, the fusing of a horizontal line does not affect the scores, as the fusional stimulus is the vertical lines. The fusing of the horizontal lines has the advantage that this overcomes any small vertical error of alignment.

This cross has been used successfully in the clinical analysis of fusional strength for the prescribing of relieving prisms.



Plan of the instrument developed to measure the fusional reserves

M.P.	Milk plastic
R.F.	Red filter
F.L.	Frosted lamp

FIG. 4.1

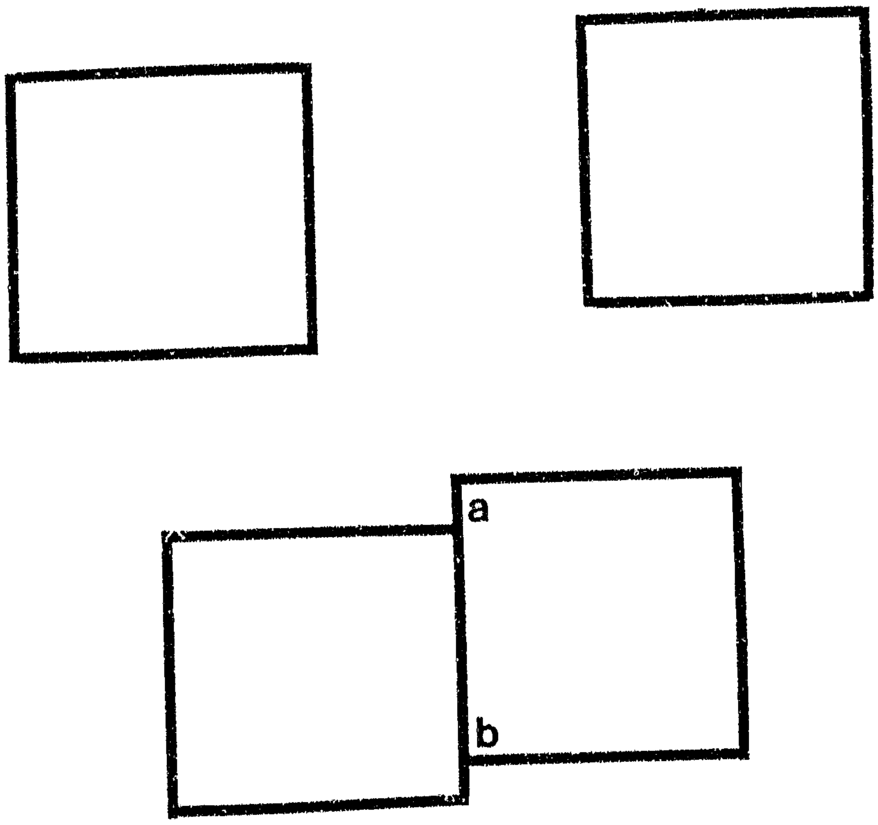


FIG 4.3

Fusion of the sides of the two squares

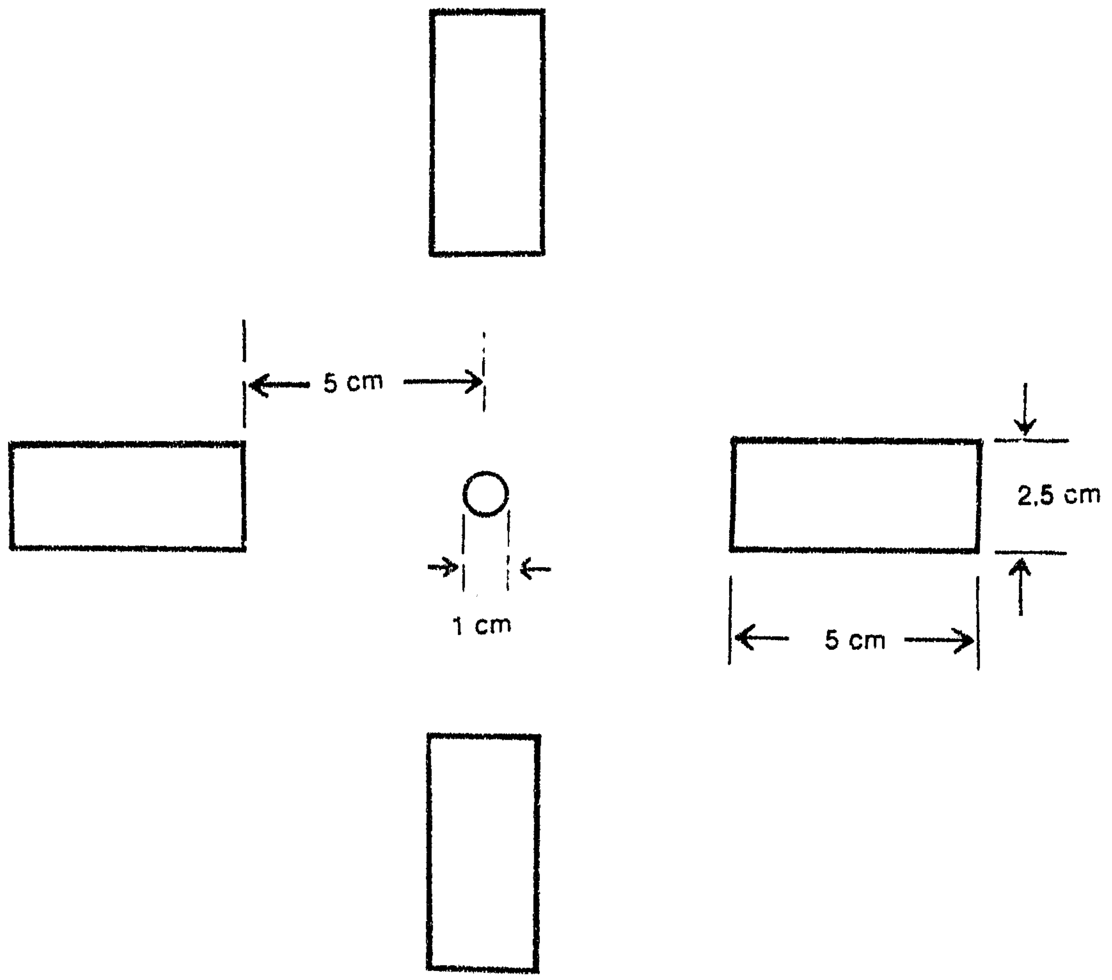


FIG. 4.4

The plan of the cross as a fusional target

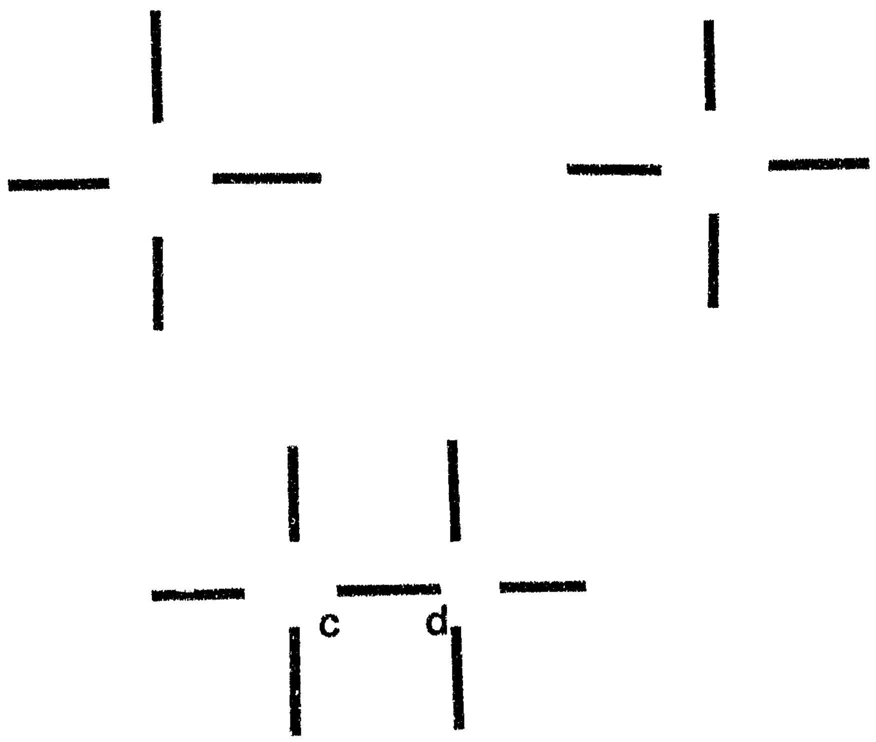


FIG 4.5

Fusion of the two crosses

Fusional Reserves from a Haploscope

F.R.'s may also be measured with a haploscope (From the greek Haplos-single). This instrument is a complicated stereoscope in which every aspect of binocular vision can be varied. The position of the individual tubes containing the targets or slides can be converged, diverged, elevated and rotated. The illumination can be increased or decreased. The width between the tubes can be increased and decreased (Figs. 4.6 and 4.7). A very large range of commercial slides is available for testing various binocular functions.

The angular subtention of the targets at the eye is much larger than the stimulus used at 20 feet and accordingly the measured F.R.'s are usually very much larger. The F.R.'s are measured with the accommodation suspended with plus lenses, but a sense of nearness usually increases the positive reserve and lowers the negative. This convergence can be measured in two ways:

(a) By using slides where a ring fits into a square so that no fusion takes place, and by noting the amount of convergence recorded, or

(b) By fusing a horizontal line with a marker above and below the line, and by aligning the two markers vertically. The excess convergence then registered is due to a sense or nearness.

This measurement can be deducted from the Positive F.R. to give the true reading.

The difficulty in using the TEN test has already been described, normal recovery not always taking place, a slide had to be found in which this reaction did not occur. There was no suitable commercial slide, but there is a slide in which a spider is placed before one eye, and its web before another. Subject is normally asked to place the spider in the centre of the web. The spider is slightly larger than the letters TEN and there is

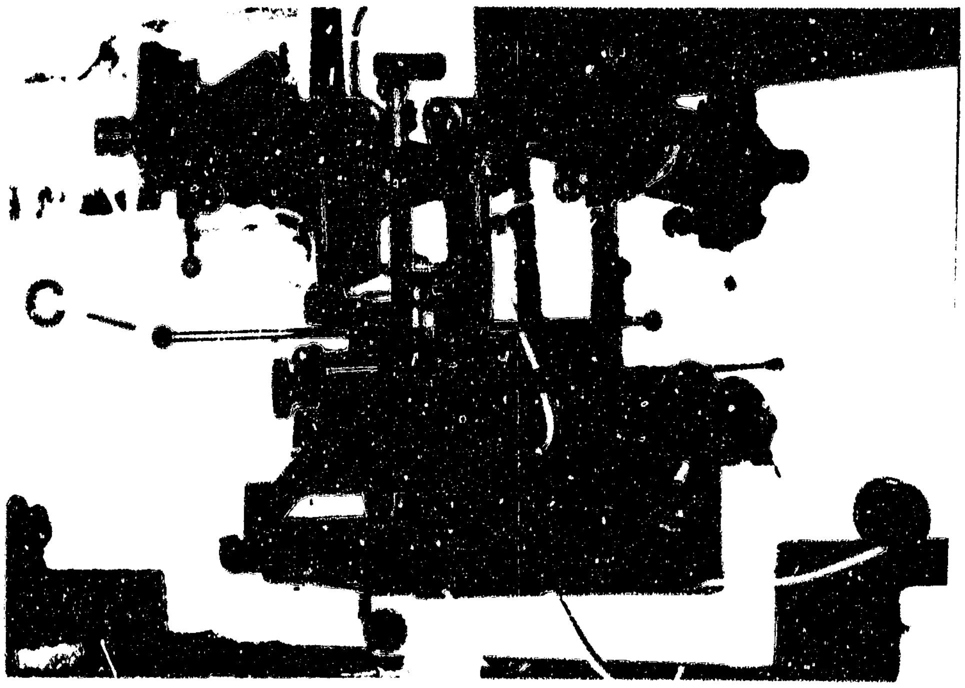


FIG. 4.6

The synoptophore as seen from the subject's side of the instrument. The tubes are converged and diverged by the handles one of which is marked C. The adjustable chin rest, head rest and adjustment for the distance between the eyes can be seen.

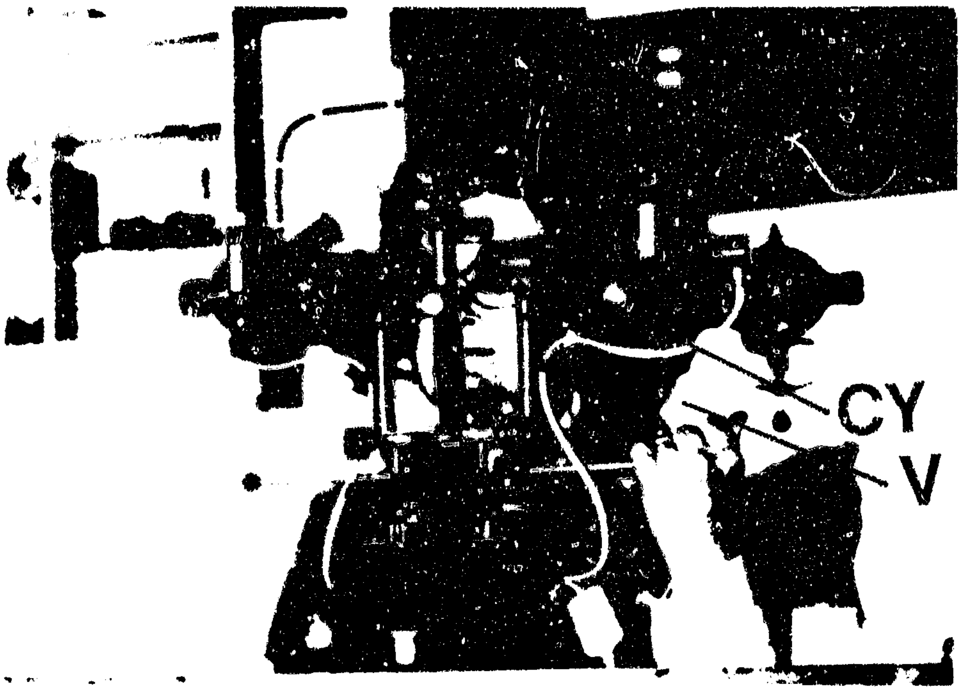


FIG 4.7

The synoptophore in use. The patient moves the convergence control to set the instrument for the position of rest. The tubes are then locked in position. The slides are rotated by the knob marked CY to measure cyclovergence and elevated and lowered to measure the vertical fusional reserve by the knob marked V.

The scale for recording the cyclovergence can be seen on the tube to the patients right, the scales which record the vertical adjustment can be seen on the operator's side of the slide holders.

no control with it, that is, if two spiders are used, the two slides are identical and the operator cannot say if the two have been fused or the one suppressed. This can be overcome by drawing large dots as controls, one to the right of the right slide and one to the left of the left slide. The fused picture is then of one spider and two dots. If suppression takes place one dot disappears. The legs of the spider provided an excellent fusional lock and this slide was used with success.

Suggestion and Motivation

Suggestion is often used in orthoptic training to improve low F.R.'s. If a child is attempting to converge the eyes on a synoptophore, the innervation can be improved by suggesting to the child that the target is getting nearer to him. If he is able to converge more, he may be able to describe a feeling of muscular movement which accompanies the effort to converge. He can be persuaded to try and increase this feeling and this sometimes results in improved convergence.

These methods were used with success with the spider target. For the first measurement subject was told to relax, to watch the target, and to report diplopia. This measurement was noted. The test was then repeated with suggestion and motivation and the measurement noted.
A score of motivational convergence could then be calculated by subtracting the first score from the second.

The Measurement of Tension

It has been noted clinically that tense patients converge more than relaxed patients. Tension and relaxation can be measured through the amount of alpha rhythm on the EEG record. This was compared with the amount of P.F.R. in relation to the amount of N.F.R.

The Cyclo-fusional Reserve

The cyclo-fusional reserve is the ability of the eye to rotate in its socket, a movement made in oblique movements of the eyes and in stereoscopic assessment of slope in the median plane. The measurement is made by fusing two lines, which have on the opposite sides of them two controls, a small cross and a small circle. The lines are then rotated in opposite directions and the eyes rotate to the extent of their reserve when they return to the primary position and the two lines open up into a cross. This measurement is much higher if the lines are vertical than if they are horizontal. The reasons for this difference have not been adequately explained and the theories put forward are very complicated. By subtracting the horizontal measurement from the vertical, a measurement can be calculated representing some binocular cortical flexibility.

The Unknown Stereoscopic Variable

An unexplained difference in stereoscopic behaviour had been noted by several clinical workers. It was also known to the University Department of Survey where apparently normal students could not see the stereoscopic maps.

The non-visual variables in these slides was isolated by presenting our large range of commercial slides to the optometry students, to selected patients, and to eight members of the staff of the neuropsychology department.

When it was found that several of the subjects could not see the stereoscopic images within 30 seconds, these slides were put on one side.

Examination showed that they could be divided into three groups. From each group, the slide which presented the most difficulty to the subjects was chosen, these were :

(a) two slides known as the "Spectrum" slides, could be seen stereoscopically by all subjects but some saw the stereoscopic picture in 15 seconds and others in three minutes

(b) two slides which had on them three rows of three coloured dolls, each doll was numbered and when seen stereoscopically the dolls formed an order from front to back

(c) two slides where there was fusion at the extreme limit of stereoscopic ability.

It was then noticed that the times taken to see the Spectrum slides divided the staff subjects into two groups, fast and slow. The actual times are given in Table 4.1.

Table 4.1

Fast and Slow Results from the Spectrum Test

Fast or Slow	Time taken to perceive the word Spectrum
F	22 seconds
F	26 seconds
F	17 seconds
F	28 seconds
S	1 minute 21 seconds
S	53 seconds
S	1 minute 17 seconds
S	Not seen

The director of the department commented that he knew of a personality difference between the two fastest and the two slowest subjects, that he regarded the fastest as very flexible thinkers and the two slowest as very rigid.

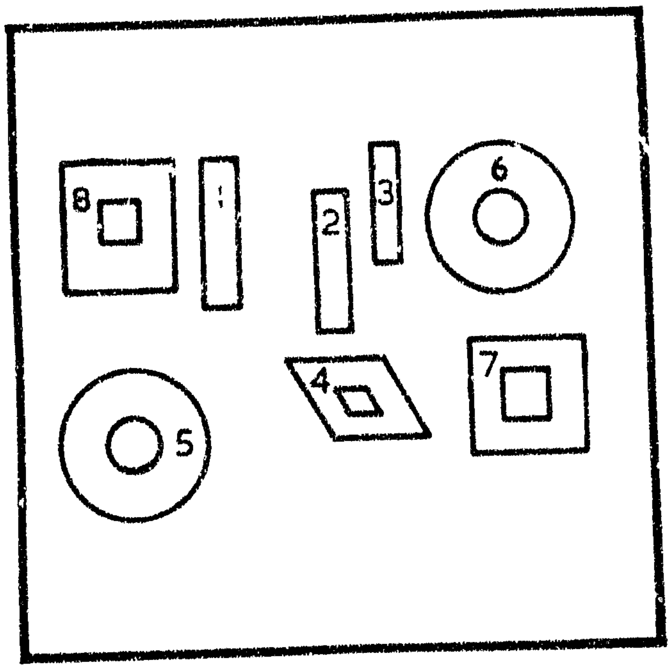
A peer rating of the subjects as to their general psychological rigidity or flexibility produced an order almost identical with the times in the spectrum test.

It was noticed that those who took a long time to see slide (a) also took a long time to see slide (b) but the ability to use the slides in the (c) group did not appear to correlate with (a) and (b). It seemed likely that slide (c) measured a stereoscopic factor and this slide was not used further, but slides (a) and (b) put no strain on stereopsis and appeared to have a non-visual factor as their variable.

It was also noted that the subjects who could see the stereo-third dimension in slides (a) and (b), had no difficulty with other commercial slides which appeared to be almost identical with them. By comparing these slides with the (a) slides a difference was found which proved to be the factor which accounted for the behavioural variation. These commercial slides consist of various shapes such as Fig. 4.8 on which there are numbers. The shapes have varying stereoscopic disparities so that they form an order from front to back and the numbers in their correct order can be read by the subject with normal stereopsis. In the slide shown in Fig. 4.8 the order is 1.3.5.7.2.4.8.6.

In the (a) type slide (Fig. 4.9) the task is similar, in that the circles form a row from the front to back and by reading the letters in the circle in this order, a word Spectrum is constructed. The production of the word is proof that the order has been perceived. Our most rigid

R. SLIDE



L. SLIDE

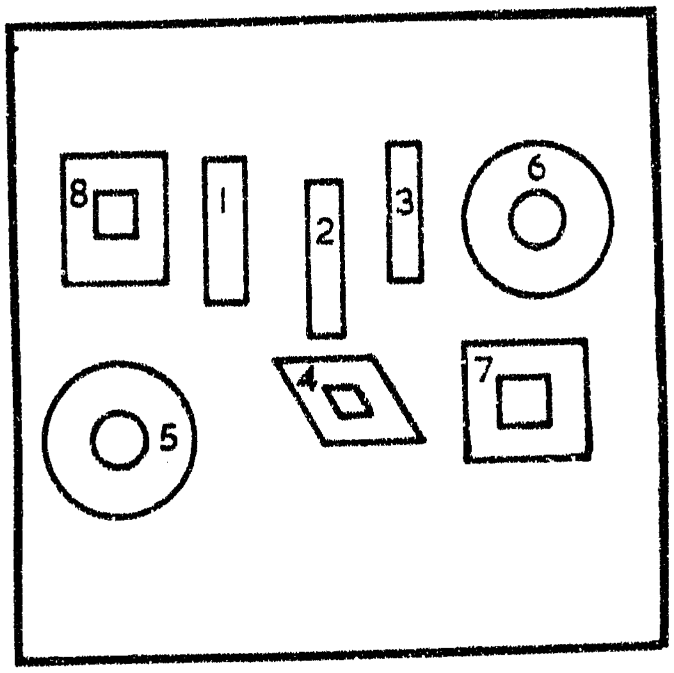
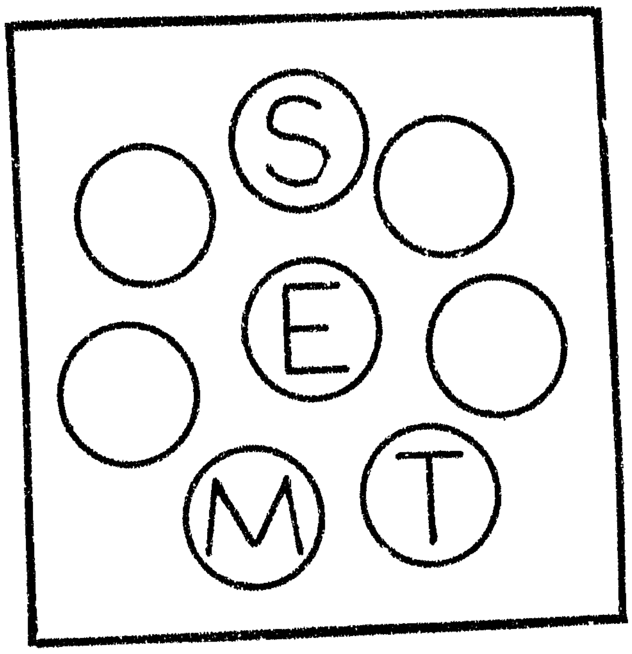


FIG. 4.8

The 21-22 Stereoscopic Slide

These stereoscopic slides are known by their trade numbers as the 21-22 slides.

R. SLIDE



L. SLIDE

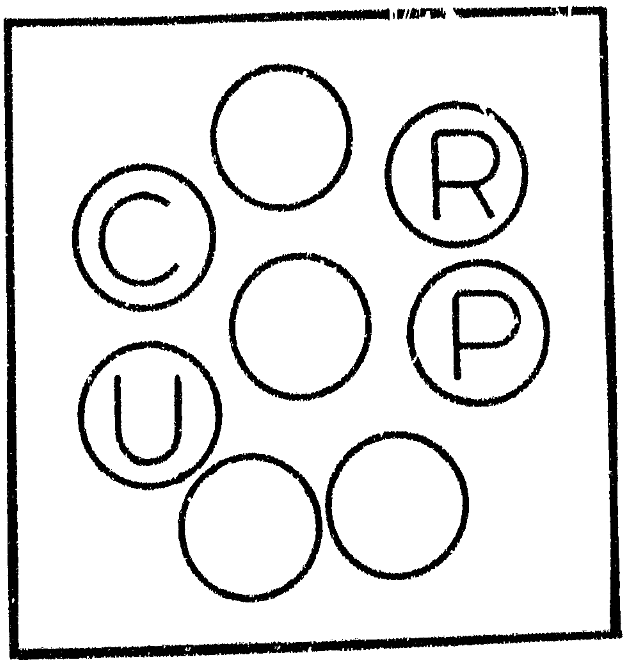


FIG 4.9

The Spectrum Stereoscopic Slide

subject could do the first slide easily, but never saw the word in the Spectrum slide. Examination of the slides shows one difference in principle, a difference which existed between all the slides found easy and those found difficult. It is the presentation of the numbers or letters monocularly or binocularly. In the slide in Fig. 4.8 the numbers are fused, as they appear on both the right and the left slides symmetrically. In the slide in Fig. 4.9 the letters are half on the right slide and half on the left slide. Consideration of this difference shows that a difficult inhibition task is set the subject trying to see the stereoscopic order in the Spectrum slide which is not present in the 21.22 slides (Fig. 4.8). If the stereoscopic perception of the letter S is considered, the visual task is as follows:-

In order to see the letter S in the right hand slide, the white centre of the left slide must be suppressed, but in order to make the stereoscopic disparity assessment, the edge of the white disc must not be suppressed. The left eye was therefore required to suppress the centre of the white disc but not its edge. It seemed a reasonable proposition that the flexible subject would do this with little difficulty but the rigid would be less flexible in arranging patterns of visual inhibition, and this might account for the failure of our most rigid subject to perform the task.

The objection to the Spectrum slide as a psychological test is that when it has once been done, the answer is known and the test cannot be repeated. For the purpose of further pilot tests, slides with other words and short sentences were made, and similar results were obtained to those from the small sample. The reliability of the test could however, not be established because it could not assumed that different words were equally easy to see. Finally, it was decided to try numbers in the form of a sum 43 x 25 x 61, which could be read out when seen. The advantage of this type of test is that if the slides are changed to give a sum 21 x 54 x 36 the likelihood of there being any difference in response from one sum to the other is small, and if the slides were made with adequate precision the difference in performing the visual part of the test is very slight. A photographic reproduction of the enlargement from which this final test was made is shown in Fig. 4.10.

The new slides were made by enlarging the slide photographically painting out the letters and painting in numbers and re-photographing the enlargement and making the slides from the new negatives.

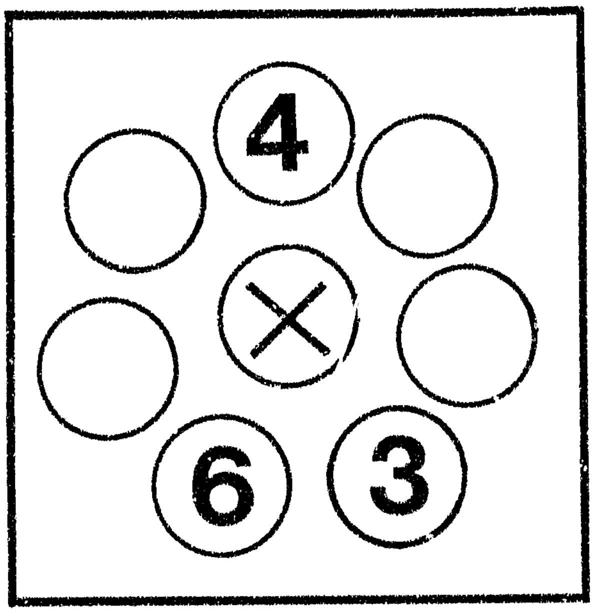
By changing the pairs of slides right and left and by using various combinations of slides, varying sums could be produced stereoscopically so that the test could be repeated.

In the pilot experiments a difficulty was encountered that some subjects hesitated because they were not quite sure what was required of them. To overcome this a model was made Fig. 4.11 which reproduced the percept seen stereoscopically. Having given the correct answer on the model, there was then no hesitation in giving the stereoscopic answer as soon as it was appreciated.

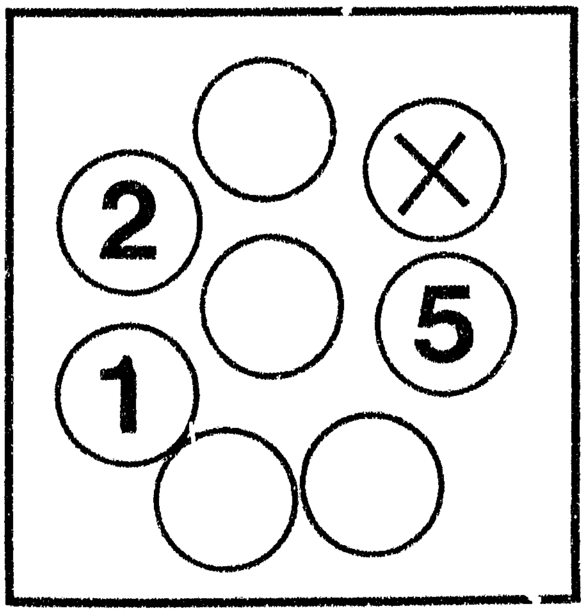
Retinal Image Size Test

The isolation of the variable in the type (b) slide was more difficult. These slides are identical right and left except for the angular disparity which produces the stereoscopic depth. In one of these slides there are nine coloured dolls in three rows of three dolls. The clue to the difficulty in seeing the stereoscopic order was provided by one of our subjects who commented that when she saw the slides without stereopsis, the

R. SLIDE



L. SLIDE



The answer seen stereoscopically front to back reads 45 × 23 × 16.

FIG. 4.10

Illustration of the slides used for the stereoscopic slide test.

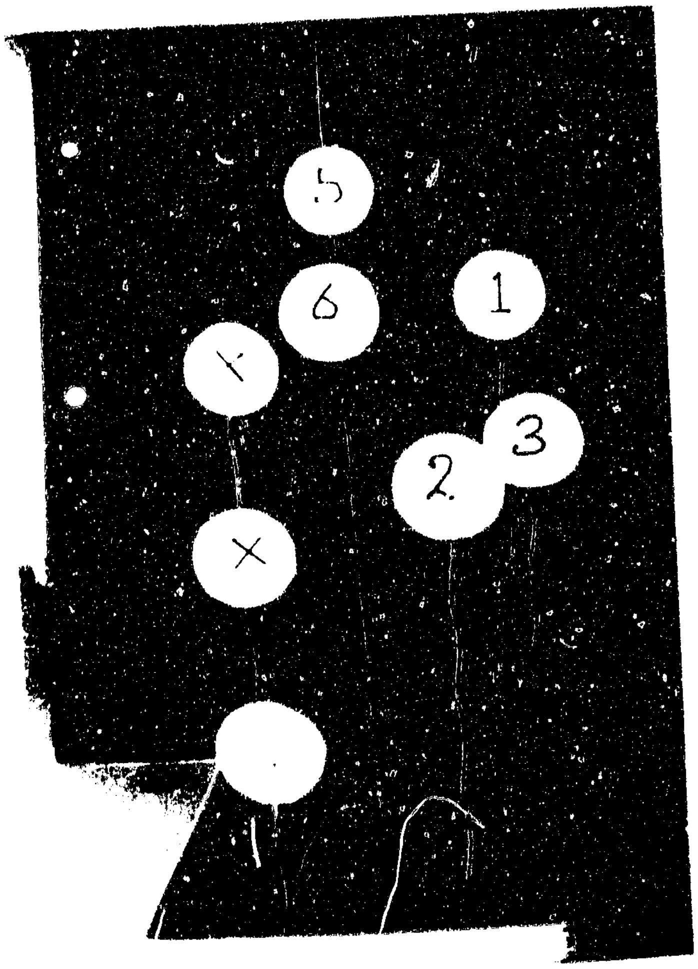


FIG. 4.11

Model to Illustrate the Use of this Test

The answer required from the subject doing the stereoscopic tests was illustrated by a model in which round discs were mounted on wires at receding intervals from the observer. It was explained that the answer was a sum consisting of three two figure numbers separated by a times sign, and that the only clue to the sum was that the discs would separate out in space so that the answer could be given by reading the discs from front to back. In the model the answer was 42 x 63 x 15.

dolls were in one order, and when they were seen stereoscopically then they were seen in a different order.

The monocular sense of order is produced by the fact that the dolls give the appearance of people standing in three rows as seen from above. They look like ranks of soldiers approaching across a parade ground when seen from the top of a building. The three dolls at the bottom of the slide therefore appeared to be to the front. In addition a blue doll at the top appeared to be further back, probably because blue is related to distance in terms of haze effect in aerial perspective.

This suggested a relation with flexibility, in that the rigid subject might see the monocular percept of distance in terms of rows of dolls and blue for distance, and be unable to inhibit the percept in favour of the stereoscopic information. It was decided to test this hypothesis by making use of a more definite clue to distance, retinal image size, and to contrast this with stereoscopic disparity.

It is well established that if a subject is presented with objects whose size or distance may be determined by various characteristics, then the apparent distance of the object is always determined by retinal image size Stewart 1963: Gogel and Newton, 1969; McDermot, (1969).

Making the Retinal Image Size Test

A test to measure the rigidity seen in the slides where an established monocular percept could not be eliminated by stereoscopic information was also made photographically.

Most of the Africans who work on farms live in huts which are not usually taller than 3 m. A hut reduced photographically to one third the size of a man, would therefore look three times the distance away. On the other hand, if these were models and were seen stereoscopically, the hut would then move forward, and be seen as a doll's hut.

A farm Tweefontein, 15 miles East of Benoni, has on it a small settlement of Ndebele who make a square type of hut with colourful decorations on it. Such a hut as background would give an air of genuineness to the slide. On the same farm are some Basutos who have a round hut. The farmer, who speaks their langugae, arranged for the workers to be at their huts with their families and photographs were taken of the Africans in groups before their huts, and also individually.

It is well known that if the texture of the foreground between objects can be seen clearly, then the distance between the two objects can be estimated accurately monocularly. The foreground had therefore to be removed from our experimental pictures. To do this, photographs of some high grass were taken, and when the models were made, this was enlarged to such a size that standing rather like a hedge before the models it hid their feet and therefore the foreground.

Stereoscopic slides were then made by the following procedure:-

The photographs of the Basutos, a man, and his wife and his small daughter were enlarged. The man and the wife were enlarged to the same size, and the child to a size slightly smaller than the mother and father. The hut and background was enlarged to use as a background. The enlargements were glued to three-ply and cut out. These cut-outs were mounted on stands so that they could be positioned anywhere in the enlargement to be photographed. The models were then photographed stereoscopically in the following order - from front to back, the man, the child, the woman.

As we had no stereoscopic camera, the stereoscopic photographs were taken in the following manner:-

A heavy wooden support was made for a Zeiss super Ikonta camera. This support was made to slide along a wooden slide marked in terms of inter-pupilary distances, and of greater distances, to obtain a greater disparity between the models. Photographs were taken on high contrast film, both with the hut as a background, and with a white board as background.

As we had no idea if the slides would measure the variable for which they were designed, and as the making of slides had proved to be extremely time-consuming, it was decided to mount the prints of these negatives on some sort of slide holder so that a pilot experiment could be tried with them.

A master printer was asked to assist us. He obtained a punch which cut a two inch hole in thick card. He then cut this card accurately to the size of the synoptophore [illegible] and punched the hole symmetrically in the centre. Fifty of these [illegible] allowed us to mount 25 pairs of prints of the photographs. Diagonals were drawn across the cards and the prints were cut accurately to carefully centred squares. The four corners of the square were then positioned on the diagonals [illegible] accurately mounted the print in relation to the card. These prints were then viewed in a synoptophore. This instrument is provided with two types of illumination. For glass slides the illumination is through milk glass. For cards the lamp holders can be moved and positioned in tubes so that they floodlight the cards. This illumination is irregular and only suitable for pilot experiments. Using this method of presentation of the cards with their stereoscopic prints an experiment was carried out on seven subjects as follows:

The synoptophore was adjusted to the subject's position of comfortable binocular vision, and a pair of cards insertea into the slide holder. One tube was switched off so that what was first seen was a monocular view of the slide. The subject was asked to give the order of the three persons, from front to back. Judgement was made in terms of retinal image size and the large relative size of the child caused her to be seen in front followed by the father and the mother. The second tube was then switched on, a stop watch started, and the subject asked to name any change in position. The stereoscopic clues from angular disparity now showed that the child was a small giant and stood behind the father. To our surprise all the subjects saw the change in position within a few seconds. Some subjects reported that they were worried by the background, and that they found it easier to see the stereoscopic change in position with the neutral background. It seemed that what was necessary was a greater conflict between perspective and stereoscopy seen before the neutral background.

The photographs of the Ndebele man, his daughter, small child, and his square decorated hut was enlarged more than the Basuto child, and the hut less, so that the effect of the retinal image size on perspective would be to bring the Ndebele child more forward and to make the hut recede into the distance. The models were cut out and mounted on three-ply with stands as before. They were then photographed stereoscopically in the position shown in Fig. 4.13.

Twenty-four photographs were taken in eight groups of three. The first negative would make the R hand slide, the second the slide in terms of a disparity equal to normal viewing, that is, the camera was moved sideways along the slide by the inter-pupillary distance 62 mm and a third photograph was taken with the camera moved to the side by a further 31 mm giving the same effect as teleostreopsis, enhanced depth by artifically widened

FIG.4.12

The Ndabele figures as seen monocularly

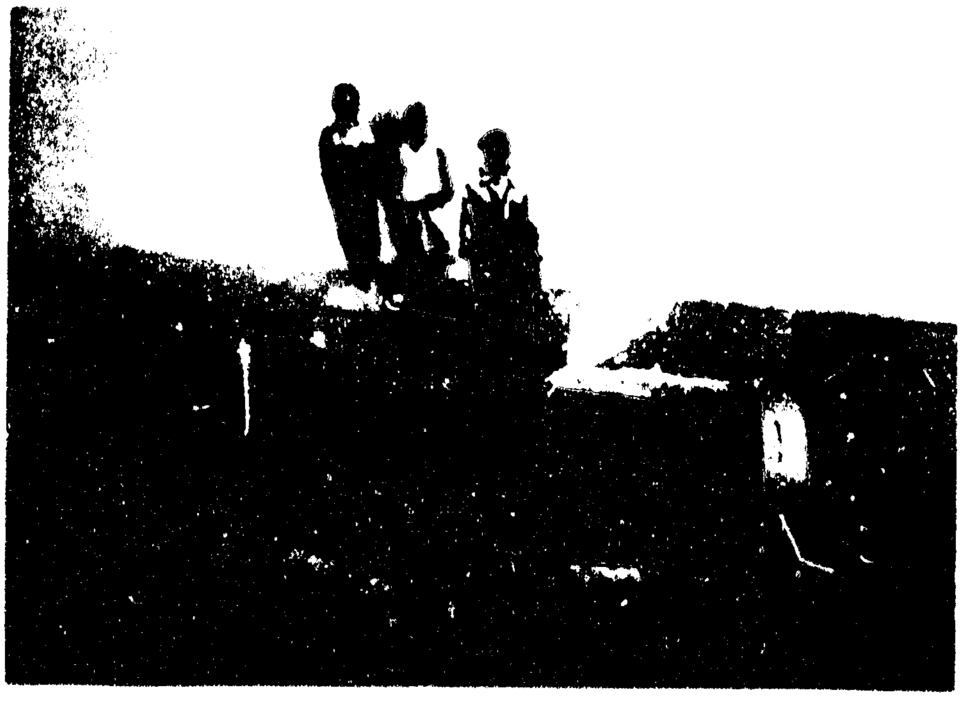


FIG.4.13

The positions actually occupied by the models inter-pupillary distance. Prints were made and mounted on the cards. The monocular appearance of these prints was of a hedge, and immediately behind the hedge a small boy (Fig. 4.12). Further back are the girl and the man and in the far distance their hut. When the second tube is switched on, the child moves backwards after a few seconds, and eventually the hut moves forward and is seen as a doll's hut in front of the child (Fig.4.13) This reaction was demonstrated on a sample of seven subjects in Benoni with widely different times for the perception of the correct stereoscopic position of the hut. The instrument and cards were brought to the N.I.P.R. to show one of the staff who had assisted so generously with the photographic work. The instrument was adjusted for him, the cards inserted and one tube switched off. He gave the normal description of the monocular picture, but when the second tube was switched on his comment was on these lines - "This is a most extraordinary experience. The man has moved forward, stopped at the hedge, and then floated forward in space leaving his legs behind him. Now the girl has done the same thing". The writer adjusted the instrument to his own settings and looked at the binocular picture, and saw the same effect. The man and the girl moved up to the hedge, the man took off into space first, following within a few seconds by the girl. After looking at the cards for some 20 seconds the man was seen to be far in front of the hedge, apparently suspended in space by some invisible force. His legs were truncated just above the knee.

The reason for this reaction was not immediately clear, but a consideration of the plan of the original photograph and the plan of what was seen provided the answer. The percept was one of pseudostereopsis, the cards had been reversed by accident and the R card was before the L eye, the L card before the R eye. The monocular photograph of the man shows him behind the hedge and his legs are occluded by the hedge. It is assumed that he has legs and stands on them. But the pseudcsteropsis brings what can be seen of him in front of the hedge so that he appears to have left his assumed legs behind the hedge, and floats in space without them. This was a most interesting situation as this gave a conflict, not with perspective but with reality. Our secondary subject was brought into the laboratory and the slides adjusted for her in the pseudoscopic position, the monocular description obtained and the second tube switched on. A most interesting reaction was described. The man and the girl moved forward to the hedge where they stood in a line with the boy, showing that the stereoscopic clues had overcome the monocular perceptive but the man and the girl remained behind the hedge, showing that the concept of reality was stronger than the stereoscopic clues.

This pair of clues offered two tests, the one when the contrast with perspective made it difficult to see the correct position of the hut, the second, with pseudosteropsis, to see the man in front of the hedge having left his legs behind him. This pair of negatives was photographed into positives and mounted as slides.

Retinal Rivalry

Most of the experiments carried out on retinal rivalry are concerned with establishing a dominance of one image over the other, of demonstrating the conditions which make a subject choose one image rather than the other. The writer was not aware of an experiment where a state of fusion was broken down into one of rivalry except that used in his own previous research (Humphriss, 1969).

The basis of this test is that subject looks through a refractor head at an aluminium screen on to which is projected a white square containing 16, 6/12 clear black letters. A red filter is then placed before the R eye, so that this eye sees 16 clear black letters on a red background. The majority of subjects do not see any red because the R eye is inhibited. Plus sphere is then added to the L eye in 0.25 steps so that the letters become increasingly blurred by the induced myopia (Fig. 4.14). In the majority of subjects the chart suddenly changes to the red of the filter. On reduction of the plus the red disappears and a white chart is seen again.

In presenting this test to the pilot sample a difficulty was encountered in that some of the subjects went into diplopia when the two images were one very blurred white image and one dull red clear one. Experiments were carried out to provide a fusional lock which would prevent the eyes from wandering and producing the diplopia.

In order that there can be a fusional lock with two eyes stimulated with different colours, it is necessary to have a framework whose outer boundaries are the same to both eyes. The only possible design of such a framework is to use a frame the same colour as the filter, as it is then seen the same colour by both eyes, and outside the border there must be a blackness. The outer edge of the frame is then common to both eyes, red inside and black outside. Suth a border round the test will hold the eyes in a locked position and prevent wandering and subsequent diplopia.

The addition of this red surround raised the level at which the inhibition reversed from white to red, but it proved to have two advantages. Subject could be shown the reversed situation when the centre of the chart appeared red. The colour was sometimes described as being red like the outside, mostly as whiter, or an off red, but rarely as darker. Subject was asked to

FIG. 4. 14

The set up for performing the retinal rivalry test is shown here. The lighting in the room is lower than that used for taking the photograph, about equal to that seen on the subject's right hand.

The letters on the chart have been blurred by an equal amount equal to one dipoptre of myopia. That is, the normal eye seeing through a + 1.00 sphere.

note the colour of the centre in relation to the outside (which remained constant) and say when the same colour was seen again. This provides a more stable end point. Also the point when the centre returns to white (again often described as off white) was similarly very definite.

An attempt was made to match these measurements by using red and green images instead of the white projected chart. If filters are used which are complimentary, the red seen through the red remains the same red, but seen through the green it appears black. A chart was made with two rectangles 7.5 x .5 cms with a 6/15 letter C centred in each rectangle. When these are normally seen they appear as red and green rectangles. When seen through the red filter they are seen as one red and one black rectangle. The change of the green rectangle to black could then be used as an end point indicating that inhibition had taken place. The measurements were so much lower than those taken when a red-white chart was used that there was insufficient variation between subjects and the experiment was discarded. It is probable that the change to red is proportional, not to the amount of plus sphere used, but to the amount of blur induced, and this will vary with several factors such as the size of the subject's pupil. A study was made (Humphriss, 1968) of the relation of amount of plus to amount of blurr in a normal population and a normal distribution was obtained. Hence some subjects with the same amount of blur had a considerably lower visual acuity than others, but the variation could not be attributed in several cases to any optometric variation.

An attempt was made to improve the plus sphere measurement by moderating the amount of myopia by some of the factors shown in the experiment as responsible for high or low acuities, but the correlations between these and other optometric scores were higher with the raw score than with the moderated score, so the raw score was used.

When we gave the test with the red margin to a pilot sample, some of them noticed that before the centre of the chart changed to red it went to a light pink. This offered another score so that from this test, six measurements were available. With the red filter before the R. eye.

1. Amount of plus before pink was seen
2. Amount of plus before the red chart was seen
3. The reduced amount of plus at which the white screen was seen again

4-6. Repeat with the filter before the L eye.

A Binocular Frustration Test

The request from the psychologists that a test be designed in which the binocular function would be weakened by some sort of frustration was met when it was known that the new target for measuring the P.F.R. gave very accurate results.

It was known that if a patient had one clear eye and one blurred eye that binocular vision was usually unstable. An experiment was tried in which this condition was imposed on a normal subject and a considerable drop in P.F.R. was recorded. An experiment was then tried on a sample group as follows: Using the refractor head rotary prisms, the P.F.R. was recorded normally and then repeated with the L eye fogged by artificial myopia in steps of 0.50 D.

In most cases it was found that the measurement with the first fogging of 0.50 D was slightly increased, probably because the practice effect was stronger than any lowering due to the weak sphere. At 1.00 the P.F.R. began to fall and with the 1.50 D sphere had fallen in some cases by 50 per cent.

To eliminate dominance effects the run was repeated with the R eye fogged.

The results were produced as histograms and these were considerably skewed, but conversion of the scores to logarithms removed much of the skewness.

A ratio score was then produced as follows:

The four measurements with plano and +0.50 sphere were added
The four measurements with the plus 1.00 and +1.50 D sphere were added
The log of the first four was then subtracted from the log of the second four measurements. This gave a score which represented the amount of collapse of binocular vision due to the fogging of the vision of one eye. It was named the Fall Off Score.

The Binocular Experimental Procedure

In addition to the main refraction theatre, the optometry clinic has a small separate clinic where experimental work can be done. It is equipped with an American Optical Co. Refracting head on a hydraulic stand and has a hydraulic chair. The cubicle is 3.3 m long and the chart is seen reflected in a mirror on a stand.

A further mirror on a stand was placed to the R of this mirror. To the R of the patient a Clason projector was positioned level with S and pointing towards the mirror. This projector was fitted with the special slides designed for the retinal rivalry measurements.

The refractor head has a red filter of the same density and colour as that used as a border which can be easily flipped into place before either eye, and the instrument can be varied in plus or minus sphere in 0.25 steps.

To the L of S, an aluminium screen and the fusional square and red dot equipment were positioned one above the other so that by adjusting the second mirror, the projected beam could be focused on to the aluminium screen, and by turning the first mirror subject could see both the screen and the fusion chart.

The inter-pupillary distance was measured and all instruments adjusted to it. This measurement (P.D.) was used in the statistical analysis because of evidence that it might relate to personality in terms of Sheldon's typology (Sheldon and Stevens, 1942; Whittaker 1966).

Subjects were refracted binocularly by the Humphriss Immediate Contrast technique (Humphriss, 1963), and the visual acuities recorded.

This technique has a particular value for this programme in that it cannot be applied to a patient without near normal binocular vision. If the patient could not be satisfactorily refracted by this method, then the case was rejected. The muscle balance was taken with a maddox rod and if a heterophoria likely to upset the fusional balance was found, the state was investigated and a relieving prism used.

At this stage the case was again reviewed. If the visual acuities were unequal by more than one line, the case was rejected. Similarly, if the muscle balance was so high that the case had to be considered as one of binocular instability it was rejected. The need for this severe screening is indicated in the results of a research programme into retinal rivalry by Alexander (1951) in which one subject with an esophoria of 7 Pr.D gave very different results from the other subjects; 7 Pr.D of esophoria is only just outside the limits of normality.

After these measurements the fusional reserves were taken with accommodation at rest. The square and red dot chart was switched on and by inserting a prism of power 6 Pr.D base up, diplopia was obtained, and by reducing the prism, re-fusion was demonstrated. This was sufficient to demonstrate to subject that the chart would double and would re-fuse to one chart.

1. The rotary prisms were placed before both eyes and the prism introduced base out until diplopia was recorded. The prism was then reduced in amount until re-fusion took place. The score was recorded in prism dioptres.

Score 83	P.F.R. to break
Score 84	P.F.R. to recover

The procedure was then repeated, introducing prism base in.

Score 85	N.F.R. to break.

The prism wa then introduced vertically.

Score 86	Vertical F.R.

2. The prisms were then returned to 0 and a plus 0.5D.Sph placed before the L eye. The P.F.R. was measured to break. The sphere was increased to 1.00 D and the P.F.R. re-measured, and the sphere increased to 1.5 D and the P.F.R. measured to break again.

This procedure was then repeated with the sphere before the right eye. The mean of the two was then calculated.

From this procedure a score was obtained as previously described.

Score 87	Log P.F.R. unfogged - Log P.F.R. fogged.

The Retinal Rivalry Test

The room lights were then switched off and the projector switched on. The red filter was placed before the right eye.

Subject was asked if the letters were clear and if the chart was coloured. In all cases the answer was clear and white. A plus 3.00 sphere was then added and the red chart was seen. The plus sphere was removed and then increased in mounts of 0.25 D sphere every half a second. The patient was asked to say when colour was seen. When the red colour was seen the plus was reduced until the white chart was seen again.

The procedure was repeated with the plus spnere before the L eye and the mean of two measurements taken, red seen, and return to white because all subjects did not see the pink chart. Two scores were derived.

81 Log of retinal inhibition level

82 Log of reversal to white.

By this time subjects were tired and sometimes complaining of a frontal headache.

The second part of the visual test was carried out after a rest of three days. If subject had a refractive error and wore glasses the glasses were neutralized and were only used for these tests if the prescription agreed with the refraction to 0.50 D. If they were out by more than this amount the prescription was put up in a trial frame. Subjects who did not wear glasses but whose refractive error exceeded 0.50 D were similarly fitted with trial lenses. The fusion tests were carried out on a synoptophore and mounted on to the hydraulic stand of the A.O. Co. by removing the stand for the opthalmometer, and making a special stand to take it. Having an adjustable stand and chair, the large difference required in height between a short and a tall subject could be adjusted for and subject could be made comfortable with the head in the upright position. This is important, as looking upwards increases the N.F.R. and reduces the P.F.R. The reverse changes are effected if the head is tilted backwards and the subject looks downwards.

The inter-pupillary distance was measured and the subject was instructed to relax and just let things happen. Measurements were taken in the following order :

1. The position of rest with the eyes dissociated, unfused.
2. Fusion was established with the spider and dots.

The tubes were converged until diplopia was reported. They were then diverged until re-fusion took place.

The tubes were then diverged further until diplopia took place and then converged to the position of re-fusion. The four measurements were recorded.

The scores were calculated as follows: The position of rest was added to or subtracted from the position of break and recover. Two scores were recorded.

97 N.F.R. to break in prism dioptres
98 N.F.R.

The N.F.R. was then deducted from the P.F.R. giving a score which represented how much more the patient was convergent than divergent. This score was thought to represent binocular tension.

Score 88 P.F.R. -N.F.R.

Subject was asked to look at the slide as though it was a real spider near to them and to try and converge their eyes to it. If they could feel the muscular effort of converging they were impressed to try and increase this feeling. A score of motivated convergence was calculated by subtracting the log of P.F.R. unmotivated from the motivated performance.

Score 89 Log motivated P.F.R. - log P.F.R. relaxed.

The slide was removed and replaced by the cyclo-line slide with the line horizontal and the cross above the line and the circle below it. As a check on the position of rest, subject was given the control and asked to place the cross vertically above the circle. The tubes were then locked into position. Subject was told that the lines would not double, as did the spider, but would turn into a scissors type of cross. They were to report as soon as this was seen. The lines were then rotated in opposite directions until the cross was seen. The tubes were then rotated back towards the parallel position and the measurement for re-fusion recorded. The test was then repeated rotating the tubes in the opposite direction.

The slides were then removed and replaced with the lines vertical and the test repeated.

It was found that the vertical score was about double the horizontal score, and this was subtracted from the higher score giving some measurement of cortical visual flexibility.

The cycloversion scores were measured as the angle when the line rotated clockwise to the position of break when the line was rotated anti-clockwise. The recovery score was similarly calculated.

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The cycloversion scores were measured as the angle when the line rotated clockwise to the position of break when the line was rotated anti-clockwise. The recovery score was similarly calculated.

Four scores were recorded :

90 Total cyclovergence to break using the horizontal line in degrees of angle

91 Total cyclovergence measured between the two recovery positions in degrees of angle

92 As 90 but with the line vertical

93 92 - 90.

The Stereoscopic Tests

The stereoscopic slide of the Ndebele was then placed in the instrument and one tube turned off. Subject was asked to look in and to say what was the order in depth of the five stimuli - the hedge, the hut, the man, the girl and the child. The same order was given by all subjects - hedge, child, girl, man, hut. The second tube was switched on and subjects asked to report any changes in position. A stop watch was started as the second tube was switched on and the time taken until subject reported that the hut had moved forwards, level with, or in front of the child.

The instrument was switched off and the slides reversed from R to L. The instrument was switched on and the stop watch re-started. Subject was asked to say what changes in position took place this time. Time was recorded when the girl was seen in front of the hedge.

The Ndebele slides were removed and the stereoscopic sum slides put in. The model illustrated in Fig. 4.11 was shown to subjects and it was explained to them that when the stereoscopic percept was seen the discs would separate out in space, backwards and forwards and that a sum could then be read by taking the numbers and the times signs from front to back. Subject was then asked to say what sum could be read from the model. When this was understood and the correct answer given subject looked into the synoptophore and the tubes were switched on. The time was taken when the correct answer was given.

Each subject was given four minutes in which to see the stereoscopic answer. The distribution of the scores was bimodal and very skewed. The skewness was improved with a logarithmic score.

Three scores were recorded:

94	Log time with the stereo sum
95	Log time with the stereo hut
96	Log time with the stereo man.

Every doubtful result was repeated, and in order not to take the doubtful measurement in isolation the complete test run was repeated and the results compared with the first test. In a majority of cases the doubtful measurements were shown to be incorrect answers. In two subjects only the inconsistencies were repeated, and these were removed.

In cases where there was no inconsistency, the mean of the two runs were taken.

From this procedure 22 scores were derived. The recovery scores for the N.F.R. and the V.F.R. were mostly near zero and these were not used in the computations. The scores used are given in Table 4.2.

Table 4.2

Description of 20 Scores of Non-Visual Variables, Resulting from the Optometric Programme

Number in 100 x 100 matrix.	Description of score
81.	Log of retinal inhibition level
82.	Log of retinal reversal to white
83.	P.F.R. to break
84.	P.F.R. to recovery
85.	N.F.R. to break
86.	Vertical F.R. to break
87.	Log P.F.R. - Log P.F.R. fogged = fall off
88.	P.F.R. - N.F.R. = tension
89.	Log P.F.R. with effort - Log P.F.R. relaxed = Motivation - suggestion
90.	Cyclovergence Hor. line to break.
91.	Cyclovergence Hor. line to recovery
92.	Cyclovergence Vert. line to break
93.	92 - 90
94.	Log time stereo sum
95.	Log time stereo hut
96.	Log time stereo man
97.	P.F.R. measured on synoptophore
98.	N.F.R. measured on synoptophore
100.	Interpupillary distance

CHAPTER 5

THE DESIGN OF THE PSYCHOLOGICAL AND NEURO-PSYCHOLOGICAL BATTERIES OF TESTS

The Principles Involved

The design of the psychological and neuro-psychological batteries of tests was based on four principles.

1. The tests must relate to the neurological model, as constructed in Chapter 2.
2. The tests must be so chosen that they would be likely to produce significant correlations with the scores from the visual battery of tests.
3. It was known clinical that certain non-variable visual variables such as motivation could be used to vary the scores.
4. All the visual tests were new tests and the project committee had no clear indication of the nature of the psychological variable responsible for their variability. The test battery therefore had to be very wide, to cover as many known psychological variables as possible.

Six proposals were advanced from these principles:-

a) It was known that binocular scores could be improved by suggestion and motivation. Therefore tests were required which measured these aspects of behaviour.

b) It was possible that the muscular behaviour responsible for bringing the eyes into a position of fusion would be similar to muscular movement in general. Therefore tests were required to measure individual muscular strength and persistence. As this might relate to general build, body measurements were taken and the ponderal index calculated.

c) It was known that a psychological tension state increases P.F.R. A test was required to measure the degree of tension of the subjects doing the tests.

d) The alpha rythm is known to be related to vision and there was some evidence that it related to binocular vision. An EEG battery was included.

e) It was possible that the particular neurology which produced binocular vision was also responsible for other visual phenomena, some of which, such as c.f.f. have produced significant correlations with psychological traits. (Tong and Ground, 1970). Several tests of this type measuring aspects of monocular vision were included. Equally the binocular behaviour might relate to sensory behaviour in general and therefore tests of auditory performance were included.

f) The search for a non-visual variable had indicated that some aspect of psychological rigidity was involved. In the case of the spectrum type test this appeared to be some type of cortical flexibility, while in the case of the dolls it appeared to be perseveration.

Three of these six proposals relate directly to the model. Proposal (b) would test muscle responses and hence might relate to muscular movement. Proposal (f) would relate to the summating mechanism as this has been shown to have flexibility within limits which varied between subjects. Several of the tests chosen were thought to measure this type of cortical flexibility.

Among the tests based on principle (f), were several where the test behaviour of the subject is altered by introducing a new dimension which required subject to inhibit a pattern already learned and to base his behaviour on a similar but slightly different pattern. It was thought that these test results might correlate significantly with the tests of visual inhibition.

It was also thought that the primary-secondary rating as defined by Heymans and Wiersma (Biesheuvel and Pitt, 1955) might be the neurological basis of the perseveration which they had found in so many of their research programmes, a large number of tests based on this thinking were included in the psychological battery.

When the testing programmes were complete, a correlation matrix 100 x 100 was calculated. The scores given to each test described, are those in this matrix.

Group (a)

A. Tests for Motivation and Suggestion

Tapping Speed. Subject is seated before a table on which is a morse key. Subject is instructed to tap with the index finger of the preferred hand using the button on the morse key. The number of taps is recorded with an electrical counter.

At the first trial of 30 seconds, subject is instructed to tap as fast as possible . At the second 30 seconds trial after an interval of 30 seconds, subject is continually encouraged to tap faster. Three scores were derived :

49. Tapping speed

50. Tapping fast when motivated

51 50 - 49.

Autokinetic Movement. The method of performing and recording autokinetic movement is surveyed by Conklin (1955). He finds the Guildford and Dallenback (1928) tracing method as used here, reliable.

Subject sits in a sound-proof dark room and looks at a small point of light. He is asked to record on a drawing pad the movement of the light. He is instructed that the eye cannot remain still in the dark and that this will produce movement of the light. Movement is recorded for 2 minutes.

Subject is then told that there will be an auditory stimulus and this by producing complex brain rythms will increase the movement of the light. Subject then records the movement of the light with the auditory stimulus.

Score is the length of line drawn. Two scores are derived :

30. Normal movement

31. Movement with suggestion.

Body Sway. Body sway was measured with a moving lever pressing against the left shoulder, which records the variation on a scale in inches of sway. The total movement backwards and forwards in a 1½ minute period is recorded. Subject has his eyes closed. Earphones are then fitted to subject and a tape recording is played to him for 1½ minutes. A monotonous voice says "You are feeling a force which pulls you forwards, forwards, forwards. You cannot remain still, you can feel the movement of your body forwards, etc."

The total movement with suggestion is then recorded. Two scores are derived :

28. Normal amount of sway

29. Range of sway with suggestion.

A test relating to suggestion was also included in the Necker Cube Tests.

Group (b)

Tests for Muscular Strength

Grip Strength. A test of grip strength was given. Subject grips a double handle and holds the two together against the resistance of a steel spring. A maximum grip strength is recorded on all subjects. The first subject is then brought back to the test and the cursor on the recording dial is set to half of the previously registered maximum grip. Subject is then asked to grip hard, raising the recording needle above the stationary cursor and keeping it above this point of "half grip" strength as long as possible. The time is taken from the moment when the recording needle advances past the stationary cursor to the moment when it passes the curson again on its return as subject relaxes his grip.

Two scores are derived :

44. Strength of grip

45. Persistence of grip.

The Skull Indices. The skull was measured with callipers and the following measurements recorded. Maximum length, maximum width, height from centre of skull to the orifice of the ear. The following scores were derived :

32. Breadth/length

33. Height/breadth.

The Ponderal Index. The pondaral index was obtained by measuring the height of the subject without shoes, and weighing the subject without shoes or jacket. The score is the height divided by the cube root of weight.

11. Ht/cube rt. wt.

Psychological tension. The amount of tension from which subject suffered in a testing situation was calculated from the lack of alpha rythm in the EEG recording.

The Neuro-Psychological Programme

1. The EEG

Two EEGs were recorded simultaneously on two instruments wired in parallel. This made it possible to record on 16 channels. For this purpose three operators were required, one with each instrument and one with subject. Subject was in an air conditioned light proof and semi-sound proof laboratory, seated in a hydraulic chair with arm rests. Six feet before the subject was an oscilloscope. To the side of the oscilloscope was an optical mirror in which subject could see reflected the equipment used in the visual battery which was erected behind him.

Eight electrodes were fastened to the subject's scalp with colloidal salt jelly and four were fastened to the face, one on the eyebrow, one below the eye on the orbicularis, one 12 mm lateral to the outer canthus and one on the nasion. Subject was provided with a recording button, and the operator in the laboratory with subject had a similar button. These buttons recorded their signals on the EEG.

Communication between subject, operator, and EEG operator was by microphone and speaker.

Subject was made comfortable in the hydraulic chair, asked to close his eyes and when EEG registration appeared satisfactory the standard procedure for recording, already described, was used.

Alpha blocking with visualisation was then recorded. Subject was instructed "Think of Mr. Humphriss's face. When you have a clear picture of his face press the button." When the signal arrived the instruction was given "Now let the image go, when it has gone press the button." When this signal was received the procedure was repeated with the auditory image of rain beating on a window pain, and with the kineasthetic image of holding the legs out from the chair up in the air.

Retinal inhibition procedure was then followed. As a refractor head could not be used, a trial frame was placed on subject's face and plus lenses in 0.25 steps put up in a rack three at a time. When the 0.75 had been exposed and no reversal was recorded, a 1.00 D sphere lens was placed in the trial frame and the rack used to increase the plus up to 1.75. A second plus 1.00 was then placed in the trial frame. This was sufficient to produce reversal. Plus was then reduced until a white chart was seen. Subject indicated that the inhibition had occurred by pressing his button when the chart changed from white to red, and again when it reversed back from red to white.

A small rotary prism which had been especially made was fitted into the trial frame and was sufficient to record a vertical fusional reserve. The operator signalled when the addition of prism before one eye had begun and subject signalled when diplopia resulted, and again when

Communication between subject, operator, and EEG operator was by microphone and speaker.

Subject was made comfortable in the hydraulic chair, asked to close his eyes and when EEG registration appeared satisfactory the standard procedure for recording, already described, was used.

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A small rotary prism which had been especially made was fitted into the trial frame and was sufficient to record a vertical fusional reserve. The operator signalled when the addition of prism before one eye had begun and subject signalled when diplopia resulted, and again when refusion had taken place. It was hoped to find some change in the EEG which coincided with the diplopia.

Photic Stimulation. A mercury vapour lamp producing a short high intensity flash was placed two feet from the subject's face. Subject is told to keep his eyes closed and to report what he sees. As some subjects become confused when the frequency of the light agrees with their alpha frequency, they are made to keep up a running commentary and not allowed to lapse into silence.

Flicker is first presented at 1 hz and the frequency increased slowly up to 40 hz. The frequency is then reduced back to 1 hz. The EEG operator writes on the EEG the comments of subject on what subject sees.

This total EEG programme took about 45 minutes. At the end of the programme most subjects were feeling discomfort and some complained bitterly of a headache. They gave the impression that they were completing the test by driving themselves to do so.

Ten scores were obtained from this programe :

48. Alpha frequency
64. Alpha amplitude)
) thought to be reduced in tension states
65. Alpha index)
66. Alpha location
67. Alpha response
68. Alpha response visual
69. Beta incidence
70. Theta incidence
71. Degree of abnormality
72. Flicker response.

Group (e)

Tests of Visual and Auditory Ability

Size Constancy. Size constancy was measured in two experiments which were carried out in the lecture hall of the Institute. The first test consisted of a comparison between circles held at half the distance from the stimulus circle. Subject was asked to say if the circle presented was larger, smaller or equal to the stimulus circle. The stimulus circle was then moved forwards so that the test circles were presented in the same order at double the distance to the stimulus circle.

The second test was carried out with a variable triangle which could be adjusted in size electrically. The test triangle was similarly positioned at half and at double the distance to the stimulus triangle. Firstly the test triangle was increased in size and subject pressed a button when he judged that it was of equal size to the stimulus triangle. Secondly, the test triangle was decreased in size, and again when subject judged that it was the same size as the stimulus, he pressed the button.

Seven scores were derived from the test :

1. Mean constancy
2. Short estimate minus long estimate - lack of constancy
3. Difference between ascending and descending trials
4. Range of response

5, 6, 7. As in 1, 2, 4 but with the triangle.

Stereoscopic Acuity. A three needle test for stereoscopic acuity was included in the apparatus used to produce the Necker cube.

The Exner Spiral. The Exner Spiral consists of a black and white spiral one foot in diameter which is rotated slowly. Subject sits three feet from the spiral and watches it rotate. Fixation is then changed to a dull matt surface and a rotating after-image is seen moving in the opposition direction. One score is derived :

10. The duration in time of the after-image.

Visual Perception Rate

In an electronic tachistoscope, cards are presented which are designed like a chess board, with all white squares divided by black lines. Some of the white squares are filled in. The number filled in varies randomly from one to 10. The card is exposed for .2 seconds. Subject states the number of black squares seen. Score 62 is the number correct out of a total of 16 cards.

C.f.f. was recorded with the apparatus of de Wet (1962). This apparatus was placed on a table to the side of subject so that by turning his head slightly and leaning forward he could fixate the small flickering square.

The speed of flicker was increased until subject reported no flicker and the speed then reduced until flicker was seen again. Subject was instructed to press his button when flicker disappeared and when it appeared. Speed of flicker was increased and when the operator saw subject press his button, c.f.f. was recorded. Flicker speed was then reduced until subject pressed his button again. C.f.f. was again recorded. Three ascending and three descending trials were made.

(f) Measurement of Psychological Rigidity

There are many psychological tests which claim to measure an aspect of rigidity. With the exception of those which measure perseveration, these tests present a difficulty that the meaning of their score is not clearly defined. An example is "Flexibility of closure".

For this reason a test was used where the scores are very clearly defined. This test was given to all the samples. The initial research work, a factor analysis of temperament, from which the instrument was developed, was done at the institute, and the senior staff were sure that a measurement was obtained of the stability or excitability of the subject.

The Temperament Comparator is a self-rating, forced-choice test developed by Melany Baehr and R.W. Pranis and available from the Industrial Relations Centre, Chicago. Scoring is semi-automatic.

The subject rates himself by comparing two adjectives with each other and deciding which of the two describes him better. The adjectives are calm, cautious, decisive, demonstrative, emotionally stable, energetic, enthusiastic, even tempered, lively, persevering, prompt starter, quick worker, seeks company, self confident, serious, social at ease, steady worker, talkative.

The adjectives are printed adjoining radials of a circle equally spaced around the circumference. In the centre of the circle is a disc like a gramaphone record engraved with horizontal lines so that at the end of each line there is an adjective. Subject makes his choice between the adjectives by making a pencil mark in a hole at one end of the line. When all the adjectives at the ends of the lines have been compared, the disc is rotated by the space between one pair of adjectives so that the lines are now slightly oblique and the L upper adjective is compared with the R lower adjective. Each adjective is then compared and the circle rotated by one more adjectival space.

The holes on the lines in which the pencil marks are made are on a spiral so that each choice can be scored in terms of the number of dots made against each adjective. Best results are obtained if the subject is pressed to work as fast as possible, and should subject be in doubt about the choice to guess and not to ponder on the choice. Six scores are obtained, five being factors of temperament and the sixth is obtained by inconsistency in performance :

38. Controlled
39. Stable
40. Self-reliant
41. Excitable
42. Sociable
43. Inconsistency score.

The Problem of Persereration

At the time that this research was carried out, three separate departments of the Institute were concerned with research on perseveration. Discussion with those in charge of these experiments suggested that perseveration was almost certainly one of the factors producing the variability in binocular behaviour.

This was of particular interest to the Department of Neuropsychology.

Perseveration is known to represent the state of the brain. In a brain that is physically damaged, perseveration is greatly intensified (Shivack and Levine, 1956), it is considerably increased in some psychotic states (Guilford, 1933),and greater in patients who have had electric shock therapy (Fisichelli et al., 1955).

Its measurement by the rate of change of ambiguous figures is reliable and changes little from day to day (Fisichelli et al., 1955; Ruttiger, 1963).

This type of thinking caused the early psychologists to consider perseveration as a built-in delay in reaction in the central nervous system which would affect all behaviour, and it would seem that perseveration must be one of the simplest forms of psychological rigidity.

Yet as long ago as 1946 Cattell says of "The riddle of perseveration. 'Perseveration is not a unitary characteristic.'" The variability of the amount of perseveration with differing targets was demonstrated by Brown (1955) who also surveys the literature on changes in reversible figures.

Donahue and Griffiths (1931) found that with static figures simple figures reverse faster than complex figures. Phillip and Fisichelli (1945) found the opposite with moving figures and showed that the faster the movement the greater the change.

From his experiments, Sakano (1963), deduced that a change in perception was accompanied by a change in ocular movement.

A measurement of oculo-motor perseveration can be extracted from the experiment of Herberg (1955).

While investigating the speed of saccadic eye movements, and hoping to find a correlation with EEG and flexibility measurements, he failed to find a significant correlation, but an examination of his statistics shows an interesting correlation with fixational time. The subject was required to look as quickly as possible from one dot to another. The eye movements were photographed, and the length of time that the eye remained fixated on one dot before moving to the second dot was calculated. These fixational

times, which represent perseveration of fixation, correlate significantly with alpha frequency and intelligence scores. The author found a correlation between saccadic speed and mean fixation time and Pauli total additions and between fixation and convexity of work - 0.61
Fixation time to S.A. Group Intelligence test - 0.56,
Fixation time to verbal I.Q. - 0.49; to non-verbal - 0.56.
These correlations were significant at the 1 per cent level of confidence.

With this background in mind, three tests of perseveration were chosen, one with a static target, and two with dynamic targets. In addition, one of the tests with a dynamic target was repeated with varying types of fixation to see if our results supported the conclusion that there are low correlations between tests of perseveration where there is a change of target, but high correlations when the target is constant and the testing conditions varied.

A piece of apparatus had been developed at the Institute for investigating the relation of stereoscopic vision and size of image to reversal on the Necker cube. The apparatus consisted of an elongated box, open at one end. In the middle of the box was an opening where glass slides could be dropped into grooves. Subject viewed the slides from the distance of six feet before the box. The Necker cube could then be broken up into parts and the one part put before or behind the other. It was found that this did not interfere with the reversal although stereoscopically it could be determined which of the two squares was in front.

Various presentations of the Necker cube were made and subjects asked to tap a pencil on the table when the geometrical reversal took place. Subject was scored on the number of reversals in one minute. Subject was then asked

to stop the cube reversing and was scored over one minute.
Two scores were derived :

73. Mean alterations per minute
74. The control index, the ability to control the rate of change

Reuning has designed a moving ambiguous figure constant in its pattern, but which can be seen in several different perceptions. This stimulus is produced by shining a parallel light across a set of vertical rods which rotate on the diameter of a gramaphone table. Two rows of shadows are cast on a frosted glass screen which move in opposite direction with a maximum speed at the centre of the screen. The subject viewing the shadows from the opposite side of the screen can see the shadows as moving into the centre and then moving out again, as two sets of shadows crossing each other or as various patterns of rotation. There are six possible different percepts.

Two scores were derived from this test:-

8. The square root of frequency of change of percept divided by time
9. The time up to the first change

An apparatus for measuring perceptual change in a dynamic consistent pattern has also been devised by Nelson. It is produced by having two sine waves moving across the face of a cathode ray tube at a frequency of 1 per second, and 180 degrees out of phase with each other. These can be seen three ways. The common perception is a string of sausages moving across the screen, which changes to two fishes apparently not moving forwards, but swimming up and down as against a current. A third percept which is rarely achieved is something like a rotating elipsoid.

The oscilloscope was turned on when the experiments began so that it would be hot, and therefore more consistent in its performance when it was required. During the preceding experiments the tube was covered; the laboratory light was turned out and the two sine waves were focused and adjusted to a frequency of 1 cycle per second. The operator stood in front of the screen and advised subject that he would see a moving pattern which would change and the three possible percepts were described to him. He was told to press his button every time that a change took place. The operator then advised the EEG operator that he was going to begin, and pressed his button as he stood away from the screen. After 55 seconds EEG operator counted out the last five seconds and at the end of the minute the operator stepped in front of the screen again. Subject was then instructed to look at a small blue light 22.5 cms below the moving target, but to continue to press the button for any changes in the moving pattern. This produced a change in fixation in that the image was para-foveal and fixed, whereas the previous fixation had been macular and roving. Fixation was then changed to a small white light 22.5 cms to the R of the tube and the experiment repeated. Three scores were obtained, 55, 56 and 57 being the number of changes per minute with each type of fixation.

Visuo-motor Perseveration

This test was carried out with an instrument devised by de Wet (1962) and is based on a similar but simpler one constructed by R.H. Seashore who called it a "Serial Discrimeter" and used it to measure simple choice reaction-time. The present instrument was intended mainly for the measurement of perseveration. Certain scores on it derived from a group of pupil air pilots showed significant correlations with their success or failure on a flying course.

Subject looks at a small window about one inch square in which appears one of four symbols, coloured red or black. At the bottom of the instrument is a row of eight keys marked with the eight symbols, four in red and four in black.

Using one finger of his preferred hand, subject is required to press the key marked with a symbol corresponding to the one in the window, and if the correct key is pressed, the symbol changes. If the wrong key is pressed the symbol does not change, and an error is scored. When a run of 16 has been completed, subject is given new instructions.

This time subject must press the key marked with a symbol having the same <u>shape</u> as the one in the window, but the other <u>colour</u>. For example, if a red triangle appears in the window, he must press the "black-triangle" key and vice versa. However, occasionally a symbol appearing in the window has a large dot below it. This means that the correct key to press is the one marked with the same shape <u>and</u> colour as in the first part of the test.

S has four runs, the two as described and the two repeated.

Two scores are extracted. Mean time and errors for the four runs.

52. Visual discrimination errors

53. Visual discrimination time.

<u>Flexibility in Visual and Auditory Perception</u>

<u>Thurston Repeated Letters</u>

Subject is presented with eight sheets of printed letters, some of which are repeated twice and some three times thus :

g h x dd c u v l j z w u y y y r v p

Subject is asked to ring each pair or group of repeated letters and to separate adjoining groups, thus :

s i a x $\boxed{n\ n}$ $\boxed{r\ r}$ c a m

Score : Number correctly ringed in three minutes.

Two scores are derived :

35. Number correct
36. Log of errors.

The Stroop Test

The Stroop test is described by Thurstone (1943) and the effect of its distraction factor is confirmed by Pritchett (1968).

In order to make clear to subject what he must do, subject is given a black print on which is a line of ten coloured dots 7 mm round. He is told to count the dots of a certain colour starting from the L. He is then given an identical black print on which are the words yellow, red, green and blue in different colours. He is now told to count the words having the same colour of the ink. Having understood the test he is given two cards upside down containing 100 test circles and 100 words.

Subject's time and performance are recorded. Six scores are obtained from the test.

Without interference, counting the coloured dots :

13. Time; 17. Errors; 18. Performance.

With interference, counting the words:

19. Time; 20. Errors; 21. Performance.

Asterisk-digit Counting

In the Asterisk-Digit counting test, subject has to count rows of asterisks or rows of numbers. The distraction factor is the number which will mostly not agree with those being counted and will distract the counter.

The stimuli are arranged in columns thus :

* * * * . * *	4.4.4.4.4.4.4.4
* * *	4 4 4
* * * *	3 3 3 3 3
* * * *	7 7 7
* * * * * *	1 1 1 1

Three scores are derived from the test

24. No interference, counting asterisks. No. correct

25. With interference, counting digits. No. correct

26. Interference score 25-24.

Thurston Pursuit Test

This test is described by Biesheuvel and Pitt (1955) who included it in a large battery of motor-speed and flexibility tests.

The test consists of a series of curved lines which twist up and down crossing each other. The lines are contained within a rectangle, and are numbered from top to bottom at the beginning of the line on the L side of the rectangle. Subject holds a pencil and beginning at the L end of the line, follows the line with the pencil to its ending at the other side of the rectangle where the number of the line being followed is marked.

Subject is scored for the number of lines followed correctly. Thurston who adapted the test from a test by MacQuire considers that it measures flexibility of closure.

34. This score is the number correct.

The Loud Soft Test

This test is an auditory version of the Stroop test. Its essential element is distraction. The words loud and soft are repeated at random and standardised intensity so that of 100 times in the test 50 are consistent with the word, and 50 are reversed, that is the word l [illegible] said softly.

Subject is instructed to listen to a tape recording and to respond to the intensity and not to the word. Subject writes L for loud and S for soft.

In applying the test many subjects became confused and lost their place so that the scores were of no value as they could not be checked as correct or incorrect.

Perseveration and Gestalt Domination

The problem posed was to develop a test which by itself did not contain a definite gestalt, so that a measurement could be made of a function without interference. It was then required that some change in the test should complete a Gestalt so that this impression would interfere with the previous measurement when it was taken under the altered circumstances.

Various tests were tried, but they were found not to be measurable with sufficient accuracy, and when tried on the pilot samples gave completely unreliable results.

An arrangement was then tried of altering the standard three needle stereoscopic test in which the middle of three needles is seen through a horizontal rectangle and the middle needle is moved forwards and backwards, subject having to say when the three are in line.

It was found that this apparatus does not give a very strong sense of "Window". If, however, a horizontal needle is added to the centre of the rectangle, a strong sense of "Window" consisting of six panes of glass is obtained. The objection to this construction is that the difference in depth of the vertical and horizontal needles is at all times apparent, even when the window percept is strong. A piece of apparatus was built consisting of a bench along which a slide carrier moved a vertical needle. At the front of the bench was a mask in which had been cut a rectangular opening. Behind this opening and at the side of the aperture were two vertical fixed needles. The moving needle was seen symmetrically between the two fixed needles. This needle could be moved away along the bench and used for measuring stereoscopic acuity.

A third needle could be dropped into two horizontal clips at the side of the aperture, and the addition of this horizontal needle gave a strong Gestalt of "Window".

This test was tried out on a pilot group and gave a satisfactory measurement of stereoscopic acuity without the horizontal needle, and gave completely different readings when the horizontal needle was in place.

The procedure used was as follows :

Subject was seated looking along the bench through the aperture. The moving needle was against the aperture. Subject was asked to close the eyes and the needle was moved away from the aperture. Subject was asked to open the eyes and say if the needle had moved. This was continued in steps until movement of the needle away from the aperture was seen.

Subject was then asked to make estimates of the distance of the moving needle from the fixed needle at various random large and small distances.

The procedure was then repeated with the horizontal needle in place.

Subject was scored in terms of his accuracy in correctly placing the moving needle. Two scores were derived :

73. Gestalt variation
74. Stereoscopic depth acuity.

Flexibility in learning

K.V.T. Sorting Test

Konzentrations-Verlaufs-Test
(Concentration over time test).

Subject is given a pack of 60 cards. On each card are 16 small patterns. The patterns consist of a square divided into nine rectangles and these rectangles are filled in either symmetrically or asymmetrically. Subject is given a tray with four compartments on which are four illustrations, one at the back of each compartment. Subject is told that each card has one of four groups of patterns on it.

1. As example A.
2. As example B.
3. Contains both.
4. Contains neither.

The cards are to be sorted carefully.

The subject is given the last five cards to sort to see that he understands the instructions and then sorts the complete pack of 60. Two scores are derived :

22. Sorting errors
23. Sorting speed.

The administration and scoring of the Pauli test is described by Reuning (1957). The subject has in front of him a large sheet containing printed columns of one digit numbers which must be added together in pairs as fast and as accurately as possible. The sum of each consecutive pair of figures is written in the space to the right of the two figures being added, if this sum is 10 or more than 10, only the last figure of the result is written down. Each figure, except the first and last of a column, is used twice, once with the figure above, once with the one below thus:-

7 While the subject is busy with this continuous adding, a signal
  1 is given at intervals of three minutes so that the total
4 testing time of one hour is divided into 20 three-minute periods.
  9 Each time the signal is given the testee has to underline the last
5 sum he has written down, as the 4 is underlined in the example.
  0 These marks enable the experimenter to score the 20 period totals
5 which when plotted against time, give the Pauli Test Curve.
  4 All scores, except errors and corrections are either computed
9 from the sub-totals or read from the curve drawn on graph paper.
  5
6
  8
2

The following scores are derived from this test.

12. Convexity 11.
13. Total
14. Slope
15. Log 1 plus E%
47. No. of corrections.

Convexity 11 is the difference between the sums of the first and last five period totals and the ten period totals in the middle of the test, that is, the outer ten subtracted from the middle ten.

Slope is the rise of the curve taken from the nearest straight line which fits the curve.

Log 1 plus E% is an error score.

Flexibility of mental image formation

Speed of Image Formation

This test is derived from an experiment described by Gordon (1962). Subject is seated, is told to relax and when relaxed is asked to form a mental picture of a motor car. The following instructions are then given:-

Can you see a car standing in front of a garden gate? What is its colour? Try and see it in another colour. Can you now see the same car lying upside down? Now put the car back on its four wheels. Now can you see the car running along the road?

Can you see it climb up a steep hill?

Can you see it climb across the top of the hill?

Can you see it get out of control and crash through a house?

Can you now see the same car running along the road with a handsome couple inside?

Now can you see the car cross a bridge and fall over the side into a stream below?

Can you now see the car all old and dismantled in a scrap yard?

The time taken for the formation of the two images is recorded. One score is derived:-

77. Imagery mean time.

The Blox Test

Subject is shown a three-dimensional perspective drawing of three blocks standing beside or on top of each other. Subject is then shown four rows of drawings of blocks similarly drawn. In each row there is a replica of the relative position of the three blocks, but drawn from a different angle. The subject is required to make a visual image of the three blocks and to turn these in his mind's eye so that he can reproduce them as they would be seen from above, below or from an oblique side angle. He then selects the drawing which represents this rotation. With each sheet the drawing becomes increasingly complex in the oblique relation of one block to the others and differences in the test drawings are diminished. Subject is scored on his performance.

37. Number correct.

All the psychological and neuro-psychological tests were given at the laboratories of the National Institute of Personnel Research, Johannesburg. When the score was the amount of work done in a set time, the test was given to the whole group, when the test was timed tney were given individually.

The programme was very long and went on for several weeks. This produced a methodological error in that the test for tension in the EEG battery might have been given a month after the test for the P.F.R. The subject might therefore have been relaxed on the day the P.F.R. was measured and tense when the EEG was done.

Otherwise the testing conditions were ideal as the laboratories are especially designed for this type of work.

CHAPTER 6

THE EXPERIMENTAL PROCEDURE

The First Pilot Study

The optometry programme for the first pilot study of 23 optometry students was carried out in an individual consulting room at the Optometry College.

The psychological and neurological tests were given to the students in the laboratories of the National Institute for Personnel Research which are specially designed for this purpose.

The experimental procedure began with a thorough visual examination of each subject. They were refracted, and any case of slightly subnormal visual acuity rejected. The muscular balance between the two eyes was measured for distance and near fixation, and the convergence observed. Any tendency to slip easily into diplopia or suspension of the vision of one eye was cause for rejection. The eyes were examined externally and internally for any pathology which might interfere with the results.

The result of this total procedure was probably over-screening of the samples which were drastically reduced in size.

We had hoped to raise an initial sample of 60 optometry students who would do all the tests in the batteries, but many volunteers had to be removed because of the stringent visual conditions. Twenty-eight students, screened as monocularly and binocularly normal, agreed to do all the tests. Three of these did not complete them due to absence, one was found to be epileptic, and the final sample of 24 included a girl. It was decided to remove her and analyse the small but homogeneous sample of 23 male students.

With so small a sample and the large battery of tests described in Chapters 4 and 5, the resulting correlations could only be used to select tests to be given to a larger sample. Fortunately the picture which emerged from a study of the data was clear and served this purpose.

When this sample had completed all the tests in the three batteries, each student had more than 100 scores. Some of these were considered to be unsatisfactory in that students who had performed well on a majority of the tests produced very bad performances on particular tests.

On some of the visual tests there was very little variation, the scores being all near zero. By this type of inspection the scores were reduced to 100, being 60 psychological, 20 neuropsychological and 20 binocular tests. A 100 x 100 correlation matrix was computed and analysed.

Of the six proposals investigated, one was clearly supported, three not supported, and two, the EEG results in the psychological rigidity-binocular behaviour results were not clear. It was therefore decided to investigate these further.

The Second Pilot Study

The design of the battery of tests for the second study was determined by the availability of the staff of the Institute as subjects. Their time is valuable and hence they cannot be submitted to long programmes. On the other hand it is a condition of employment at the Institute that employees will undergo any tests required by departments, and many of them had recently been subjects for EEG experiments.

As the EEG results from the first pilot study suggested some relation between binocular vision and EEG scores, and as the EEG programme is very time-consuming and cannot be done as a group, it was decided to use these subjects and to give them the full binocular battery and the temperament comparator tests.

The sample numbered 56 when first chosen, but owing to visual abnormality and non-availability for testing due to posting and so on, the final sample who completed all the tests only numbered 37.

As the administrative staff included the telephone operators and typists, the sample was very heterogeneous with a large spread of age and I.Q. All the subjects, male and female, were of European ancestry.

Method

A replica of the college consulting room in which the students were tested was set up in the Institute. The writer was fortunate in being able to purchase a second-hand Bauch and Lomb adjustable stand on which a refractor head could be mounted. A refractor head from the Benoni practice was mounted on the Bauch and Lomb stand. A Clason projector was also moved to the Institute and hence the whole battery of binocular tests, as done by the students was repeated on the staff. From the results of the second pilot study it was decided not to continue with the EEG battery.

The Third Pilot Study

A study of the results of the two pilot studies suggested that there was some factor of rigidity which was measured by eight of the binocular scores. In the first pilot study this rigidity correlated significantly with the temperament self rating scores, but in the second study this was not confirmed. The eight tests from which the eight scores of binocular rigidity were obtained, and the temperament comparator was given to a group of 48 students to see if the relation with temperament was repeated or not.

The optometric practice in Benoni has a part-time bookkeeper who works in the mornings only. She has a quiet well-lit office and the psychological tests were given there in the afternoon.

The binocular tests were given in one of the Benoni consulting rooms where conditions were identical to those set up at the Institute. The same instrument was used with identical targets.

The Larger Sample

In an attempt to select a reduced number of psychological and binocular tests which could be given to a larger sample; Cattell Clusters (Cattell, 1952) were generated from the 100 x 100 matrix.

One cluster contained the cycloversion and stereoscopic scores, the scores for perseveration and two of the temperament comparator scores.

This cluster appeared to be suitable for factor analysis. The visuomotor perseveration test was given to the sample of 48 students.

An additional sample of 16 students was tested at the Institute. These were given the cyclovergence and stereopsis tests, the temperament self-rating and the perseveration tests.

By adding together the original student sample of 23 to that of 48 and the additional 16, a sample of 87 was achieved who had done all the tests in the cluster. The results of this sample were factor analysed.

CHAPTER 7

THE RESULTS

Six proposals were put forward to account for some of the non-visual variables in binocular performance. Each is examined in relation to the correlations which were computed from the tests designed to investigate it.

It may assist the reader if these proposals are re-stated. They were :-

(a) That it was known that binocular scores could be improved by suggestion and motivation. Their increases by this means might correlate significantly with scores of suggestion and motivation.

(b) That the ocular rotation resulting from muscular movement would correlate with scores of physical strength or the ability to maintain it.

(c) That a state of psychological tension produces convergence and reduces divergence. This state can be measured in an EEG score as tension reduces alpha amplitude and index.

(d) That the binocular scores would relate to EEG scores. It is thought that the response scores and some element of central excitability of the nervous system would relate to flexibility in behaviour.

(e) That the binocular behaviour would relate to other visual measurements such as c.f.f. and after image duration, and possibly to the acuity of other senses such as hearing.

(f) That the binocular scores would relate to scores of psychological flexibility-rigidity (F-R).

In terms of psychological rigidity or other variable the binocular scores were rated as follows:

Scores 81 and 82. A type of perseveration.

Scores 83, 84, 85, 86, 97 and 98. Uncertain

There are two factors governing the strength of the fusional lock. The measurement of the lock itself should be some type of rigidity in binocular vision, but this would be offset by the fact that a loose convergence-accommodation neural relation would also give a higher fusional reserve reading. These might well offset each other.

Score 87 measures the strength of the fusional lock in terms of its ease of collapse, without convergence or accommodation being involved. Hence this score should be one of flexibility in binocular vision.

Score 88 should relate to binocular tension.

Score 89 should measure an increase in the fusional reserve due to suggestion-motivation.

Scores 90, 91 and 92 will measure the strength of the fusional lock in terms of cyclovergence movements, and should be a score of binocular rigidity.

It is not known what score 93 would measure.

Score 94 will measure flexibility in binocular inhibition, but being a time score will relate to rigidity.

Scores 95 and 96 will measure a form of perseveration.

Score 100, on the basis of the Sheldons hypothesis should relate to flexibility.

The Scores

The numbering of the psychological scores is not in strictly numerical order. This is because numbers were allocated to scores when the programme was designed, but these tests were allocated to different parts of the testing programme. The order of presentation of the scores is the order in which they were performed.

The Correlations

Some of the tests were given to two of the pilot studies and some to all three of them. When more than one matrix of correlations is available from the same tests but given to different samples, they are produced under the same table number but classified a.b and/or c.

a. Suggestion and Motivation

Convergence was firstly measured by the standard method. It was then increased by suggesting to the subject that the image seen was nearer to him, and by motivating his performance by asking him to try and look at the end of his nose, to feel the pull of the internal recti muscles and increase this sensation and to try and hang on to the single image and not let it slip into diplopia.

Convergence was increased by this method and a mean score (89) of 11.2 prism dioptres was obtained by subtracting convergence when relaxed from convergence increased by suggestion and motivation. The two tests of suggestion already described were given to the sample and one of motivation.

The subjects swayed more with suggestion and one subject fell over backwards and had to be caught by the psychologist. More autokinetic movement was produced with suggestion. The increases are given in Table 7.1.

Table 7.1

Increase of function with suggestion and motivation

Mean convergence	Relaxed	32 Pr D
Mean convergence with suggestion		43 Pr D
Mean sway without suggestion		33 in
Mean sway with suggestion		46 in
Mean autokinetic movement		
- without suggestion		111 units
- with suggestion		323 units

Several of the students were able to increase and decrease the rate of change of the Necker cube. Their ability to control the perception was scored as a control index so that the actual change in rate of reversal is not known.

A tapping test was given to measure motivation, but it was a failure. A majority of students tapped slower on the second run when asked to tap faster, possibly because of fatigue.

Correlations between scores of suggestion and motivation and the binocular performance are mostly negative or not significant (Table 7.2), and the conclusion is that, in general, most of the binocular scores are not greatly affected by this variable, as with the exception of convergence, subject cannot improve his performance this way, in fact in most cases the subject was instructed to relax and just let things happen.

Table 7.2

Correlation between binocular scores and suggestion

N. 23

	29.	31.	N.23
81.	-0.01	0.08	
82.	-0.35	0.05	
87.	0.05	-0.44	
90.	-0.27	-0.09	
92.	-0.37	-0.13	
94.	0.35	0.10	
95.	-0.23	0.22	
96.	0.14	0.21	
83.	-0.30	0.05	
97.	0.04	-0.17	
85.	-0.29	0.06	
98	-0.23	-0.26	

Score	Definition
81.82.	Retinal rivalry
87.	Fall off of fusinal lock
90.92.	Cyclovergence
94.95.96.	Steroscopic tests.
83.97.	Positive fusional reserve
85.98.	Negative fusional reserve

Score	Definition
29.31.	Increased score due to suggestion.

Significant correlations have been underlined.

There were no significant correlations between the binocular motivation-suggestion score 89 and the psychological scores for suggestion and motivation, indicating no general factor of motivation (Table 7.3).

Table 7.3

Correlations between scores of suggestion, motivation and increased convergence

N. 23

	28	29	30	31	49	50	89
28	1.00						
29	0.97	1.00					
30	0.51	0.39	1.00				
31	0.24	0.13	0.29	1.00			
49	0.15	0.09	0.20	0.11	1.00		
50	0.17	0.26	0.37	-0.02	0.86	1.00	
89	0.35	0.34	0.24	-0.07	0.33	0.38	1.00

Score	Description
28	Mean sway without suggestion
29	Mean sway with suggestion
30	Mean autokinetic movement without suggestion
31	Mean autokinetic movement with suggestion
49	Tapping fast
50	Motivated tapping fast
89	Increased convergence

There were no significant correlations between the binocular motivation-suggestion score 89 and the psychological scores for suggestion and motivation, indicating no general factor of motivation (Table 7.3).

Table 7.3

Correlations between scores of suggestion, motivation and increased convergence

N. 23

	28	29	30	31	49	50	89
28	1.00						
29	0.97	1.00					
30	0.51	0.39	1.00				
31	0.24	0.13	0.29	1.00			
49	0.15	0.09	0.20	0.11	1.00		
50	0.17	0.26	0.37	-0.02	0.86	1.00	
89	0.35	0.34	0.24	-0.07	0.33	0.38	1.00

Score	Description
28	Mean sway without suggestion
29	Mean sway with suggestion
30	Mean autokinetic movement without sug
31	Mean autokinetic movement with sugges
49	Tapping fast
50	Motivated tapping fast
89	Increased convergence

The increase of convergence with motivation-suggestion in both samples was highly significant (Table 7.4 a and b).

Table 7.4 a

Students N.23

Mean increase of convergence	11.2 Pr D
Standard deviation	3.99
Critical value for a one tailed T test	1.72
Value of T	12.9

Table 7.4 b

Staff N.37

Mean increase of convergence	13.2 Pr D
Standard deviation	3.91
Critical value for a one tailed T test	1.69
Value of T	19.5

b. There was only one significant correlation between the binocular scores and scores of muscular strength and persistence . The correlation was between scores 44 grip strength and the negative (divergence) fusional reserve score (Table 7.5).

Table 7.5

Correlations between scores of strength and binocular vision

N. 23

	44	45
81	0.14	0.09
82	0.20	0.10
87	-0.16	0.03
94	0.18	0.20
95	0.08	-0.16
96	0.22	-0.24
83	0.27	-0.31
97	0.36	-0.28
85	0.03	-0.11
98	0.53	-0.13
90	-0.27	0.35
92	-0.11	0.27

Score	Definition
81. 82	Retinal Rivalry
87	Fall off of fusional lock
90. 92	Cyclovergence
94. 95. 96	Steroscopic tests
83. 97	Positive fusional reserve
85. 98	Negative fusional reserve

Score	Definition
44.	Grip strength
45.	Grip persistence

Significant correlations are underlined

There were no significant correlations between speed and movement scores and the recovery scores after break on a binocular test (Table 7.6).

Table 7.6

Correlations between scores of speed and muscular strength and the recovery from break of the fusional reserve

	23	49	44	45
84	0.15	0.10	0.24	-0.18
91	-0.09	0.14	-0.21	-0.23

84	Recovery from break of the positive fusional reserve
91	Recovery from break of cyclovergence
23	Sorting speed
49	Tapping speed
44	Grip strength
45	Grip persistence

The proposal is therefore not supported, but it is interesting to note that the only binocular score with a significant correlation is one of movement and not one of sensory reaction.

c. That convergence is increased and divergence decreased in a state of psychological tension.

Lack of tension can be recorded by the EEG where a relaxed subject produced more alpha and of a higher amplitude than those who are tense. There are no significant correlations between ocular tension score 88 and alpha amplitude or index (scores 64 and 65) Table 7.7a .
Scores 19 and 20 (Table 7.7 b.) The proposal is not supported by the experiment.

As it is known clincially that there is such a relation, it is probable that it exists in patients who are pathologically tense, and not in normal subjects.

Table 7.7 a

Correlations between ocular tension and the EEG measure of tension

Students N.23

	64	65
88	0.06	0.09

Scores		Description
88	8	Ocular tension

Scores		Description
64	19	EEG. Alpha aplitude
65	20	Alpha index

Table 7.7 b

Staff N 37

	19	20
8	-0.06	0.25

Hypothesis d

That there would be a relation between the EEG scores and the binocular scores because of the involvement of vision with both of them.

The correlations between the EEG scores and the binocular scores demonstrate some slight relation between binocular vision and alpha frequency (Table 7.8 a). When the same tests were repeated on the staff sample of 37 (Table 7.8 b), some slight relation between EEG and binocular scores was indicated, but a comparison of Tables 7.8 a and 7.8 b does not reveal its nature.

Table 7.8 a

Correlations between the binocular and the EEG scores

	48	64	65	66	67	68	69	70	71	72
81	-0.21	0.27	0.17	0.07	0.44	0.04	0.03	-0.39	-0.07	-0.33
82	-0.45	0.28	0.10	-0.13	0.47	0.23	0.15	0.00	0.24	-0.36
F87	-0.43	-0.37	-0.01	0.02	-0.04	0.25	0.23	0.31	0.15	0.37
90	-0.44	0.18	0.16	-0.06	0.35	0.03	-0.22	-0.11	0.08	-0.35
92	-0.40	-0.02	-0.09	0.25	0.04	0.09	-0.36	0.01	-0.28	0.05
94	-0.44	0.29	0.05	0.07	0.27	-0.30	-0.14	-0.24	-0.26	-0.56
95	-0.03	0.24	0.26	0.20	-0.11	0.07	-0.39	-0.11	-0.21	-0.06
96	-0.40	0.25	0.22	0.05	-0.11	-0.04	-0.16	-0.25	-0.20	-0.02
83	0.06	-0.04	0.05	0.03	-0.12	-0.12	-0.10	0.09	0.45	0.32
97	0.07	0.22	0.22	0.05	-0.11	-0.04	-0.16	-0.25	0.20	0.02
85	-0.04	-0.06	0.26	0.00	-0.09	0.11	-0.13	-0.26	-0.04	0.35
98	-0.18	0.06	-0.17	0.22	-0.29	0.19	0.11	0.31	-0.04	0.12

Score	Description
81. 82.	Retinal Rivalry
87.	Fall off of fusional lock
90. 92.	Cyclovergence
94. 95. 96.	Steroscopic Tests
83. 97.	Postivie fusional reserve
85. 98.	Negative fusional reserve

Score	Description
48.	Alpha frequency
64	Alpha amplitude
65	Alpha index
66	Alpha location
67	Alpha response
68	Alpha response visual
69	Beta incidence
70	Theta incidence
71	Degree of abnormality
72	Flicker response

Significant correlations underlined

Table 7.8 b

Correlations between EEG and binocular scores

Staff sample 37

	F.				F	F	F	F
	18	19	20	22	23	24	25	32
1	0.12	-0.13	0.06	-0.03	0.25	-0.17	0.11	0.03
2	-0.30	0.19	0.09	-0.08	0.39	-0.18	0.16	0.23
F5	-0.09	0.33	0.41	-0.08	0.35	-0.37	-0.03	0.07
F6	0.23	-0.22	0.01	0.15	-0.26	-0.02	0.05	0.04
9	-0.26	-0.37	0.34	0.19	-0.22	0.15	0.02	0.12
11	-0.01	-0.36	-0.40	0.16	-0.11	0.09	0.07	0.15
13	0.10	0.02	0.17	-0.09	0.01	0.04	0.13	0.26
14	-0.01	0.01	-0.08	-0.03	-0.05	0.24	0.11	0.18
15	0.28	-0.12	-0.01	0.28	-0.23	0.08	-0.04	0.06
3	-0.05	-0.22	-0.20	-0.11	0.04	0.01	0.19	0.15
16	-0.03	-0.12	-0.19	0.03	-0.23	0.02	0.01	0.08
17	0.13	0.21	-0.11	0.05	-0.07	0.11	0.11	0.07

Score	Definition
1. 2.	Retinal rivalry
5. 6.	Fall off of binocular vision
9. 11.	Cyclovergence
13. 14. 15.	Steroscopic scores
3. 16.	Positive fusional reserve
17.	Negative fusional reserve

Score	Definition
18.	Alpha frequency
19.	Alpha amplitude
20.	Alpha index
22.	Alpha location
23.	Alpha response
24.	Beta incidence
25.	Theta incidence
32.	Degree of abnormality

All significant correlations are underlined.

e. That the binocular scores might relate to various sensory abilities or with size constancy.

There are very few significant correlations between these scores and no clear pattern of correlations. The proposal is not supported (Tables 7.9 and 7.10).

f. That there is some relationship between binocular vision and psychological rigidity. The tests used to measure various aspects of psychological rigidity were grouped as follows :-

1. Tests of perseveration
2. Temperament self-rating
3. Tests where the performance is reduced by distraction, the rigid subject showing a poorer performance and a greater number of errors.
4. The Pauli Test
5. Body dimensions

The correlation between these scores and the scores of rigidity in binocular vision are given in the following tables:-

1. Table 7.11
2. Table 7.12 a, b and c Intra-test correlations

   Table 7.13 a, b and c Correlations with binocular tests taken from the pilot sampl
3. Table 7.14
4. Pauli Test. The error score is included in Table 7.14
5. Table 7.16.
6. Table 7.17 a, b and c. The inter-test correlations of the binocular scores suggest the existence of some general factor of rigidity.

Table 7.9

Correlations between binocular and sensory ability scores

N. 23

	64	62	74	10
81	0.27	-0.41	-0.20	0.02
82	0.28	-0.35	-0.15	-0.20
87	-0.37	0.22	-0.22	0.26
90	0.10	-0.23	0.18	-0.15
92	-0.02	-0.08	-0.03	-0.43
94	0.29	-0.21	0.26	0.19
95	-0.05	0.24	-0.26	-0.32
96	0.03	0.25	-0.10	-0.08
83	-0.04	-0.13	-0.01	-0.06
97	0.22	-0.28	-0.01	-0.05
85	0.27	-0.06	0.09	-0.01
98	0.06	0.59	-0.09	0.09

Score	Description
81. 82.	Retinal Rivalry
87.	Fall off of fusional lock
90. 92.	Cyclovergence
94. 95. 96.	Steroscopic Tests
83. 97.	Positive fusional reserve
85. 98.	Negative fusional reserve
64.	C.F.F.
62.	Visual Perception speed
10.	After image duration
74.	Steroscopic acuity

Significant correlations have been underlined.

Table 7.10

Correlations between binocular scores and size constancy scores

N. 23

	1	2	3	4	5	6	7
81.	0.10	0.02	-0.19	-0.24	0.32	0.05	-0.16
82.	0.02	0.13	-0.16	-0.03	0.23	-0.16	-0.29
87	0.01	-0.36	0.18	0.14	-0.16	0.07	0.04
90.	-0.01	0.01	0.16	0.04	0.19	-0.08	-0.05
92.	-0.09	-0.05	0.19	0.13	-0.11	-0.28	-0.11
94.	-0.07	0.28	-0.30	-0.31	0.47	-0.06	0.11
95.	0.24	0.39	0.26	0.15	-0.28	0.21	-0.01
96.	0.30	0.03	0.09	0.08	0.10	0.38	0.18
83.	-0.03	0.22	0.00	0.00	-0.09	0.15	-0.29
97.	0.00	0.01	-0.37	-0.12	0.13	0.15	-0.00
85.	0.15	-0.23	0.12	0.01	-0.03	-0.22	0.05
98.	0.00	0.11	-0.05	-0.08	-0.20	0.19	-0.42

Score	Description of Score
81. 82.	Retinal Rivalry
87.	Fall of fusional lock
90. 92.	Cyclovergence
94. 95. 96.	Stereoscopic tests
83. 97.	Positive fusional reserve
85. 98.	Negative fusional reserve
1. 5.	Size constancy
2. 6.	Lack of constancy
3.	Difference
4. 7.	Range

Significant correlations have been underlined

Table 7.11

Correlations between binocular and perseveration scores

N. 23

	8	9	55	56	57	75	52	53
81	$\underline{-0.42}$	0.10	-0.02	0.01	-0.22	-0.10	-0.05	-0.14
82	-0.11	0.16	0.16	0.24	0.07	-0.15	-0.06	0.16
87	0.16	0.15	-0.19	-0.13	-0.27	0.22	-0.37	-0.26
90	$\underline{-0.42}$	$\underline{0.47}$	-0.11	0.02	-0.26	-0.04	0.10	0.03
92	-0.35	$\underline{0.45}$	-0.23	-0.13	-0.24	0.12	0.18	-0.01
94	-0.12	0.14	0.14	0.11	-0.03	-0.02	0.27	0.41
95	-0.12	-0.11	$\underline{-0.44}$	$\underline{-0.51}$	-0.37	$\underline{-0.46}$	0.16	0.05
96	0.03	-0.24	-0.12	-0.27	-0.11	$\underline{-0.46}$	-0.04	-0.02

Score	Description of Score
81. 82.	Retinal rivalry
87.	Fall of fusional lock
90. 92.	Cyclovergence
94. 95. 96.	Stereoscopic tests
83. 97.	Positive fusional reserve
85. 98.	Negative fusional reserve
8. 56. 57. 75.	Ambiguous figures No. of reversals
9.	Time to first reversal
52.	Discrimitor time
53.	Discrimitor errors.

Significant correlations have been underlined.

Table 7.12 a

Intra-test correlations for the temperament rating on the student sample

N. 23

	38	39	41	
38	1.00			Controlled temperament
39	0.37	1.00		Stable temperament
41	-0.25	-0.83	1.00	Excitable temperament

Table 7.12 b

Staff sample N. 37

	26	27	29	
26	1.00			Controlled temperament
27	0.61	1.00		Stable temperament
29	-0.40	-0.77	1.00	Excitable temperament

Table 7.12 c

Student sample N.48

	13	14	16	
13	1.00			Controlled temperament
14	0.53	1.00		Stable temperament
16	-0.45	-0.81	1.00	Excitable temperament

Table 7.13

Correlations between the temperament rating and binocular scores

a.

Students N. 23

38 39 41

		38	39	41	
1	87	0.20	-0.37	0.40	Fall off
2	90	0.15	0.38	-0.43	Cycloversion
3	92	0.03	0.19	-0.31	Cycloversion
4	81	0.16	0.50	-0.47	Retinal rivalry
5	82	-0.27	-0.15	-0.22	Retinal rivalry
6	94	0.09	0.62	-0.52	Stereopsis
7	95	0.06	-0.37	-0.10	Stereopsis
8	96	-0.10	0.37	-0.15	Stereopsis

b.

Staff N. 37.

		26	27	29
1	5	-0.36	-0.22	0.27
2	9	0.04	0.08	-0.14
3	11	0.02	0.08	-0.17
4	1	0.13	-0.18	0.24
5	2	0.19	-0.19	0.00
6	13	-0.24	-0.19	0.13
7	14	-0.11	-0.04	0.00
8	15	-0.25	-0.13	0.14

Scores 38 26 13 Temperament Controlled
Scores 39 27 14 Temperament Stable
Scores 41 29 16 Temperament Excitable

c.

Students N. 48

		13	14	16
1	35	0.02	0.06	-0.07
2	17	0.08	-0.18	0.17
3	19	0.15	0.00	0.20
4	31	-0.11	-0.19	0.17
5	32	0.05	0.05	0.08
6	27	-0.19	-0.15	0.30
7	28	0.02	-0.17	0.15
8	29	0.08	-0.18	0.34

1st column new score 2nd column original score

In each type of binocular score there is one significant correlation with a speed-flexibility score (Table 7.14). If the correlations below .20 are removed, a clear pattern of signs emerges, Table 7.15 indicating a low level of relationship between rigidity in binocular vision and poor performance on many psychological tests of this type. The proposal is supported in that there is some relationship between binocular rigidity and psychological rigidity.

There is no clear indication of any relationship between binocular vision and body dimensions. The proposal is not supported (Table 7.16).

Table 7.14

Corrections between Binocular and Speed-rigidity Flexibility Scores

	21	23	24	25	34	35	15	19	20	22	47
87	-0.16	0.13	0.42	0.14	0.30	0.11	-0.09	0.02	-0.08	-0.49	-0.46
81	0.12	0.30	-0.04	-0.42	-0.31	0.16	0.10	-0.11	0.07	0.30	0.31
82	0.14	-0.29	-0.07	0.05	0.13	0.13	0.01	0.06	0.18	0.18	0.14
90	0.02	-0.21	-0.13	-0.23	-0.11	-0.09	0.29	0.05	0.22	0.06	0.24
92	0.17	-0.01	-0.08	-0.22	-0.04	0.09	0.16	-0.06	0.43	0.03	0.27
94	-0.10	-0.38	-0.28	-0.16	-0.22	-0.34	-0.06	-0.19	-0.13	0.32	0.14
95	0.21	0.05	-0.20	-0.01	0.02	0.28	0.25	0.40	0.36	0.27	0.47
96	0.07	0.09	-0.44	-0.09	-0.21	0.07	0.10	0.15	-0.01	0.09	0.22

Score	Description
81. 82.	Retinal rivalry
87 F	Fall off of fusional lock
90. 92.	Cyclovergence
94. 95. 96.	Stereoscopic tests
15. 47 R	Pauli test. Errors
19 R	Stroop test Time with distraction.
20 R	Stroop test Errors with distraction
22 R	Sorting errors
Scores of F1	
21	Stroop performance
23	Sorting speed
24	Asterisk counting performance
25	Digit counting performance
34	Pursuit performance
35	Repeated letters performance

Significant correlations have been underlined.

Table 7.15

Correlations of .20 and above between scores of performance and binocular rigidity

	E 15	T 19	E 20	E 22	P 21	P 23	P 24	P 25	P 34	P 35
87				-0.49			0.42		0.30	
81				0.30			-0.42	-0.31		
82						-0.29				
90	0.29		0.22			-0.21		-0.23		
92			0.43					-0.22		
94		0.40		0.32		-0.38	-0.28		-0.22	-0.34
95	0.25		0.36	0.27	0.21		-0.20			0.28
96		0.21					-0.44		-0.21	

Correlation signs which are not consistent with the proposal have been underlined.

E	Error score
T	Time score
P	Performance score

Table 7.16

Correlations between binocular scores and body dimension scores

	11	32	33	79	100
81	-0.30	0.10	-0.15	0.01	-0.06
82	-0.27	-0.05	-0.18	0.11	0.12
87	0.34	-0.60	0.39	-0.17	0.08
90	-0.05	-0.04	0.21	-0.05	0.24
92	0.11	-0.09	0.39	0.09	0.19
94	-0.42	0.32	-0.40	0.12	0.04
95	0.23	0.16	-0.02	-0.16	-0.18
96	-0.09	0.36	-0.33	-0.09	-0.13

Score	Description
81. 82.	Retinal rivalry
87.	Fall off of fusional lock
90. 92.	Cyclovergence
94. 95. 96.	Stereoscopic tests
83. 97.	Positive fusional reserve
85. 98.	Negative fusional reserve

Score	Description
11.	Ponderal index
32.	Skull/ br/Length
33.	Skull ht/Br.
79.	Skull depth
100.	Distance between eyes.

Significant correlations have been underlined.

The Factor Analysis

Throughout the correlations relating binocular vision to psychological rigidity, there appears some vague relationship, which can also be seen in the factor analysis of the larger sample. Its existence can be seen by a study of the signs of the correlations between the binocular scores which were designed to measure rigidity in binocular vision (Table 7.17 a, b and c).

Table 7.17

Correlations between binocular scores designed to measure rigidity in binocular vision

(a) Students N.23

		F 1	2	3	4	5	6	7	8	
F	1	1.0								1. Fall Off
	2		1.0							2. Cyclovergence
	3			1.0						3. Cyclovergence
	4	-0.30	0.35							4. Retinal Rivalry
	5	-0.30	0.47	0.40		1.0				5. Retinal Rivalry
	6	-0.38	0.34		0.40		1.0			6. Stereopsis. Rigidity of inhibition
	7	-0.44	0.17	0.22	0.28			1.0		7. Stereopsis. Conflict
	8	-0.43	0.16		[illegible]				1.0	8. Stereopsis. Conflict

The correlations below .10 where the sign is largely due to chance have been removed. Score 1, the fall off of binocular vision relates to flexibility, the other scores to rigidity. In terms of the proposal incorrect signs have been underlined. Intra-test correlations which would always be positive have been replaced with a cross.

(b) Staff N.37

	F							
	1	2	3	4	5	6	7	8
F1	1.0							
2	-0.51	1.0						
3	-0.39	x	1.0					
4	-0.22		0.32	1.0				
5	-0.22		0.30	x	1.0			
6			0.10			1.0		
7	-0.15		0.25			x	1.0	
8	-0.14	0.30	0.18			x	x	1.0

(c) Students N.48

	F							
	1	2	3	4	5	6	7	8
F1								
2	-0.28	1.0						
3		x	1.0					
4	-0.10		0.24	1.0				
5	-0.10		0.21	x	1.0			
6	-0.18	0.12		0.10		1.0		
7		0.24	0.41			x	1.0	
8		0.20	0.24	0.11	0.14	x	x	1.0

In the sample of 87 students (Table 7.18), there is a clear relation between perseveration and cyclovergence and the stereoscopic scores. The correlation matrix is given in Table 7.18 and the factor analysis in Table 7.19. All the individual scores had a measure of sampling adequacy (M.S.A.) of above .541. The mean M.S.A. was 0.771.

Keiser's criterion indicated two factors. The two factors can be seen to be one of perseveration which is also responsible for variability in binocular scores and a second factor of temperamental rigidity which is seen to be slightly involved in binocular rigidity.

An orthogonal rotation of the factors was computed by the Varimax programme (Keiser, 1959) and an oblique rotation by the Direct Quartimin programme (Jennrich and Sampson, 1966).

The factor loadings are given in Table 7.18. In terms of the definitions of these scores, they are all measures of rigidity with the exception of score 41 which measures excitability of temperament. This is the only score with a negative loading (Table 7.14). This negative loading disappears when the factors are rotated. The low level of loading of the temperament comparator scores and the negative loading on score 41, suggests that there is some relation between the rigid temperament and binocular vision.

This type of relationship below the 5 per cent significance level appeared regularly during the research work, and was one of the reasons why the original programme was abandoned, there being no clear-cut and significant relation between the psychological and binocular vision scores.

Table 7.18

Correlations between scores of Psychological Rigidity and Binocular Rigidity from a sample of 87 students

		1	2	3	4	5	6	7	8	9	10	11
1	38	1.00										
2	39	0.51	1.00									
3	40	0.11	0.32	1.00								
4	41	-0.38	-0.81	-0.34	1.00							
5	52	0.12	0.19	0.21	-0.16	1.00						
6	53	0.04	0.04	0.15	-0.05	0.76	1.00					
7	90	0.12	0.12	0.16	-0.10	0.74	0.76	1.00				
8	92	0.10	0.10	0.12	-0.09	0.75	0.74	0.97	1.00			
9	94	0.05	0.12	0.15	-0.02	0.71	0.76	0.84	0.79	1.00		
10	95	0.07	0.06	0.01	-0.01	0.46	0.46	0.55	0.57	0.53	1.00	
11	96	0.09	0.08	-0.02	0.09	0.47	0.57	0.58	0.57	0.70	0.62	1.00

Score	Description
38.	Rigid Temperament
39.	Controlled Temperament
40.	Self Assured
41.	Excitable Temperament
52.	Perseveration
53.	Perseveration
90.	Cycloversion
92.	Cycloversion
94.	Rigidity in stereopsis
95.	Rigidity in stereopsis
96.	Rigidity in stereopsis

Table 7.19

Two unrotated factors

Score	Definition	Factor 1.	Factor 2.
38	Rigid Temperament	0.12	0.49
39	Rigid Temperament	0.13	0.88
40		0.15	0.35
41	Flexible Temperament	-0.10	-0.86
52	Perseveration	0.79	0.09
53	Perseveration	0.80	-0.06
90	Cyclovergence	0.98	-0.01
92	Cyclovergence	0.97	-0.02
94	Stereopsis	0.86	-0.04
95	Stereopsis	0.59	-0.05
96	Stereopsis	0.63	-0.10

Scores 38 - 40 measure rigidity in temperament by self assessment.
41 measures flexibility in temperament
52 & 53 measures Perseveration in a visuo-motor situation
90 & 92 measures cyclovergence
94 - 96 measures rigidity in binocular vision via a stereoscopic test.

The factors are quite clear. Factor 1 is some type of rigidity affecting perseveration tests and binocular tests. Factor 2 is rigidity in temperament measured by self assessment and slightly affecting binocular vision.

Table 7.20

Orthogonal rotation of factor analysis verimax rotation

Score	Factor 1	Factor 2
38	0.05	0.50
39	0.01	0.89
40	0.11	0.37
41	0.01	-0.87
52	0.77	0.20
53	0.80	0.05
90	0.97	0.12
92	0.96	0.11
94	0.86	0.07
95	0.59	0.03
96	0.64	-0.02

Oblique rotation of factor analysis

Score	Description
38.	Rigid Temperament
39.	Controlled Temperament
40.	Self Assured
41.	Excitable Temperament
52.	Perseveration
53.	Perseveration
90.	Cycloversion
92.	Cycloversion
94.	Rigidity in stereopsis
95.	Rigidity in stereopsis
96.	Rigidity in stereopsis

Table 7.21

Oblique factor rotation

Old Score	New score	Factor 1	Factor 2
38	1	0.01	0.51
39	2	-0.06	0.90
40	3	0.08	0.37
41	4	0.09	-0.88
52	5	0.76	0.13
53	6	0.80	-0.02
90	7	0.97	0.04
92	8	0.97	0.02
94	9	0.87	-0.00
95	10	0.60	-0.03
96	11	0.64	-0.07

Score	Description
38.	Rigid Temperament
39.	Controlled Temperament
40.	Self assured
41.	Excitable Temperament
52	Perseveration
53.	Perseveration
90.	Cycloversion
92.	Cycloversion
94.	Rigidity in stereopsis
95.	Rigidity in stereopsis
96.	Rigidity in stereopsis

CHAPTER 8

DISCUSSION OF THE EXPERIMENTAL RESULTS

The Relation to the Model

The model of the process whereby single vision results from two retinal inputs was based on the established neurology. This was shown to innervate three separate processes, all controlled by the same or closely related areas of cortex, concentrated between Brodman's areas 18 and 22. This area, mostly involving the walls of the angular gyrus and the cortex adjacent to it appears to be finally responsible for the control of the three processes, the motor control, the summation of the two inputs and the inhibition of the conflicting parts of these inputs. The discussion of the results in relation to the non-visual variables found in binocular performance is based on their separation into these three areas.

The Motor Control

The experiment on the motivation of convergence shows that the subject responds in a normal way to suggestion and motivation. In this sense, these stimuli are established as non-visual variations affecting binocular behaviour.

There is merely a possibility that the ocular movement may be more powerful in those with stronger muscles.

There was no clear deduction to be drawn from the recovery points which it was thought would give some evidence as to the nature of the controlling mechanism.

The Summating Mechanism

It was proposed that because the summating mechanism produced the fusional lock, the variability of this mechanism could be measured through the fusional reserves. These are of two types, the horizontal measurements relating to convergence and divergence, and the cyclofusional reserves involving ocular tortion.

Both of these fusional reserves measure some aspect of the flexibility of the fusional lock. The break measurement measures its rigidity and the recovery point represents the ability of the motor control to re-establish fusion.

The horizontal measurement involves two functions, the strength of the fusional lock and the rigidity of the convergence accommodation neural linkage. The linkage changes its nature with age due to the hardening of the crystalline lens. The effect of this was seen in the sign of the correlation between the F.R.scores and the psychological scores which was opposite in the two pilot studies, probably because of the age difference between the samples.

A further source of variability in this measurement can be seen by comparing the results between the test when given at distance with a rotary prism, with the measurement obtained by converging and diverging the tubes of the haploscope. The correlations between the two sets of measurements of the two functions are not significant.

This is thought to be due to the operation of a sense of nearness, in that, although the accommodation is relieved by plus lenses and the subject's eyes are parallel, as though looking to infinity, the subject knows that they are looking into tubes some 30 cm long.

The results from the pilot studies suggest that the value of the horizontal fusional reserve as a measure of rigidity in binocular performance is very limited.

The Cycloversion Scores

This objection does not apply to the cycloversion scores. Four such scores were included in the binocular test battery. The two recovery scores proved to be unreliable compared to the measurement to break with a vertical and a horizontal line as a target.

These two scores have consistently correlated positively with scores of psychological rigidity and with time scores on performance. The factor analysis relates the score to perseveration.

The Fall-Off Score

This score represents the reciprocal of the strength of the fusional lock and was measured in terms of the amount of fogging of one eye which would cause fusion to collapse. The score appears to measure the flexibility of the binocular lock and to relate to psychological rigidity.

The Inhibition Mechanism

The Retinal Rivalry Score

This score measures an aspect of the flexibility of the normal inhibition process in binocular vision when an image is partly fused and partly inhibited, through the ease of reversal of retinal rivalry in that part of the image has to be inhibited, firstly by the right eye and then by the left eye.

The pilot test results suggest that it measures some aspect of rigidity in this process and relates vaguely to psychological rigidity.

The Stereoscopic Scores

Three tests of stereopsis were used in the binocular battery. The first test measured an aspect of ease of suspension of part of an image and hence was similar to the retinal rivalry test. All three of the stereoscopic tests measure some aspect of rigidity in binocular vision. In the second and third tests the monocular sense of perspective and reality were put into conflict with the stereoscopic data. In all these tests the distribution was bimodal, several subjects in each sample being unable to exchange the monocular percept for the binocular, or in the case of the first test, being unable to make the necessary suspension to see the stereoscopic picture. The factor analysis relates the function clearly to visuo-motor perseveration.

The Selection of Eight Binocular Scores

From this consideration of the results of the two pilot studies, eight scores were selected as measuring an aspect of rigidity in binocular performance.

One score only related to flexibility in binocular vision, that is the fall-off scores which measures the ease of collapse of the fusional function.

Two cyclovergence measurements, the retinal rivalry scores and the stereoscopic scores measure rigidity in binocular vision.

The suggestion that there might be a type of rigidity common to all eight binocular tests is supported in Tables 7.17 a, b and c in which correlations were calculated between the eight scores selected. The signs between these correlations are all positive except those with the score for the fall-off, the only score where it was predicted that the measurement would be of binocular flexibility, the other seven measuring binocular rigidity.

It was also proposed that perseveration might be the common factor. This is supported by the factor analysis given in Table 7.20 which selected the two scores 52 and 53 representing perseveration in a visuo-motor test, as the major non-visual variable in the cyclovergence and stereoscopic tests.

In the light of this finding, it is interesting to consider the results of the research on perseveration and their support or refutation of the results of previous workers in this field.

The Results of the Perseveration Tests

In considering tests for perseveration it was stated that the evidence from previous research was that if the test target was kept constant and the testing conditions varied, that a high correlation was found between the test results, while if the target was changed but the testing conditions kept constant, the correlations were of a low order. This was borne out in the research programme.

Perseveration was measured by three methods in the pilot study, by the tendency of an ambiguous figure not to change, by the difficulty of changing to a new pattern of response to visual signals in a visuo-motor test, and by the difficulty in changing an imagined picture to its opposite.

The consistency of perseveration when the stimulus is constant, but the viewing method is changed is shown in the correlations between scores 55, 56 and 57. The subject watched a moving ambiguous pattern, firstly with roving fixation then with steady fixation, firstly to the right of the target and then below it. The correlations are given in Table 8.1.

Similarly there is a significant correlation of .52 between the time taken to do the test and the number of errors scored in the Discriminator visuo-motor test. The correlation between the time to the first change and the number of changes in unit time for the moving rods was not quite significant at the 5 per cent level, being -.37.

Table 8.1

Correlations between the rate of change of perception of a dynamic ambiguous figure

	55	56	
55	1.0		Roving fixation
56	0.93	1.0	Fixation to the right
57	0.89	0.79	Fixation below the target

In contrast to these results the correlations between the rates of change of different ambiguous targets are very low and only one is significant and has the correct sign, some signs being opposite to that anticipated (Table 8.2).

The two tables provide interesting support for the hypothesis despite the small size of the pilot sample.

Table 8.2

Correlations between scores thought to measure perseveration

	8	9	52	53	55	56	57	75	77
8	1.0								
9	-0.37	1.0							
52	-0.42	0.11	1.0						
53	0.13	-0.06	0.51	1.0					
55	0.05	-0.26	0.00	0.53	1.0				
56	-0.07	-0.11	-0.01	0.41	0.93	1.0			
57	0.18	-0.38	0.12	0.50	0.90	0.79	1.0		
75	-0.04	-0.14	0.10	0.15	0.23	0.37	0.11	1.0	
77	-0.05	-0.02	0.19	-0.01	-0.14	-0.14	0.04	-0.32	1.0

Scores 9, 52 and 53 measure rigidity. The other scores relate to flexibility.

Score	Description
8	Ambiguous figure rate of change
9	Ambiguous figure time to first change
55	Ambiguous figure rate of change
56	Ambiguous figure rate of change
57	Ambiguous figure rate of change
75	Necker cube rate of change
77	Imagined picture. Ability to change
52	The Discriminator. Errors in visuo-motor test
53	The Discriminator. Total time

The suggestion that there might be different types of binocular perseveration resulting from the effect of experience on a very small basic built-in perseveration in all central nervous systems, is contained in the correlations in Table 7.11.

The correlations suggest that the perseveration which results in the length of time to the first change of perception in the moving rods ambiguous figure test and the lack of this perseveration producing a high rate of change, is the same perseveration which results in the resistance to change measured with the cyclovergence lines (Scores 8, 9, 90 and 92). Similarly the rate of change of the dynamic ambiguous figure (scores 55, 56, 57) relates to the inability to see the stereoscopic figure because the monocular percept has persisted (score 95) and the rate of change of the Necker cube is related negatively to the long time taken to change from the monocular to the stereoscopic percept (Scores 75, 95 and 96).

The factor analysis (Table 7.19) suggests that there is only a very vague relationship between the rigidity measured with the temperament comparator and the binocular scores. This can be similarly compared with the results from the three sample pilot studies. The correlations are given in Tables 7.13 a, b and c.

The correlations between the rating of temperament Tables 7.12 a, b and c suggest that the stable temperament rating represents a type of rigidity and the excitable temperament a type of flexibility. These scores correlate negatively with each other at the 1 per cent level of confidence.

The pilot study, Tables 7.13 a, b and c suggest that this flexibility-rigidity is part of the rigidity in binocular vision, but the correlations are only repeated in the staff sample with scores one, six and eight (Table 7.13 b). They are not repeated at all on the sample of 48 (Table 7.13 c).

This type of result is mentioned by Cronback (1960) as typical of research into psychological rigidity. He wrote:

> To summarise the research on generality is next to impossible. For some traits such as "rigidity" there have been a dozen papers summarising correlations, and even the summaries are in disagreement. Some conclude that there is a general rigidity, some find three or four rigidity factors, (never the same from study to study) and some argue that the very concept of rigidity is invalidated by the date.

The Authoritarian Personality

This variability might account for the failure to find an aspect of binocular rigidity common to measures of authoritarianism. The writer was particularly interested in this aspect of rigidity because of the trait found in the authoritarians of a dislike of dichotomy. It seemed possible that this was similar to a dislike of diplopia, the end point of so many of the binocular tests and was a reason that rigidity appeared to be a variable in their performance.

The monumental work of Adorna et al. (1950) has been severely criticised. Several workers have found that the authoritarian personality and the F and D scales can be factor analysed (Warr, Lee and Joreskog, 1969), but the factors extracted are not the same from study to study. Eysenck (1971) states that these factors are not pure. Coleman and Lambley (1970), repeating the work on authoritarianism giving correlations between this trait and American racialism, found that the correlations in South Africa were much lower. The original work of Adorna et al. and the subsequent criticisms, have been studied by Schepers (1968) and Steyn (1971), and a long programme of research was initiated by the Institute in order to arrive at a reliable score for measuring Authoritarianism in South Africa.

Steyn found that the South African Authoritarian was based on a somewhat loose syndrom of six semi-independent variables which were named. The intercorrelation with each other is shown in Table 8.3.

Table 8.3

Significant Correlations between factors extracted from research on the South African Authoritarian

	1.	2.	3.	4.	5.
1. Emotional passivity					
2. Over-regimentation	.24				
3. Exaggerated self confidence	.46		.21		
4. Concern about health			.23	.21	
5. Authoritarian submission	.16		.60		
6. Authoritarian aggression			.32		.51

As the students who underwent the tests described in this thesis were almost all South Africans, and as a dislike of dichotomy does not appear in the factors, the writer's proposal that this trait might be responsible for the non-visual variation, was not supported.

Studies of prejudice among children show that, like ocular dominance, we are born without it. It would seem reasonable therefore to argue that as psychological rigidity has been isolated and measured in every part of our behaviour, that each one of these rigidities has developed differently according to our experience of life. This being so, only low correlations will be found between the tests which appear to measure prejudice.

This thinking is supported by one of W. Penfield's observations, that the association function of parietal cortex develops according to the needs of the individual. He found that an area of parietal cortex gave rise to auditory association in persons from musical families, while the same cortex gave rise to linear and visual association in persons who were artists.

If this is so, then the behaviour resulting from innervations of Brodman's area 22 will vary from person to person depending on how they made use of their binocular vision in their developing years.

This would account for the variability found in all three aspects of the fusional function, and for the fact that its distribution is not like that of a physiological function, but more like that of the intelligence quotient.

It would also explain why significant correlations were found with perseveration which is thought to develop with experience and not with temperament which is thought to be inherited.

CHAPTER 9

EVALUATION AND CONCLUSIONS

The programme of research into binocular vision has developed tests which isolate non-visual variables in binocular performance and has measured them with a reasonable degree of accuracy. A study of the correlations between eight of these tests suggests that there is a common factor of rigidity to all of these functions. The psychological programme, by a process of elimination, has shown this to be perseveration.

The published evidence on binocular vision, supported by the result of the EEG research programme provided the material from which a model of the process whereby one visual percept from two retinal inputs was created. It is basic to this thesis that this process was shown to be of three parts, and that the neurology finally controlling each part was located in the parietal lobe.

This area of cortex might well be considered the centre of association where incoming sensory information is constructed into percepts, related to memory and recognised. It is the very core of perceptual psychology.

This is in complete agreement with the experimental results, where the scores from eight of the binocular tests are shown to have a variability which is not visual and which is psychological.

The factor analysis indicates that the major variable is perseveration.

A further study of the pilot results suggests that perseveration is not a unitarian function, but varies from one situation to another. As a result it may be assumed that the measure of perseveration in binocular vision is unlikely to be of very great value to psychological clinical work.

The Value of the Research to Psychology

The disadvantage of binocular tests as a measure of rigidity is immediately apparent from the severe screening of subjects which is necessary before the measurements can be made. To screen accurately an optometric assessment is necessary. The only tests where this disadvantage might be overcome are the stereoscopic tests. The measurement of the strength of the fusional lock in terms of its collapse is difficult and could not be performed by a psychologist without optometric training. This also applies to the retinal rivalry test used in this programme. The cyclovergence test could easily be done, but it would require that the subject was visually screened within certain limits. The test has the advantage that it is very simple to administer. The target, a single line, is free of most emotional stimulation. In the binocular battery the test was given with the synoptophore, but it would be easy to devise an uncomplicated stereoscope in which the test could be given.

The subject for the stereoscopic test could be given any standard test for the existence of the normal stereopsis and if they pass this, then they could be subjected to the special stereoscopic test of monocular perseveration.

The bimodal distribution of the results obtained from the stereoscopic tests suggest a possible clinical value. Several of the subjects who were unable to see the stereoscopic picture were peer rated as a flexible or a rigid thinker on a 1-5 point scale, and all those subjects who were unable to see the stereoscopic pictures were rated as markedly rigid.

This test offers a fruitful area of future research. The programme would require the design of a simple instrument in which the stereoscopic sum test could be given. Subjects already classified by another psychological test as rigid or flexible would then be given the test and a correlation matrix calculated to discover if any such psychological test correlates significantly with the sum times, and hence indicates what type of rigidity it measures and how useful it might be.

The Value of the Research to Optometry

The information gathered from the results of the pilot studies with the binocular tests have proved to be of great clinical value to optometry.

From one of the experiments described in Chapter 2 a new binocular refractive technique was developed and a paper describing the research on which it was based, and the method of clinical application, was read to an International Optometry Conference in London, and subsequently published (Humphriss and Woodruff, 1962). Further research on the method improved its accuracy so that Rabbetts (1972) investigating the consistency of ocular tortion in near and distance vision, and requiring a refractive technique which had a high test-retest correlation, found the Humphriss Immediate Contrast Technique to be the most effective.

The method described for measuring sensory retinal rivalry was improved and a method of measuring sensory ocular dominance derived from it. The relationship between this dominance and personality was published in America (Humphriss, 1969).

There is also a value to academic optometry. Some of the refractive techniques which are taught depend on the use of a mean score obtained from a binocular test. This is clearly not satisfactory, as the distribution of these scores is shown in this research to have a large standard deviation. It is doubtful if a score which can be applied to any one individual can be established, and new tests will ve to be found which avoid the use of the mean, and which measure the values for the particular person being refracted.

In addition to the clinical results, the reading which had accompanied the research work had convinced the writer that the unity of vision does not come about according to some of the published theories, but from some sort of psychological assembly of monocular data which has been processed previously and independently. The arguments in favour of this thinking were presented at the South African Optometric Association's Memorial Lecture (Humphriss, 1964). This thinking is also supported by EEG research presented in this thesis which established a centre for visual suppression in the parieto-temporal cortex, outside the area normally considered to be visual cortex.

If the author had to justify the time spent by psychologists on this programme of research, he would do so by demonstrating the many fields of research where cross discipline work has resulted in the explanation of mysteries not solved by the one discipline on its own. In this case the need to explain the function of suppression to the psychologists and to draw parallels within their field, led to the discovery which has established the new valuable refractive technique.

The Effect of the Research on the Model

Academically the facts relating to psychology and derived from the research programme have changed the appearance of the model of the process which produces single binocular vision especially in its final and most sophisticated process.

In Chapter 2 this model was built up by deduction from the neurology described there. None of the experimental results is a misfit with this model, some support it strongly, others only at a lower level of correlation.

The optometric correlations show that there are non-visual factors present in all the processes which take place before unification of the two retinal inputs is achieved, and are also responsible for the strength of the mechanism which maintains it.

The EEG research suggests that it is a learned process, and hence open to all the variations which accompany learning.

The act of obtaining a single binocular percept from two retinal inputs may then be visualised in this manner. Assuming that the viewer changes the direction of gaze from one point to another his right and left ocular directions will firstly be directed monocularly initially by a reflex innervation, probably physiological, followed by a voluntary innervation which will direct the two visual axes to the new point of interest. The binocular apparatus will take over from the occipital and frontal innervations when the two eyes have reached the point of interest and the retinal images fall within the macula area. At this point control is passed to the binocular neurology in the parietal lobe, and the psychological variables become operative. They will determine the speed and accuracy with which the two retinal images are aligned. They will subsequently determine the strength of the fusional lock which will keep the images in their firmly related positions. If the two images are only partly fusible, this cortex will examine the extent of the difference. If this is considerable the images will be relayed away from the parietal cortex, possibly to the hippocampus where one image will be selected in terms of psychological familiarity, or personal prejudice against one of them. The other will then reach the conscious level.

If the image is mostly fusible with parts in rivalry, then the parietal cortex will decide which parts to inhibit and will fuse the balance and bring the single image to consciousness.

Probably, at the same time, the process of comparing the angular differences between the parts of the two images and converting them to the stereoscopic sense of the third dimension will take place, although the experimental results show this to be a slow process whose operation may be totally suppressed by a previous strongly held impression of the appearance of the object from a monocular examination of it.

The platform on which this model of binocular vision is erected consists of the facts indicating that the end processes take place in association cortex and not in primary sensory cortex.

The working of this parietal cortex is known to be mostly learned and its operation is affected by perseveration, and probably by the other factors which make up psychological rigidity.

This parietal cortex, where learning takes place, and where binocular vision is concentrated is responsible for all the final acts which produce the haploscopic percept. The non-visual variables pervade all its operations and its output and hence they will affect all the end processes which bring to consciousness the world as we perceive it.

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