

THE IDENTIFICATION OF VESTIBULAR PROCESSING

DYSFUNCTION IN DISORDERS OF SENSORY

INTEGRATION

By

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ABSTRACT

The aims of this study were:

- to compare the Southern California Postrotatory Nystagmus Test and electronystagmography as measurements of vestibular function;
- to compare the electronystagmograms of normal children with those of children who have vestibular based sensory integrative problems;
- to determine whether Ayres' test criteria distinguish between normal and abnormal vestibular function, as determined by electronystagmography.

The control sample consisted of 23 boys with no learning or sensory integrative problems; and the experimental sample consisted of 23 boys identified according to Ayres' test criteria as having a vestibular based sensory integrative problem. Ages ranged from 6 years to 8 years 11 months.

All children were subjected to a battery of tests consisting of The Southern California Sensory Integration Tests (1980), the Southern California Postrotatory Nystagmus Test (1975) and Ayres' clinical observations (1972).

Children in both samples were then given an electronystagmographic examination which took place in a darkened room. Vestibular nystagmus was induced by rotating the child in a purpose built electrically driven chair. The

child wore blacked out goggles, and during rotation his head was held at a 30 degree angle by an adapted neck brace. Nystagmus was measured in the standard way.

Mean maximum speed of slow slope of nystagmus is considered to be the most accurate and objective measurement of vestibular function. Comparison of the mean maximum speed of the slow slope of nystagmus recorded during electronystagmography (ENG) and scores obtained in The Southern California Postrotatory Nystagmus Test showed no significant correlation.

No significant difference was found in the mean maximum speed of slow slope, symmetry of response or duration of postrotatory nystagmus when ENG measurements of the experimental and control samples were compared. A significant difference between the two samples was however found in the frequency of nystagmus beats.

The 28 test variables constituting Ayres' selection criteria, did not show significant correlation with the mean maximum speed of slow slope.

The following conclusions were drawn from these results:

1. The Southern California Postrotatory Nystagmus Test is invalid and should no longer be used to identify vestibular dysfunction.
2. Sensory integrative disorders cannot be attributed to vestibular dysfunction since the ENG did not identify the

children as did Ayres' test criteria.

3. The symptoms and signs which these children present, stem from integrative disorders which are likely to be of cortical origin, rather than due to vestibular dysfunction.
4. The relevance of evaluating vestibular function in children with sensory integrative disorders, and the validity of vestibular stimulation in therapy is questioned.
5. Further research is necessary to establish the reasons for the positive results which undoubtedly follow sensory integrative therapy.

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CHAPTER 1

INTRODUCTION

Ayres (1969, 1972) believes that many learning disabilities are the result of sensory integrative disorders. She has postulated that the vestibular system, because it is one of the earliest sensory systems to develop and because it has multiple connections throughout the central nervous system, exerts an important influence on "sensory integration." She defines sensory integration as:

"The organization of sensory input for use. The "use" may be a perception of the body or the world, or an adaptive response, or a learning process, or the development of some neural function. Through sensory integration, the many parts of the nervous system work together so that a person can interact with the environment effectively and experience appropriate satisfaction." (Ayres, 1979, p. 184)

To date the Southern California Sensory Integration Tests (Ayres, 1980) and the Southern California Postrotatory Nystagmus Test (Ayres, 1975), together with certain clinical observations suggested by Ayres (1972) have been the occupational therapist's tools for diagnosing vestibular problems affecting sensory integration.

Arising from her work Ayres developed a treatment technique called "Sensory integrative therapy". This is defined as:

"Treatment involving sensory stimulation and adaptive responses to it according to the child's neurologic needs. Therapy usually involves full body movements

that provide vestibular, proprioceptive, and tactile stimulation. It usually does not involve activities at a desk, speech training, reading lessons, or training in specific perceptual or motor skills. The goal of therapy is to improve the way the brain processes and organizes sensations". (Ayres, 1979, p.184)

This technique is widely used by South African occupational therapists for children with disorders in sensory integration, many of which are vestibular based.

Polatajko, (1981), carried out a study on the relationship between vestibular function and academic learning. Among other things she concluded that:

1. The Southern California Postrotatory Nystagmus Test constitutes a combination of vestibular and visual stimulation and should therefore not be used to diagnose vestibular dysfunction.
2. The practice of classifying children according to the integrity of the vestibular system should be abandoned and evidence of vestibular dysfunction should be regarded as a neurological "soft sign."

There is an increasing awareness amongst South African occupational therapists of the shortcomings of the Southern California Postrotatory Nystagmus test based on the following observations:

1. As noted by Polatajko (1981) this test is administered with the child's eyes open. The resultant visual stimulation produces an optokinetic reflex. The test is therefore not a pure measure of vestibular nystagmus.

2. No attempt is made to keep the child mentally alert during testing, despite the fact that mental alertness is known to affect the nystagmic response. (Eviater and Eviater, 1979; Strauss and Gottesberge, 1978)
3. No steps are taken to maintain the child's head at a thirty degree angle, which is necessary in order to ensure that the horizontal semicircular canals are being stimulated during rotation.
4. The child is rotated manually. This entails slight variations in the speed and smoothness of rotation. These will affect the nystagmic response which is directly related to the quality of the stimulus. (Fluur and Mendel, 1969)
5. On cessation of rotation the child is asked to look towards a blank wall without focussing on a fixed point. Since the normal adaptive response is to fixate on an object, which in turn inhibits nystagmus, this command is difficult for the child to obey. It is also impossible for the therapist to determine whether the child is fixating or not.
6. Postrotatory nystagmus is visually monitored and its duration is timed with a stopwatch. This method of recording nystagmus is inaccurate since the beginning and end point of nystagmus are difficult to determine visually. In addition, duration of nystagmus is considered to be one of the least reliable measures of vestibular function. (Mulch, 1978; Corvera and Romero, 1964; Polatajko, 1981; Tibbling, 1969)

Although clinical signs related to vestibular function and other scores in the Southern California Sensory Integration Tests are taken into account when identifying a vestibular based sensory integrative disorder, considerable weighting is given to results of the Southern California Postrotatory Nystagmus Test.

If this test is indeed invalid, incorrect deductions may be made regarding the nature of the child's problem, with the possibility of inappropriate therapy. Thus a further study seemed justified.

1.1 AIMS OF THE PRESENT STUDY

The present study was undertaken:

- 1 To ascertain whether results of the Southern California Postrotatory Nystagmus Test correlate with results of an electronystagmogram in measuring vestibular function, assuming that this latter investigation is the most accurate measurement of vestibular function.
- 2 To discover whether there is a significant difference between the electronystagmograms of children identified as having vestibular based sensory integrative problems, and the electronystagmograms of normal children.
- 3 To discover which of Ayres criteria, individually or in combination, discriminate best between normal and abnormal vestibular function as determined by electronystagmography.

CHAPTER 11

REVIEW OF THE LITERATURE

2.1 ANATOMY OF THE VESTIBULAR SYSTEM

A resume of literature on the anatomy of the vestibular system will be given in this section.

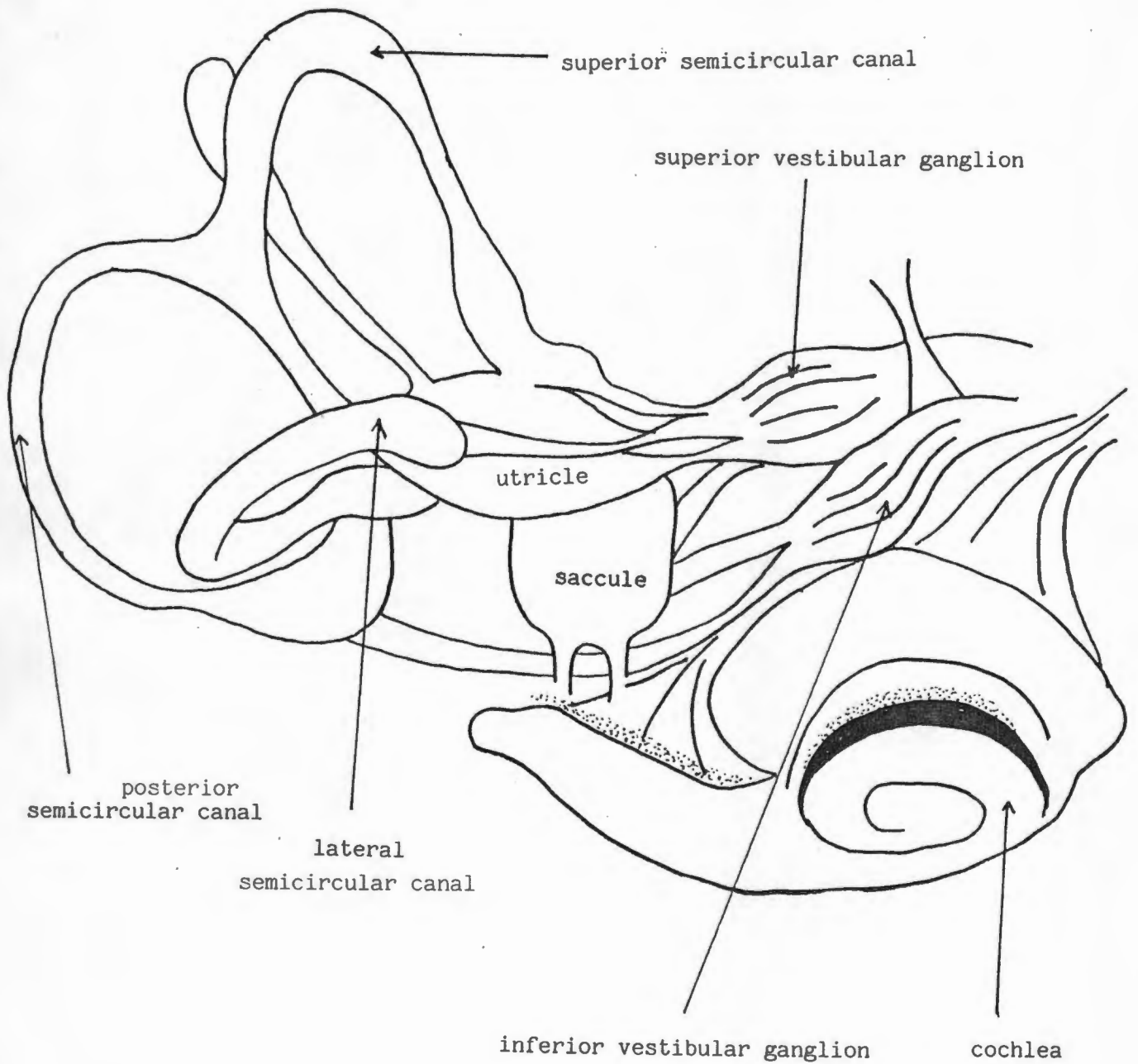
The earliest studies of vestibular function were carried out in the mid-nineteenth century (Kalinovskaya, 1978). These and subsequent work demonstrated manifold connections between the vestibular system, the brain and the spinal cord; and there is now general consensus amongst authors of authoritative texts concerning the structure of the vestibular system. (Guyton 1971; Chusid 1976; Noback 1967; Ganong 1979; Carpenter 1972; Brodal et al 1962 and Bannister 1973). It is made up of the vestibular receptor organ, the vestibular nerve, the vestibular nuclei and their central connections.

VESTIBULAR RECEPTOR ORGAN

The vestibular receptor organ is located in a membranous labyrinth, which is situated in the petrous part of the temporal bone. It consists of three semicircular canals, the utricle and the saccule. This entire complex is encased in a rigid box, the bony labyrinth, from which it is separated by fluid called perilymph.

Figure 1

THE SEMICIRCULAR CANALS (From Wilbarger, 1979)



Semicircular Canals (see fig. 1, p.6)

The three semicircular canals - superior, posterior, and external or horizontal, are arranged at right angles to each other as are the three corners of a cube, so that they represent all three planes in space. When the head is tilted thirty degrees forwards, the two external canals are approximately parallel to the surface of earth. The superior canals are in a vertical plane which projects forwards and 45 degrees outwards from the midline. The posterior canals are also vertical, projecting backwards and outwards at 45 degrees. The superior canal on one side of the head is thus in a plane parallel to that of the posterior canal on the opposite side. The external canals on either side of the head are in the same plane.

Each canal is 0.1 mm. in diameter and 10 to 15 mm. long and has one bulbous end - the ampulla. The ampullae (1 mm. diameter), contain small crests called the crista ampullae which are sensory receptors and consist of hair cells. These are embedded in a gelatinous mass called the cupula. The cupula resembles a swinging door with the hinge represented by the crista and the free swinging edge brushing against the curved wall of the ampulla. Any movement of endolymph pushes the cupula and bends the hairs, setting off impulses in sensory nerve fibers which connect the hair cells to the vestibular nerve.

Figure 2

THE MEMBRANOUS LABYRINTH (from Noback, 1967)

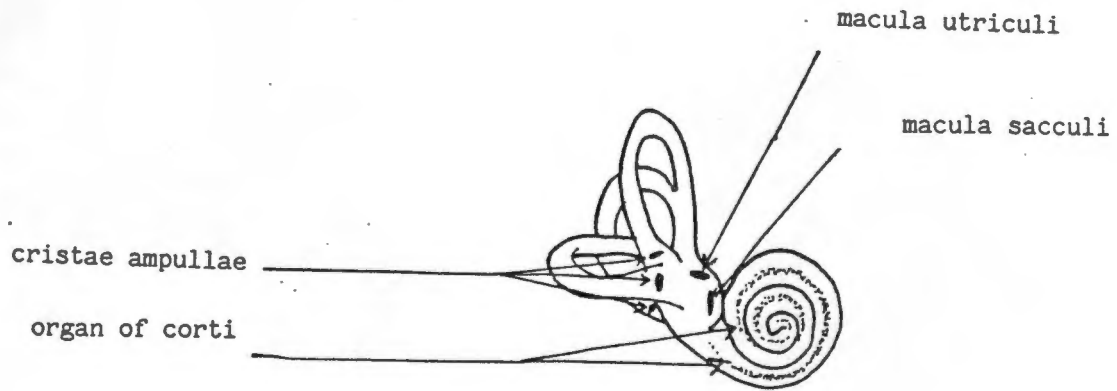


Figure 3

THE CRISTA AMPULLA (from Noback, 1967)

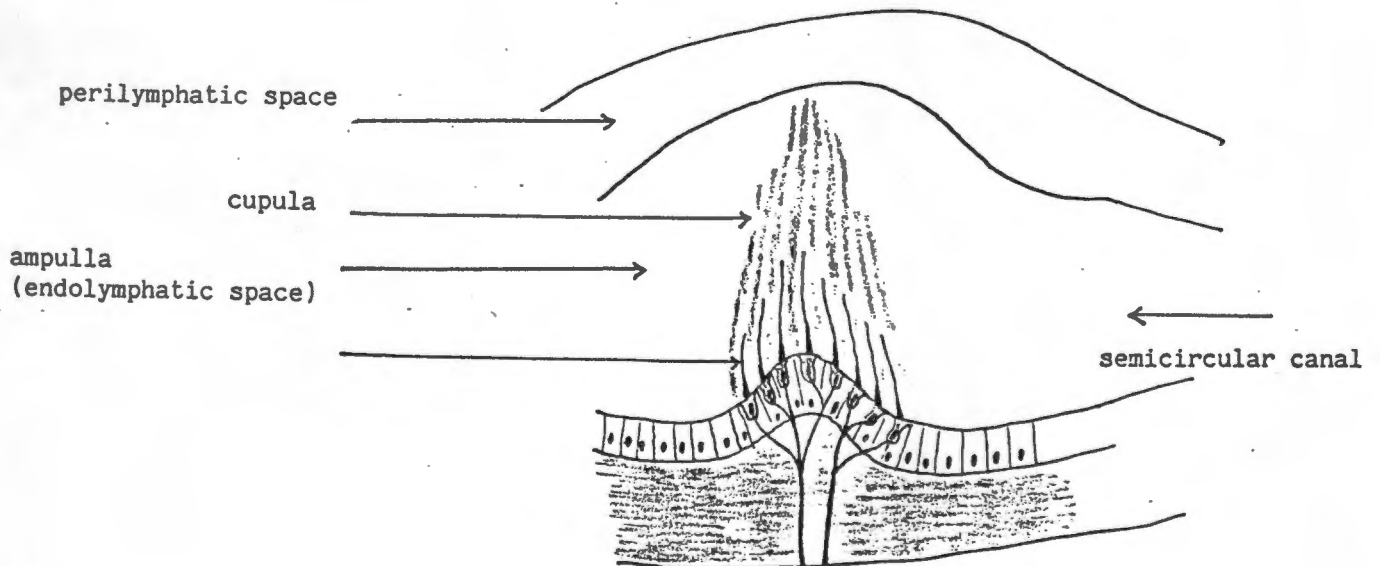
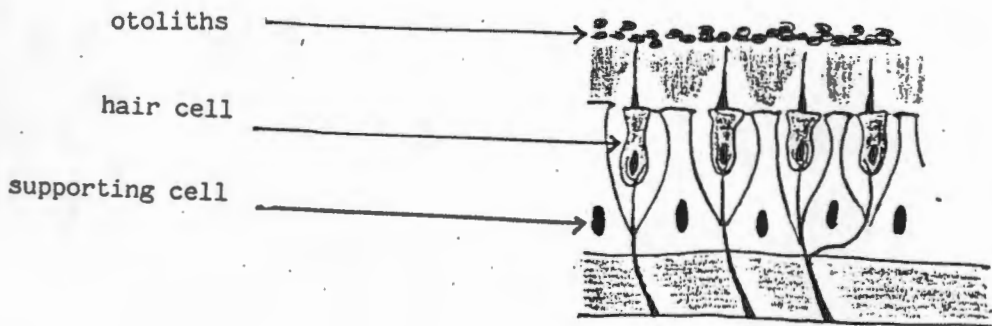


Figure 4

THE MACULA (from Noback, 1967)



Each hair cell has a number of small cilia plus one large cilium - the kinocilium. This is always located on the same side of the cell with respect to its orientation on the ampullary crest and accounts for directional sensitivity. When the flow of fluid in the canals bends the cupula to one side, certain hair cells are stimulated, while bending in the opposite direction results in inhibition. Thus appropriate signals are sent via the vestibular nerve to the central nervous system.

Utricle and Sacculle

The utricle and sacculle are two membranous sacs in communication with the semicircular canals. Both contain a ridge called the macula, composed of hair cells (cilia) and supporting cells which act as the receptor area. The hairs are embedded in a gelatinous mass containing minute crystals of calcium carbonate - the otoliths or otoconia, which are located near the tips of the hairs (see Fig. 4, p. 9). The

long axis of the macula in the utricle is in a horizontal plane, and in the saccule in a vertical plane (see Fig. 2, p. 9). In the macula of the utricle different cells have different orientations thus allowing certain cells to be stimulated for each respective position of the head in space. Around the hair cells are entwined sensory fibres of the vestibular nerve. Distortion of hairs to one or the other side, initiates impulses which reflect the relative positions of the otoconia in the gelatinous mass over the macula.

THE VESTIBULAR NERVE

The eighth cranial nerve - the acoustic, consists of two separate parts: the cochlear and the vestibular nerves. The cochlear nerve transmits exteroceptive impulses, perceived as hearing, from the organ of Corti. The vestibular nerve transmits proprioceptive impulses from the saccule and utricle, and impulses important in the maintenance of equilibrium and orientation in space from the semicircular canals. Impulses conveyed by the vestibular nerve are consciously perceived only to a limited extent.

The 19000 nerve fibres of the vestibular nerve have their bipolar cell bodies in the vestibular ganglion (Scarpa's), near the membranous labyrinth (see fig. 1, p. 6). The bipolar cells in the vestibular ganglion give rise to peripheral fibres which pass to the neuroepithelium in the ampullae of the semicircular canals and the maculae of the utricle and saccule, and central branches. These central branches are the primary fibres of the vestibular nerve which pass into

the upper medulla deep to the inferior cerebellar peduncle, bifurcate into short ascending and descending branches and terminate in specific regions of the vestibular nuclei.

Some fibres carrying impulses from receptors in the semicircular canals do not reach the neurones of the vestibular nuclei directly, but via suprasegmental structures such as the flocculonodular lobes of the cerebellum and other regions of brain stem, particularly the reticular formation. There are also anatomically poorly defined pathways along which impulses from the vestibular receptors are relayed via the thalamus to the cerebral cortex (Ganong 1979).

In addition to afferent fibres coming from various parts of the labyrinth, an efferent component has been demonstrated in the vestibular nerve. The number of efferent fibres is small. They presumably mediate central control of the vestibular receptors, but it is not certain how this occurs.

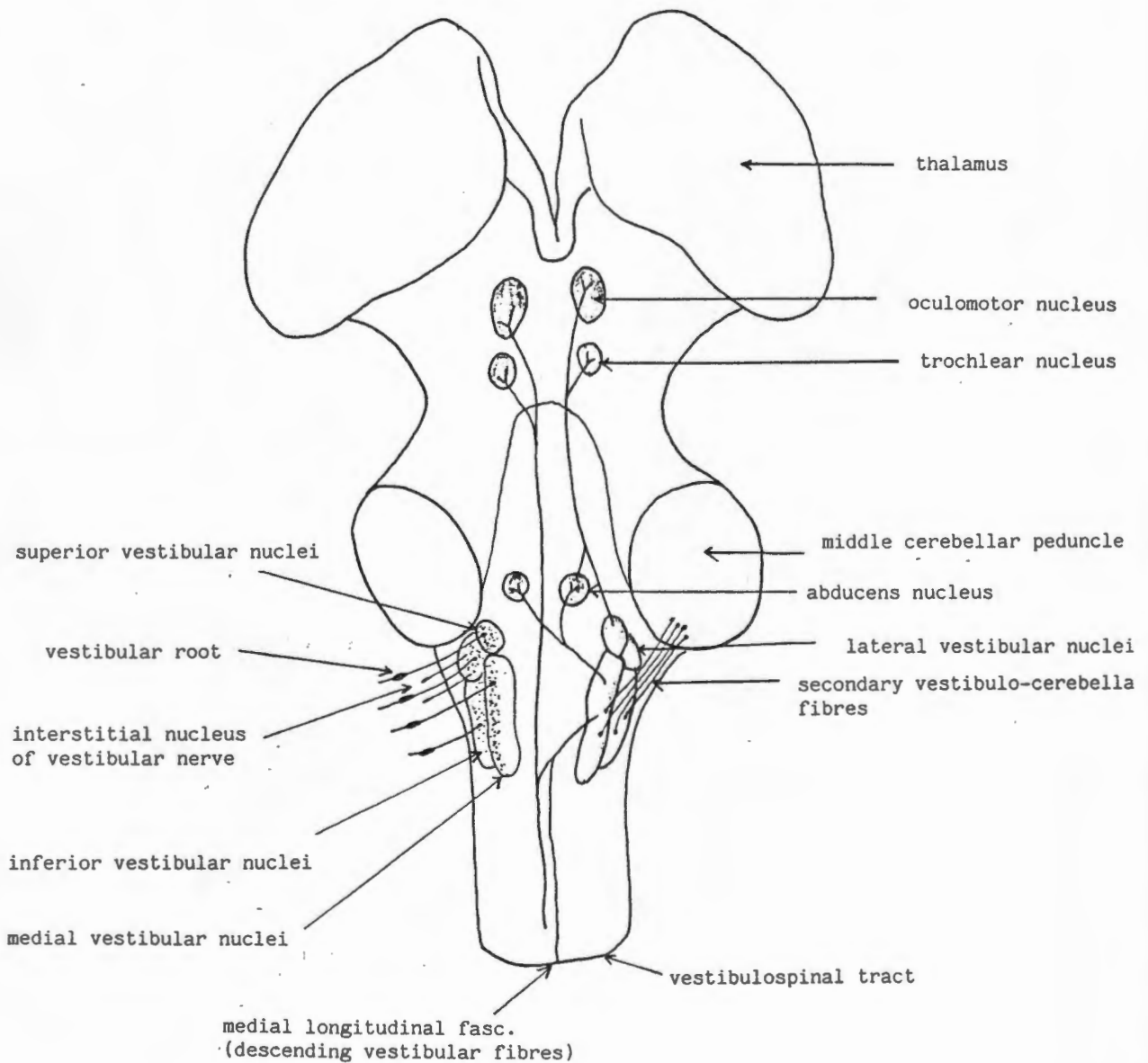
THE VESTIBULAR NUCLEI

Within the vestibular nucleus complex are four large nuclei - superior, lateral, medial and inferior. In addition to these four main nuclei there are several minor cell groups. The entire vestibular nucleus complex occupies a considerable area below the floor of the fourth ventricle. The vestibular nuclei are arranged with the inferior, lateral and superior nuclei lying lateral to the medial nucleus (see fig.5, p.12) The anatomical and functional organisation of the vestibular nuclei is extremely complex and far more differentiated than

was assumed a few decades ago. The vestibular nuclei receive fibres from other areas of the brain in addition to those contained in the vestibular nerve. Authors agree that although there are precise anatomic patterns in the fibrous connections of each vestibular nucleus which appear to have special functions, the four nuclei may be considered as a single functioning unit.

Figure 5

VESTIBULAR NUCLEI AND CONNECTING PATHWAYS (Noback, 1967)



CENTRAL CONNECTIONS

Cells of the vestibular nuclei are connected to the receptor and effector systems of the central nervous system by numerous ascending, descending and circular afferent and efferent pathways. (Kalinovskaya 1970)

Much research has been done by Brodal et al (1962) on the connections between the vestibular nuclei and the nuclei subserving oculomotor muscles and muscles of the neck, trunk and extremities. A brief summary is given here.

The vestibular nuclei project secondary fibres to: (see fig.6, p. 15)

1. The upper brain stem. These originate from the superior and medial nuclei via the medial longitudinal fasciculus. All contralateral projections from the vestibular nuclei to the medial longitudinal fasciculus decussate at the level of the vestibular nuclei. Most ascending fibres terminate in the nuclei of the extrinsic eye muscles (cranial nerves III, IV, and VI) Some run to other motor neurones of cranial and spinal nerves via the medial longitudinal fasciculi. The medial longitudinal fasciculus originates in the spinal cord. Although it contains other ascending fibres, the bulk come from the vestibular nuclei.

The vestibular nuclei also project many secondary fibres to the reticular formation in the brain stem. Through these the vestibular nuclei exert an influence on the

spinal cord as well as on the oculomotor muscles.

2 Specific portions of the cerebellum. These originate in the superior and lateral vestibular nuclei. As mentioned above, a small number of impulses reach the cerebellum direct via primary vestibulocerebellar fibres. Despite this connection, the vestibular apparatus exerts limited influence on cerebellar function, while cerebellar control over the vestibular nuclei is significant. The efferent fibres in the vestibular nerve arise from the fastigial nucleus of the cerebellum and terminate on hair cells of the membranous labyrinth.

3 Spinal cord. There are two efferent pathways along which the vestibular nuclei may exert influence on the activity of the spinal cord:

- The lateral vestibulospinal tract comes from the lateral vestibular nucleus, descends ipsilaterally and can be traced to the sacral levels of the spinal cord. It exerts a facilitatory action on extensor motorneurons.

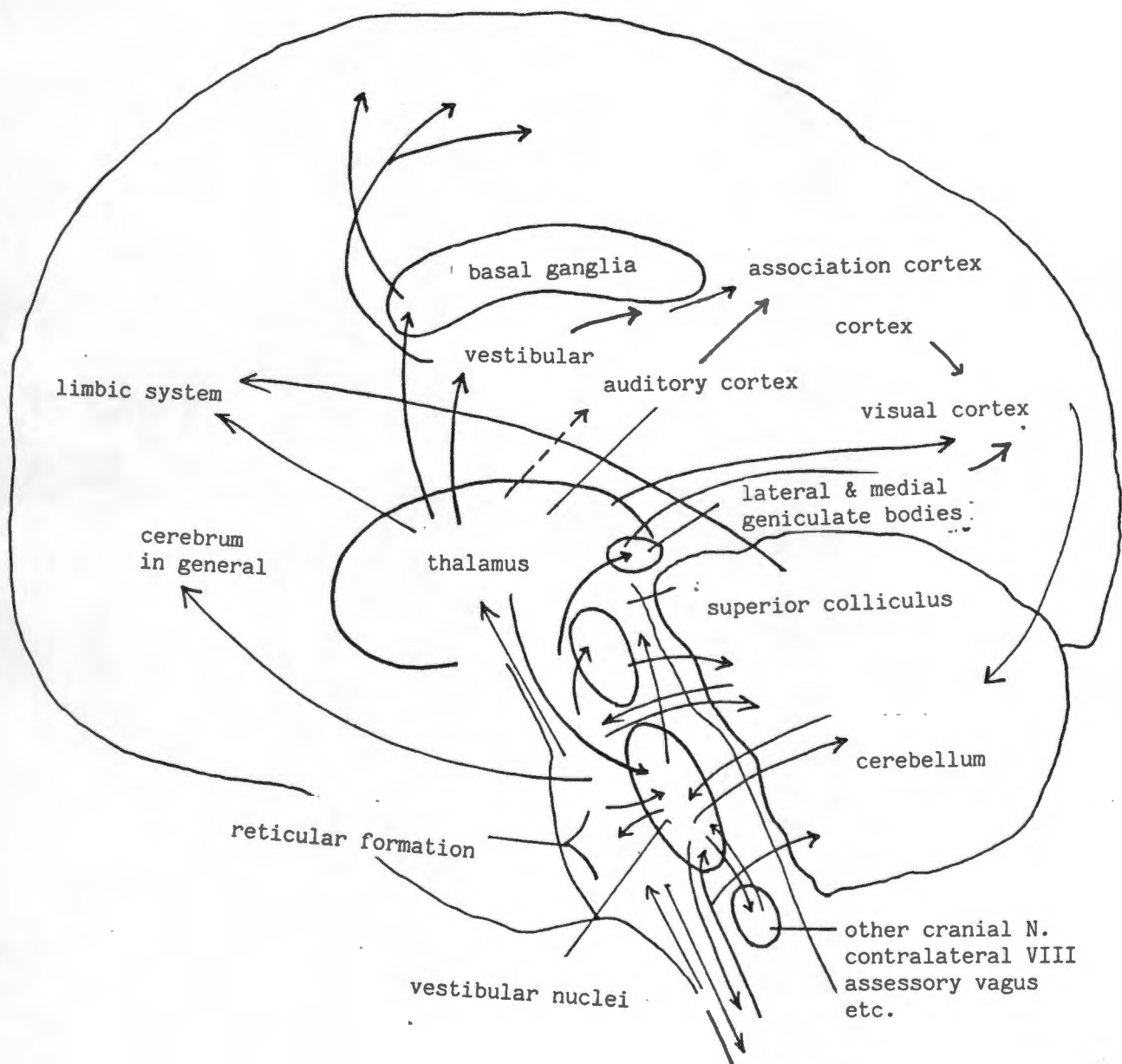
- The medial vestibulospinal pathway arises from the medial vestibular nuclei and descends crossed and uncrossed only to the upper thoracic segments.

There is a small direct pathway in the opposite direction called the spinovestibular tract. Spinal fibres may reach the vestibular nuclei by other routes, particularly via the reticular formation and the cerebellum.

Figure 6

CENTRAL CONNECTIONS OF THE VESTIBULAR NUCLEI

(from Ayres, 1974)



This section of the literature review deals with function of the semicircular canals, macula and utricle and with the vestibular reflexes.

The vestibular portion of the inner ear is concerned with orientation in three dimensional space, equilibrium and the modification of muscle tone. (Carpenter 1972)

THE SEMICIRCULAR CANALS

Stimulation of the semicircular canals results in nystagmus. Kosey (1977) defines nystagmus as an involuntary oscillation of the eyeballs either with an undulating pendular motion or more commonly with a jerking motion. The jerking type of nystagmus has a fast and a slow component. By convention the direction of nystagmus is labelled according to the fast component. The slow component moves the eyes from the periphery to a more central position in the orbit while the fast component moves the eyes from this central position back to the point of fixation. The amplitude of the slow component depends on the point of fixation relative to the central position at the start of the slow component. (Corvera and Romero, 1964).

Physiology of nystagmus

According to Bannister (1973) the posture of eyes depends on two sets of impulses. Firstly visual, which regulate the eyes in relation to an object of visual interest and secondly

labyrinthine, which regulate the position of the eyes in relation to the position and movement of the rest of the body, especially the head. The position of the eyes is coordinated by means of a central mechanism which receives these afferent impulses and controls efferent impulses to the eye muscles (central vestibulocerebellar system).

Ganong (1979) explains the mechanism which causes nystagmus as follows:

Rotatory acceleration in the plane of a given semicircular canal stimulates the crista of that canal in the following way: endolymph, because of its inertia, is displaced in a direction opposite to that of rotation. The fluid pushes the cupula which swings like a door and bends the processes of the hair cells which then generate impulses that produce nystagmus. Movement of the cupula in one direction causes an increase in impulses from its cristae whereas movement in the opposite direction inhibits neural activity. Since the canals on one side of the head are the mirror image of those on other side, the endolymph is displaced towards the ampulla on one side and away from it on the other. The pattern of stimulation reaching the brain therefore varies with direction as well as plane of rotation. The direction of the quick component of nystagmus is in the direction of rotation. When a constant speed of rotation is reached, the fluid spins at the same rate as the body, and the cupula swings back to an upright position, and nystagmus ceases. This takes place in 15 to 20 seconds.

A sudden stop after sustained rotation causes reversal in the direction of nystagmus. This is called postrotatory nystagmus. It occurs because the semicircular canals stop when the head stops but the endolymph with its inertia continues to move thereby pushing the cupula and processes of the hair cells in the opposite direction to that of rotation. Postrotatory nystagmus is accompanied by the following features: a sensation of turning (vertigo or dizziness) in the opposite direction to original rotation; past pointing - a phenomenon of missing an object when reaching to touch it; and a tendency to stagger and fall over (Noback, 1967). The cupula returns to mid-position in 20-30 seconds with gradual subsidence of postrotatory nystagmus.

Although nystagmus is a reflex which maintains visual fixation on a stationary point while the body rotates it is not initiated by a visual impulse. The slow component is initiated by a centre in the labyrinths while the quick component is triggered by centres in the brain stem. (Ganong, 1979). Linear acceleration probably fails to displace the cupula and therefore does not stimulate the cristae.

Brodal (1962), explains that the conjugate deviation of the eyes which takes place during nystagmus, requires precise coordination of several muscles of both eyes. The extrinsic muscles are supplied by particular cell groups in the oculomotor nuclei. This suggests that there must be extremely precise correlation between primary vestibular fibres from

individual receptor organs in the labyrinth and the distribution to the oculomotor nerves of fibres arising from particular terminal areas in the vestibular nuclei.

On the basis of anatomical and physiological studies it has been concluded that vestibular-oculomotor fibres in the medial longitudinal fasciculus are linked in elementary three neurone reflex arcs. These arcs are finely differentiated and powerful mediators of vestibular influences on ocular muscles. Vestibular nuclei may also influence nerves controlling the ocular muscles via indirect routes through the cerebellum and the reticular formation, which also appear to be involved in the conjugate eye movements which follow vestibular stimulation. Indirect vestibular-ocular pathways are all polysynaptic and their mechanisms are not completely understood.

The semicircular canals are referred to as the kinetic labyrinth and are concerned with kinetic equilibrium. (Brodal, 1962, Carpenter, 1972)

FUNCTION OF THE MACULA AND UTRICLE

Brodal (1962) believes that it is possible to distinguish between the kinetic labyrinth consisting of the three semicircular canals, and the static labyrinth consisting of the utricle, and perhaps the saccule. According to Carpenter (1972), the utricular maculae respond to changes in gravitational forces and to linear acceleration and convey impulses concerning the position of the head in space. In

other words they are concerned with static equilibrium. Impulses from the utricle influence the distribution of muscle tone in various parts of the body. The functional role of the saccular maculae in static equilibrium is not known. Some studies suggest that they may be vibration receptors. (Brodal, 1962)

The function of the utricle in the maintenance of static equilibrium.

When the head is tilted the otolithic macula of the utricle will exert a pull on the sensory hairs. These receptors respond very slowly and continue to fire if the same position of the head is maintained. The spatial polarisation of hairs within the macula, ensures that changes in position of the head will stimulate different hair cells. This informs the central nervous system of the position of the head in relation to the direction of gravitational pull, and the reticular network reflexly excites the appropriate muscles to maintain postural equilibrium (Guyton, 1971).

Ganong (1979) points out that the maculae also discharge tonically in the absence of head movement because of the pull of gravity on the otoliths. Impulses generated from these receptors are partly responsible for reflex righting of the head, and other important postural adjustments.

The detection of linear acceleration by the utricle

According to Ganong (1979) the utricular and saccular maculae respond to linear acceleration. When the body is suddenly

pushed forward the otoconia, which are denser and therefore have greater inertia than the surrounding fluid, fall back onto the hair tufts. This generates nervous impulses which are transmitted to the central nervous system and cause the individual to feel as if he were falling backwards. This automatically causes him to lean forward causing an anterior shift of the otoconia. He continues to lean forward until the anterior shift of the otoconia exactly balances the tendency for them to fall backwards induced by linear acceleration. At this point the nervous system detects a state of equilibrium and further forward shift ceases.

Thus the otoconia operate to maintain equilibrium during linear acceleration in the same way as they operate in static equilibrium. They do not however contribute towards the detection of linear motion.

Brodal (1962), comments that linear acceleration may influence the semicircular canals to some extent, but it is doubtful whether angular acceleration affects the maculae.

CONCIOUS AWARENESS OF VESTIBULAR STIMULATION

Stimulation of the vestibular system together with impulses from eye movements and visual stimulation cause a conscious spinning sensation or vertigo (Noback, 1967).

Brodal (1962) and others hypothesize that since vestibular stimulation gives rise to consciously perceived sensations, there must be pathways from the vestibular nuclei to the

cerebral cortex. There has however been disagreement on the regions receiving these signals as well as the pathways followed. Authors agree that the vestibular-cortical pathway has a thalamic relay. It appears that this relay also receives input from non-vestibular sensory afferents for example, muscle afferents. In addition to direct vestibulo-thalamo-cortical pathways it is likely that alternative pathways via the cerebellum and reticular formation also exist.

Cortical vestibular areas are also important for the conscious appreciation of motion and of spatial orientation.

VESTIBULAR REFLEXES

These are reactions or reflexes elicited by action upon the semicircular canals or the otolith organs. Pieterse (1967) gives the following classification based on elicited actions. He describes three categories of reflex:

- 1 Vestibulo-ocular reflexes. These consist of all ocular reactions that may be elicited by various forms of labyrinthine stimulation and include nystagmus, compensatory ocular movements and pupillary reactions.

- 2 Vestibulo-spinal reflexes. These reflexes are induced by labyrinthine stimulation and bring about changes of posture and movement affecting the head, neck, upper limbs, trunk and lower limbs. Most important are those that mediate deviations of the arms in various planes during walking, blindfold walking and inclination and

rotation of the body.

Guyton, (1971), explains that primary pathways for reflexes concerned with the maintenance of equilibrium begin in the vestibular nuclei and continue to the reticular network in the brain stem. The reticular network controls the interplay between facilitation and inhibition of extensor muscles thus automatically controlling equilibrium. For example when someone is pushed to the right, the right leg will extend before he moves more than a few degrees. In other words this mechanism anticipates a possible fall. Another protective reflex occurs when an individual's head suddenly falls downwards. The upper limbs extend forwards, trunk extensor muscles tighten and muscles in the back of the neck contract to prevent the head from hitting the ground.

Guyton (1971) points out that the flocculonodular lobes of the cerebellum also play a part in the maintenance of equilibrium. He also describes the vestibular righting reactions. Impulses transmitted by the maculae of the utricle inform the nervous system of the status of the individual with respect to gravity. If the individual is supine these impulses can elicit appropriate reflexes from the vestibular and reticular nuclei to enable him to climb onto his feet.

3 Vestibulo-vegetative reflexes. These consist of all reactions of the autonomic nervous system evoked by

labyrinthine stimulation and include pupillary reactions, vasomotor changes, respiratory changes, gastrointestinal symptoms, skin resistance and vertigo. (Pietersen 1967)

From this discussion of the anatomy and physiology of the vestibular system, it can be concluded that its structure and function is highly complex and not yet fully understood.

This section of the literature review deals first with symptoms and signs of vestibular dysfunction, and then with the effect of vestibular dysfunction on child development and learning in terms of Ayres' hypotheses.

EFFECTS OF LABYRINTHECTOMY

Labyrinthectomy results in loss of balance and other distressing symptoms such as vomiting and dizziness. Compensation occurs however, and after one to two months the symptoms disappear. The symptoms do not occur after bilateral destruction of the labyrinths but spatial disorientation is present (Ganong, 1979).

Brodal (1962) observed that the vestibular apparatus in man appears less important than in animals. Individuals with no demonstrable labyrinthine function manage quite well in daily life and may even drive a car safely. The eyes and proprioceptors compensate in such cases for the absence of information from the labyrinths.

Consequences of the destruction of the labyrinths and of the vestibular nerves are not identical to those of destruction of the vestibular nuclei. (Carpenter, 1972)

SIGNS AND SYMPTOMS OF ACUTE VESTIBULAR DYSFUNCTION

Carpenter (1972) states that labyrinthine stimulation, irritation or disease cause vertigo, (the subjective

sensation of rotation either of the individual himself, or of his environment), postural deviations, unsteadiness on standing and walking, deviations of the eyes and nystagmus. Nystagmus is the most prominent objective sign of vestibular involvement. (see p.16)

Brodal (1962) listed the following features associated with vestibular dysfunction: vertigo, nystagmus, past pointing, and a tendency to fall. Symptoms reflecting involvement of the autonomic nervous system, including nausea, vomiting, hypotension and excessive perspiration frequently accompany signs and symptoms directly related to vestibular dysfunction. Autonomic symptoms often occur to a moderate degree during caloric and rotatory tests, indicating reflex connections between vestibular nuclei and visceral efferent neurones of the lower cranial nerves, especially the vagus.

Lesions of the vestibular and cochlea nerves may give rise to symptoms of Meniere's disease. These include nystagmus, vertigo, falling and reduced hearing.

THE HYPERACTIVE VESTIBULAR RESPONSE

Torok (1970), studied the significance of an unusually strong reaction to rotatory or caloric stimulation. While a weak or apparently absent nystagmus response was identified as a defect in vestibular function, an extremely forceful vestibular response was regarded as an increase in vestibular sensitivity. Similar conclusions were reached when mild stimulation caused reactions such as vomiting,

perspiration and pallor. In his study individuals were subjected first to weak and then to strong stimulation. Their reactions were recorded and these lead to the following conclusions:

a) An increased nystagmic response following rotation or caloric stimulation does not represent an increase in excitability of the receptors of the vestibular end organs. The enhanced response is mediated by some change in vestibular pathways.

b) When vestibular stimulation evokes autonomic nervous system responses with or without an increase in nystagmus, this does not indicate increased sensitivity of the receptors but rather a less inhibited response of the autonomic nervous system.

From these conclusions it may be deduced that an increase in vestibular responsiveness does not reflect labyrinthine disease but rather disease of the central nervous system.

NYSTAGMUS

Since nystagmus is the most frequently observed sign of vestibular dysfunction and this study is concerned with the measurement of the nystagmic response during and after vestibular stimulation, a discussion of literature on this subject will follow.

Description of nystagmus

According to Bannister (1973), and Kosey (1977) a description of nystagmus should include the following information:

1 Type

Nystagmus may be pendular in which speed of movement is equal in both directions, or jerky in which there are fast and slow components.

2 Direction

Nystagmus may be horizontal, vertical, or rotatory. It may be clockwise or counter-clockwise.

3 Intensity

This is described according to clinical judgement or by measurement using an electronystagmogram.

4 Unilateral or bilateral

Monocular nystagmus is rare.

5 Spontaneous or induced

Spontaneous nystagmus occurs without external stimulation to the patient. The induced type may be secondary to a pathological process or follow stimulation applied for diagnostic purposes.

6 Congenital or acquired

7 Associated or dissociated

Associated nystagmus refers to that in which the eye movements occur in unison. Dissociated nystagmus is present when individual eye movements occur in opposite or different directions.

8 Reflex

This type of nystagmus is a physiological response to certain stimuli.

9 Etiology

Nystagmus may be classified according to underlying pathology. In clinical practice it is always necessary to

establish whether nystagmus is physiological or pathological (Toglia, 1976). Various types of nystagmus are described in the literature. Some are always pathological in nature and others physiological up to a point after which they should be regarded pathological.

Classification of nystagmus

1 Spontaneous nystagmus

Spontaneous nystagmus is observed when the patient is not subject to any external stimuli such as rotation, gaze deviation or postural change. It arises from disturbances in the functioning of the optical or vestibular systems or the extraocular muscles and is not common. Kosey (1977) classifies spontaneous nystagmus as follows:

a Normal

Normal individuals may display low intensity vertical or horizontal nystagmus with their eyes closed. Spontaneous nystagmus of less than 6 to 10 degrees can be recorded by ENG in 20 to 25 % of normal subjects. According to Kalinovskaya (1970) spontaneous nystagmus may also be seen in the form of isolated tics in normal subjects.

b Vestibular

This includes all jerky nystagmus with a fast and slow component. It has a horizontal beat directed away from the side with diminished tonus, is conjugate and decreases with fixation. It is associated with peripheral lesions of the vestibular apparatus.

c Ocular

Spontaneous ocular nystagmus is usually congenital and is often associated with squints and congenital deficits of visual acuity. It has a sinusoidal pattern and is horizontal. It is suppressed by convergence and enhanced by fixation.

d Central spontaneous nystagmus

This type is identified by the exclusion of vestibular and ocular nystagmus. It may be of brain stem or cerebellar origin e.g. paroxysmal alternating nystagmus.

2 Gaze nystagmus

Gaze nystagmus is included by some authors under the heading of spontaneous nystagmus. Kosey (1977) describes it as follows:

Normally the eyes assume a central position at rest. Any rotation away from centre initiates physiological mechanisms which bring the eyes back to a central position. Thus if the eyes are deviated in extreme lateral gaze there is slow drift back to the centre followed by a fast motion to replace the image on the fovea. This is a normal phenomenon when it occurs with extreme lateral gaze.

When the eyes are rotated off the midline, not in extreme lateral gaze, a person should be able to fixate on an object without nystagmus. Pathological gaze nystagmus indicates an extravestibular central nervous system disorder in centers that control voluntary ocular

deviation. These include pregyral, pontine and cerebellar coordination centers. Pathological gaze nystagmus occurs in multiple sclerosis and cerebellar tumours. Gaze nystagmus accompanied by intense spontaneous vestibular nystagmus indicates peripheral vestibular disease. (Kosey, 1977; Toglia, 1976)

3 Optokinetic nystagmus

Kalinovskaya (1970) defines optokinetic nystagmus as: "an adaptive physiological reaction that ensures clear perception of non-moving objects when an animal or human is moving spatially." Its absence therefore, is always considered pathological.

A repetitive series of visual stimuli passing in front of the patient's eyes causes pursuing movements of the eyes in the direction of the moving stimulus (slow phase), and quick jerky movements in the opposite direction (fast phase). Optokinetic nystagmus may be induced in a horizontal or vertical plane, depending on the plane in which the visual stimulus is moving. (Toglia, 1976)

4 Vestibular nystagmus

Toglia (1976) classified vestibular nystagmus according to the stimulus which produced it. It is binocular, horizontal or vertical, jerky, unidirectional and usually inhibited by fixation. The fast phase is directed towards the side of the labyrinth which is over-stimulated or away from the labyrinth which is paralysed. The slow phase is attributed to the endolymphatic flow in the semicircular canals, and

the fast phase to central mechanisms. Vestibular nystagmus may be induced by rotatory, caloric, galvanic or positional stimulation.

a Rotatory nystagmus

Rotatory nystagmus is induced by rotation of the patient. In order to stimulate the horizontal canals, the head must be flexed forward to a 30 degree angle. This results in nystagmus in the horizontal plane. Rotation of the head around a bitemporal axis, which is achieved with the patient lying on his side, causes homologous endolymphatic flow in both anterior canals, and an opposite flow in both posterior canals. This causes nystagmus in a vertical plane. Rotation of the head around a fronto-occipital axis causes the same direction of endolymphatic flow in one anterior canal and the opposite posterior canal. This causes rotating nystagmus (Toglia, 1976). Postrotatory nystagmus which occurs when movement has ceased, is in the opposite direction to that of rotation.

b Caloric nystagmus

Caloric nystagmus is induced by irrigating the external auditory canal with cold or warm water. The temperature change is transmitted to the semicircular canals in the inner ear causing convection currents in the endolymph.

c Galvanic nystagmus

Galvanic nystagmus is caused by applying galvanic stimulation to the mastoid region. This form of nystagmus has low frequency, a small amplitude and short duration.

d Positional nystagmus

Positional nystagmus accompanied by vertigo is induced by an alteration of head position. It is attributed to disease of either the otoliths or their central vestibular connections. Jonkees (1964) suggests that positional nystagmus should be considered pathological when present in more than one position or when the maximum speed of the slow phase of nystagmus is greater than seven degrees per second.

5 Central nystagmus

This may be of any form or type. It is usually increased rather than inhibited by visual fixation (Toglia, 1976).

Central nystagmus is common in lesions of the brain stem and the cerebellum. It may be found in conditions of raised intracranial pressure involving the vestibular nuclei. It differs from peripheral nystagmus in that vertigo is often absent or slight and nystagmus is usually to the side of the lesion. Central nystagmus in children occurs most commonly as a sign of drug intoxication or cerebellar disease.

VESTIBULAR BASED SENSORY INTEGRATIVE DYSFUNCTION

Ayres (1972) observed that recurring clusters of symptoms occurred in children with learning problems. She felt that these reflected sensorimotor disorders which formed the basis of the learning problems. She identified the clusters of symptoms by means of a series of factor analyses of scores obtained in tests of perceptual, motor, auditory/language

and neuromuscular function administered to different populations of learning disabled children.

Five syndromes were identified according to consistently recurring signs and symptoms. These were:

- 1 "Disorder in postural, ocular and bilateral integration"
- 2 "Apraxia"
- 3 "Disorders in form and space perception"
- 4 "Auditory/ language problems"
- 5 "Tactile defensiveness."

A sixth syndrome, "unilateral neglect" was tentatively identified.

Ayres postulated that these syndromes all represent evidence of disorder in neural systems or sub-systems which tend to operate as a unit. Thus a low score in a test of one function would be reflected by low scores in tests of other related functions.

In more recent literature (Ayres, 1979; Kimball, 1981) the first syndrome mentioned - "disorders in postural, ocular and bilateral integration", has been re-named, "vestibular bilateral integration disorder"; and "apraxia" has been renamed "developmental dyspraxia".

Ayres (1979) divided vestibular based sensory integrative disorders into two broad categories:

- 1 Those related to an underactive vestibular system,
- 2 Those related to an overactive vestibular system.

Both these disorders, she hypothesises, are the result of an imbalance between central facilitatory and inhibitory influences on vestibular activity.

The following characteristics are common to both these categories of vestibular based sensory integrative disorder (Kimball, 1981):

- 1 Depressed nystagmus
- 2 Depressed postural-ocular reactions
- 3 Lateralisation problems
- 4 Bilateral integration problems

Syndromes related to an underactive vestibular system

1 Vestibular bilateral integration disorder

Schilder (as cited by Ayres, 1972), conceived of the vestibular system as a coordinating centre for all sensory functions. It has an integrating role in combining information from the two sides of the body arising from all the senses (Wilbarger, 1979).

In this type of disorder, although the child appears to be normal, healthy and intelligent, he may present with some or all of the following characteristics: (Ayres, 1979)

- a Gross coordination is poor and the child may fall frequently and makes little attempt to save himself.
- b He does not enjoy games and has difficulty in catching and throwing a ball.
- c He does not develop a dominant hand. He may be considered ambidextrous but is usually not skilled with

either hand.

- d An awareness of right and left on his own body does not develop, but he often learns to discriminate left from right intellectually.
- e When learning to write he often reverses letters such as b and d.
- f He experiences problems with mathematics and reading which do not respond well to conventional remedial teaching methods.
- g He usually has a low frustration tolerance.
- h Self-esteem is low as a consequence of all the difficulties encountered.

The following signs help to identify this syndrome:

- a Short duration postrotatory nystagmus.
- b Hypotonia.
- c Inadequate co-contraction. (an inability to stabilise proximal joints)
- d Difficulty in maintaining a totally extended posture in the prone position.
- e Inadequate postural reactions.
- f Poorly integrated primitive postural reactions.
- g Difficulty in crossing the midline of the body, and inefficient bilateral hand use.
- h Incoordinated eye movements.

2 Vestibular language disorders

Language is an end product of sensory integration. Integration problems resulting from vestibular dysfunction

may be reflected as language disorders. These may be accompanied by evidence of vestibular bilateral integration disorder. Ayres (1979) does point out however that there are many other possible causes of language problems.

3 Vestibular based problems in form and space

It seems likely that the development of visual perception depends to a certain degree upon the adequacy of integration of vestibular information (Ayres 1972). Problems in form and space perception, which are also an end product of adequate sensory integration may therefore accompany other signs of vestibular dysfunction.

4 Vestibular based dyspraxia

If a child has a motor planning problem or dyspraxia in addition to the above signs of vestibular dysfunction it is likely that the vestibular problem is the underlying cause of the dyspraxia (Kimball, 1982).

Syndromes related to an overactive vestibular system

1 Gravitational insecurity

Ayres (1979), lists the following symptoms which are associated with gravitational insecurity. Not all of them will appear in any one child:

- a The child has an unnatural fear of falling, and of heights.
- b He becomes anxious when his feet leave the ground even to climb up or down steps.
- c He dislikes "rough and tumble" play, such as jumping,

- somersaults, rolling or being thrown into the air.
- d He does not enjoy playground equipment or moving toys.
 - e He is particularly slow and careful with unusual movements such as walking down a rocky hill or climbing from the front to the back seat of the car.
 - f He has a fear of walking along raised surfaces although they may not seem high to others.
 - g He appears to be perceiving space correctly although he is reluctant to move within that space.
 - h Such children are often nervous and dependent.

2 Intolerance of movement

This syndrome differs from gravitational insecurity in that the child is not made anxious or fearful by movement but merely uncomfortable. Such children often suffer from car sickness. Playground equipment makes them feel nauseous and indeed even watching others spin may make them feel sick. This problem sometimes but not always accompanies gravitational insecurity and it may be difficult to discriminate between them. Postrotatory nystagmus in these cases may be prolonged. It is thought that "intolerance of movement" affects the child's personality rather than his academic achievements (Ayres, 1979).

The importance of accurate evaluation of the vestibular system can be understood from the above discussion of Ayres' hypothesis with regard to the major role it plays in aetiology of certain types of learning disability.

This section of the literature review deals with different methods which may be used to evaluate vestibular function. Lee and Chasin (1975) point out that vestibular organs respond to many different stimuli in only a limited number of ways. They exhibit either decreased, increased or perverted function.

According to Rose (1978), advances in auditory testing far outstrip those made in vestibular testing. Present labyrinthine tests cannot differentiate between lesions of the vestibular labyrinth and the eighth cranial nerve. They can however differentiate between peripheral vestibular lesions and lesions of the brain stem and cerebellum (Rubin, 1983).

The rotating chair test and caloric tests are the most commonly described tests of vestibular function in the literature.

TESTS OF PHYSIOLOGICAL VESTIBULAR NYSTAGMUS

This type of nystagmus may be induced by rotatory, caloric, or galvanic stimulation or by changes in the position of the head. Brief mention will be made of caloric, galvanic and positional tests followed by a more detailed review of the literature on rotation tests, as these were the tests used in the present study.

1 Caloric Tests

The caloric test was introduced by Bárány in 1906. The Fitzgerald-Hallpike method is the most suitable for clinical use. (Hamersma, 1957, de Quiros, 1978).

Physiology and procedure of the caloric test.

Temperature change produces an alteration in the specific gravity of endolymph. Cold stimulation increases specific gravity inducing a downward flow in any canal brought into a vertical position. This ampullofugal movement of the endolymph decreases the firing rate of the homolateral vestibular nuclei. The contralateral vestibular nuclei thus fire at a relatively greater rate causing tonic deviation of both eyes towards the irrigated ear. This constitutes the slow phase of nystagmus. Automatic vestibulospinal reactions and reflexes are also induced. The situation is reversed by warm stimulation. This causes ampulopedal endolymphatic flow with increased firing of the homolateral vestibular nuclei and a slow phase of nystagmus away from the irrigated ear (Toglia, 1976).

After positioning the patient correctly for stimulation of the desired pair of canals, hot or cold water is introduced into the external meatus of the ear with a syringe. Nystagmus is either observed through Frenzel's glasses or measured by means of an electronystagmogram.

Advantages of the Caloric Test.

- 1 The caloric test makes possible the examination of one ear at a time. It is thus the most widely accepted vestibular test. (Eviater and Eviater, 1979).
- 2 The time required to complete the test is about fifteen minutes.
- 3 Response decline due to adaptation does not occur as it does in rotation tests. (Uemura et al 1977)

Disadvantages of the caloric test.(McClure et al 1973)

- 1 The technical problem of uniform external ear canal irrigation.
- 2 The variability of heat transfer through tissues surrounding the ear structures. This is affected by anatomical asymmetries and variations in blood flow through the area.
- 3 Lack of precise knowledge of tissue temperature creates uncertainty about the temperature gradient achieved.
- 4 In Pain's (1966) opinion, this method is unsuitable for children for the following three reasons:
 - It is unpleasant
 - The child has a small auditory canal
 - Hot water cannot be used as it may irritate the auditory membrane.

2 Galvanic Test

In this test an electrical current alters the normal flow of tonic labyrinthine impulses inducing various subjective and objective changes. The subjective responses include an acid

taste and vertigo or tinnitus. The objective responses are rotatory nystagmus away from the anode, past pointing and falling to the same side as the anode. A normal reaction depends on intact vestibular nuclei and ganglia. The galvanic response thus persists when the vestibular apparatus has been destroyed. This is the only diagnostic test of vestibular function which differentiates between neuronal and end organ lesions (Kosey, 1977). It is painful and unpleasant for the patient and is seldom used.

3 Positional Nystagmus Tests

Brodal (1962) describes a technique in which five different test positions are used while Kosey (1977) describes only one test position. In this latter method the examiner brings the patient rapidly to a supine position with his head over the edge of the table and rotated 30 to 40 degrees to one side. The examiner notes the quality of nystagmus induced and records the presence of vertigo (Kosey, 1977).

Many pathological processes cause positional nystagmus. These include conditions of the inner ear such as vascular changes and Meniere's disease, and central disorders such as encephalitis and tumours.

4 Rotation tests

These tests of vestibular function are based on the nystagmus which is produced by stimulation of the semicircular canals and vestibular nerve endings.

Procedure of Rotation Tests,

The first vestibular test using rotatory stimulation, was developed by Bárány in 1907. In this test the patient is placed in a chair and rotated ten times in twenty seconds. The examiner then stops the chair abruptly and observes the patient's eyes for nystagmus. The patient is rotated first in a clockwise direction and then after a rest in a counter-clockwise direction (Lee and Chasin 1975).

Pain (1966) describes the use of the standard Barany rotation test in children. The patient should sit erect with his head tilted forward at 30 degrees from the horizontal. The pupils and the external auditory meati should lie in a plane parallel to the floor. The chair is rotated ten times in twenty seconds. The patient's eyes are kept closed to prevent the development of optokinetic nystagmus. Nystagmus normally lasts 20 to 30 seconds after stopping the chair, depending on the speed of rotation.

Jonkees and Philipszoon (1964) raise many objections to the Bárány method. The most important is that a "well-dosed" stimulus cannot be given. The cupula which deviates during the initial acceleration does not return to its original position during the period of constant velocity which lasts only 20 seconds. Abrupt stopping of the chair therefore stimulates the cupula while it is still in a deviated position. They describe "cupulometry", a rotation test which is an improvement on the original Bárány test. In this test stimulation of more natural intensity is given. The duration of postrotatory nystagmus and other signs are measured. The

subject is positioned so that only the horizontal semicircular canals are stimulated and the speed of the rotating chair is slowly increased until a constant velocity has been reached. When nystagmus ceases, indicating that endolymph in the semicircular canals is no longer flowing, the chair is abruptly stopped. In this way a "well-dosed" stimulus to the cupula can be administered at different rotatory velocities. The "cupulogram" which plots the relationship between the angular speed and the duration of postrotatory nystagmus is a straight line. Although this is a useful and accurate method it is laborious and time consuming. It may cause fatigue with a subsequent lowering of the patient's mental alertness.

Uemura et al (1977) described a method of manual cupulometry which they felt overcame the difficulties of Jonkees and Philipszoon's method and at the same time retained its advantages. The patient sits in a manually rotated chair with his head flexed 30 degrees forward. He wears Frenzel's glasses and is instructed to close his eyes. The examiner holds onto the chair and walks slowly around it gradually increasing the length of his step until the chair reaches the required speed of rotation. A tachometer is attached to the chair so that the examiner has a measure of its velocity. Acceleration should be as slow as possible and constant speed should be maintained during the last three revolutions. Thereafter the examiner stops the chair abruptly and instructs the patient to open his eyes so that nystagmus can be observed. Duration of postrotatory nystagmus is observed

through the Frenzel's glasses and timed with a stopwatch. The duration of the response and the magnitude of the stimulation are plotted on a logarithmic scale which is called a nystagmus cupulogram. This test can be completed in fifteen minutes inclusive of rotation, observation of nystagmus and rest periods. This is about a third of the time required for the original method of cupulometry.

This test was found to demonstrate pathology in 75 % of cases of vertigo tested. It is useful for evaluating the effects of treatment.

Uemura et al (1977) also describe the Pendular Rotation Test. This test differs from the above tests in that it measures nystagmus during rotation (per-rotatory nystagmus) and is useful for detecting directional preponderance and in the differential diagnosis of central and labyrinthine lesions. The diagnostic significance of per-rotatory nystagmus and postrotatory nystagmus differs. The test was made possible by the advent of the electronystagmogram (ENG).

In its conventional form an electrically driven chair is used. The patient's head is fixed at a 30 degree angle. Visual input is varied by:

- a) fixating on a stationary object,
- b) not fixating,
- c) closing the eyes, and
- d) covering the eyes.

Eye movements are recorded on an ENG. Since alternating

stimulation is used there is no response decline. Bilateral dead labyrinths, central lesions, and directional preponderance can be detected.

In the Eccentric Pendular Rotation Test the subject sits away from the center of pendular rotation. This exposes the labyrinths to both rotatory and linear acceleration. The results obtained in this test should be compared with those of the ordinary pendulum test. Studies indicate that this test is useful in differentiating labyrinthine from central lesions.

Toglia (1976) describes several other rotation tests. He notes that all rotatory tests should be performed in the dark to eliminate the influence of optokinetic stimulation. The patient must be kept alert throughout rotation by performing arithmetical calculations. To ensure stimulation of the horizontal canals, the head should be held in a headrest flexed 30 degrees anteriorly.

In The Constant Linear Acceleration Near-threshold Test constant acceleration and deceleration of 0.5 degrees per second per second is applied to the subject. This is close to the stimulation threshold of the labyrinths and is strong enough to stimulate only one labyrinth at a time. This is a useful test when caloric tests cannot be performed.

In The Constant Linear Acceleration Supra-threshold test acceleration and deceleration of 2 degrees per second per

second are used. This test permits studies of the function of both labyrinths simultaneously.

The Sequential Alternating Rotatory Tests entail acceleration of the patient at a speed of 40 degrees per second per second. The chair alternates direction every twenty seconds with a minimum of ten rotations in each direction. The test takes approximately three minutes to administer so that possible effects of changing mental alertness are eliminated.

In his "HA Test" Rubin (1983) measured the response of the eyes to a controlled rotational stimulus. He controlled as many variables as possible. Among the advantages of his method are that position, velocity and acceleration are related in a way that is easily computed and analyzed, and the computer which controls chair motion also records eye motion. This allows direct comparison of eye velocity with chair velocity.

Advantages of rotation tests.

- 1 Rotation is a far more natural stimulus than caloric stimulation. (Toglia, 1976)
- 2 Rotation tests cause direct stimulation to the end-organ. (McClure et al 1973)
- 3 The stimulus can be well controlled and is not subject to technical error. (McClure et al 1973).
- 4 Rotatory stimuli are more easily quantified than caloric stimuli and may be repeated in the same session. (Toglia, 1976; Uemura et al, 1977)

- 5 Rotational tests provide information on short-term adaptation which caloric tests cannot do. (McClure et al 1973)
- 6 Rotation tests can detect asymmetry which varies in parallel with severity of vertigo, and is therefore important in evaluating the effects of treatment. (Uemura et al, 1977)
- 7 The rotation test may be used to differentiate between peripheral and central vestibular disorders. (Uemura et al, 1977)
- 8 By positioning the head different pairs of semicircular canals can be stimulated. (Uemura et al, 1977)
- 9 The test takes approximately 10 minutes to complete. (McClure et al 1973)
- 10 The test is not unpleasant and is well tolerated by all patients. This is an important factor when testing children. The child may be held on his mother's lap. (Lee and Chasin, 1975)
- 11 Impediments to the caloric test are avoided, e.g. scarring or perforation of the tympanic membrane, differences in direction of auditory canals and undue thickness of bone. (Toglia, 1976)

Disadvantages of rotation tests.

- 1 In Bárány's test both labyrinths are stimulated simultaneously. (Lee and Chasin, 1975)
- 2 The chairs capable of precise performance are expensive. (Toglia, 1976)
- 3 The difference in response between left and right

labyrinth is modified by central compensation. (Uemura et al , 1977)

From the above discussion, it can be seen that the advantages of rotation tests far outway any disadvantages. Furthermore it is clear that rotation is the most suitable method of vestibular stimulation for use with children.

In this study the results of the Southern California Post-rotatory Nystagmus Test (SCPNT) of vestibular function were compared with those of an electronystagmographic (ENG) assessment of nystagmus induced by rotatory stimulation. A review of literature on validity studies on the SCPNT follows.

THE SOUTHERN CALIFORNIA POSTROTATORY TEST

This test was described by A.Jean Ayres in 1975. The child is placed on a rotating board and rotated ten times first in a clockwise and then in an counterclockwise direction. The duration of postrotatory nystagmus is monitored visually and timed on a stopwatch. A full description of the Southern California Postrotatory Nystagmus Test (SCPNT) is given in Chapter 111.

Validity studies on the SCPNT

In recent years Polatajko (1981, 1985) has published papers questioning Ayres' hypothesis that many learning disorders have a vestibular basis. Results of her study in which samples consisted of forty learning disabled and forty

"normal" children, showed no significant differences in vestibular nystagmus between the two samples. Nystagmus was induced by rotating the child on an electrically driven rotating chair and was measured on an ENG. She proposed that studies that claimed to demonstrate a prevalence of hyponystagmus in children identified as learning disabled, were invalid because of the shortcomings of the SCPNT. She published the results of another study in 1983. In this study her samples consisted of twenty normal and twenty learning disabled children aged between eight and twelve years. Each child was subjected to the SCPNT and an ENG. The SCPNT was administered by a qualified occupational therapist according to standard procedure.

For the ENG the child was seated on a computer operated rotating chair with his head held in 30 degrees flexion by means of clamps. He was kept alert throughout the test which was administered in complete darkness after dark adaptation had taken place. The chair was accelerated at six degrees per second per second acceleration to a speed of 120 degrees per second for 120 seconds. Deceleration was then initiated at six degrees per second per second. Nystagmograms were scored according to the maximum speed of the slow slope in response to clockwise and to counter-clockwise acceleration.

This study showed that age was not significant and that there was no significant difference between control and experimental groups in the numbers of hypo-, normal and hyper-nystagmic responses in the SCPNT. Correlations of

scores obtained in the SCPNT and the ENG were also not significant. In consequence Polatajko recommended that the SCPNT be abandoned, as it is not a valid measure of vestibular function.

An earlier study carried out by Keating in 1979 compared results obtained in the SCPNT with results of an ENG. Her three samples consisted of twenty normal female adults, four normal girls with a mean age of 7 years 3 months, and four learning disabled girls with a mean age of 8 years 1 month. None of the subjects had central nervous system damage, seizures or hearing loss. The SCPNT was administered according to the manual (Ayres, 1975). The ENG was calibrated so that 10 degrees of eye movement was equal to 10 mm. deflection. The ENG recorded eye movements and at the same time the examiner observed the eyes and recorded with a stopwatch the duration of postrotatory nystagmus. This was measured as the length of time from the onset of nystagmus to the onset of the first full two second interval without nystagmus. Maximum excursion of the eye was estimated and recorded by measuring in millimeters the height of the nystagmus peak on the ENG.

Results revealed the following:

For the adult sample there was a significant correlation between the duration scores on the SCPNT and the ENG. For normal girls correlation between the two tests in terms of duration was significant, but there was no significant correlation in terms of excursion. Learning disabled girls showed no significant correlation between the two tests.

The following conclusions were reached:

- (i) Excursion is more difficult to estimate than duration.
- (ii) Observation is not an accurate means of measuring duration in individuals whose excursion is less than 1 millimeter.
- (iii) When recorded by direct observation nystagmus often appeared to persist for a longer period. This may have been due to the recording of eye movements which were not true nystagmus.
- (iv) Adult nystagmus was of longer duration and higher frequency than that of children.
- (v) There was no significant difference in nystagmus between the learning disabled group and normal children. This may have been due to small numbers and also to the fact that one normal child showed a reduced level of nystagmus.
- (vi) Results in learning disabled girls may have been influenced by distractability and difficulty in following directions.

A comparison of results of the SCPNT and an ENG was made in a study by Nelson et al (1984) under three conditions of illumination - bright, dim and dark. Duration and excursion were measured. Results indicated that postrotatory nystagmus does not differ between bright and dim conditions, but that there is a substantial difference between responses in light and completely dark conditions. Although correlations between SCPNT and ENG scores were statistically significant, the authors found it surprising that these were not higher. They

recommended that further studies to test the concurrent validity of SCPNT and ENG be undertaken using bigger samples.

Morrison and Sublett (1983) tested the reliability of the SCPNT with learning disabled children. They used 89 learning disabled children in the study. Results showed that this population had significantly depressed postrotatory nystagmus scores and a wider range of scores than normal children. Intra-scorer and test-retest reliabilities, although fairly constant, were less consistent than those obtained with normal children. They suggested that restlessness, distractability, and inappropriate social responses could be variables affecting the scores of learning disabled children but maintained that in spite of this variability, results of the SCPNT still discriminated between the two groups of children. They suggested that the SCPNT should be used in combination with clinical observations.

Several other studies have been carried out testing various aspects of the validity of Ayres' Test (1975).

Stillwell, Crowe and McCullum (1978) using a motorised board for the SCPNT, reported that the mean duration of postrotatory nystagmus for their sample of 62 normal children, when combined across age and sex, was almost identical to that obtained by Ayres in 1975.

Kaufman (1978) concluded that separate norms should be used for boys and girls when testing three year olds, but were not

necessary beyond that age. She also recommended that control of some of the test variables should be improved in order to achieve greater accuracy in the SCPNT. Short, Watson and Rogers (1983) reported norms for duration of postrotatory nystagmus in four year olds. They found no significant differences between males and females, thus agreeing with Kaufman's findings.

Another study on four year olds was carried out by Crowe et al (1984). The sample consisted of 41 four year old children attending preschools in the Seattle area. The SCPNT was administered according to standard instructions with minor alterations to control for extraneous variables. For example the rotations were counted aloud and the child was positioned in front of a white sheet to discourage visual fixation on cessation of rotation. The mean duration, standard deviation, and range of scores for postrotatory nystagmus were computed. Results indicated that there was no significant difference between males and females. The mean postrotatory nystagmus time for males was however longer than that for females. There was no significant difference in mean postrotatory nystagmus duration between this study in Seattle and Ayres' study (1975) in Los Angeles. The authors recommended that although the SCPNT appeared to be reliable further research and refinement were urgent priorities in order to establish its credibility within and outside the field of occupational therapy.

Kimball (1981) also considered the possibility of different norms for postrotatory nystagmus duration in different

geographical areas. She compared data from 222 normal children in Syracuse, New York, with Ayres' data (1975), which were obtained in Los Angeles. Approximately 40 children in each age group from five to nine years were used in her study. When comparing Ayres' data with the Syracuse data, Kimball found significantly higher means and standard deviations in the latter. Differences between males and females were not significant. In consequence she proposed a combined standard score table with a higher cut-off point for the diagnosis of abnormally prolonged nystagmus.

Dunn (1981) examined postrotatory nystagmus scores in 129 five year old boys and 134 five year old girls. She found higher mean durations and larger standard deviations than those reported by Ayres (1975). No statistical tests were applied to determine whether these differences were significant.

In 1982, Punwar did a comparative study using a bigger sample and a wider age range than Ayres (1975) to test the general applicability of her data. Three hundred and seventy two subjects aged three to ten years were tested using the SCPNT. Comparison of the data with that of the Ayres' study showed close agreement for left, right and total nystagmus duration. No significant differences in vestibular response were found for age or sex. It was concluded that norms supplied for the SCPNT applied accurately to subjects three to ten years of age.

Several studies have been carried out investigating the test-retest validity of the SCPNT.

In 1980, Royeen carried out a pilot study involving primary grade children to assess whether time of day or sex affected the test-retest reliability of the SCPNT. The SCPNT was administered at two week intervals to 12 boys and 12 girls. The Pearson Correlation Coefficients revealed a reliability coefficient of .85 for total duration measurements in her group, leading to the conclusion that the reliability coefficient was not affected by the time of the test or the sex of the child. In her study a typical response to the SCPNT by the subject was one of pleasure. It was unusual for subjects to show alarm, threat or loss of balance while rotating. This was in keeping with Ayres (1975) findings.

Deitz et al (1981) reported test-retest reliability coefficients for 28 three year olds and 42 four year olds. They found these to be .62, and .83 respectively showing that test-retest reliability is weak for three year olds, and adequate in four year olds. In consequence they questioned the use of the SCPNT in three year old children.

In her 1981 study, Kimball retested 63 children two and a half years after the initial testing and obtained a test/retest reliability coefficient of .80 for total duration scores. Although these results indicated that the SCPNT was stable with normal subjects Kimball warned that results should be interpreted cautiously in children with problems.

In Punwar's study (1982) a test-retest reliability coefficient of .82 was found for total duration scores in the SCPNT. This was comparable to that found in the original

study by Ayres (1975), and with the findings of Kimball (1981) and Royeen (1980).

Kennedy (1984), attempted to make the SCPNT more reliable by controlling some of the administration variables. She conducted a pilot study to compare the performances of three, five and six year old children on the standard version of the Southern California Postrotatory Nystagmus Test and on a revised version of this test. In the revised version, the following modifications were made:

A wooden corner seat was attached to the rotating board in order to control trunk stability. A velcro strap attached to the seat provided additional support. A desk lamp shade with padding inside was attached to the corner seat to control the position of the head. The position of this shade could be varied. The child was encouraged to help the therapist count the turns in order to maintain mental alertness. The number and the rate of rotations was the same as in the original version. Dimmed lighting was used to reduce visual stimulation and the examiner sat far to the left of the subject to eliminate the possible use of peripheral vision for fixation. Both the standard version of the SCPNT and the revised version of this test were administered approximately one hour apart on two occasions. Scores were compared using the Student t test. These did not reveal statistically significant differences. Pearson product moment correlations were determined between both forms of the test for each age group. Coefficients for the the three year old group were not significant but were significant for the older group.

Since there was a significant correlation between the total scores of the two tests for the five and six year age groups, it was concluded that they measure the same neural mechanism mediating the nystagmus response. As there was no correlation of scores in the three year age group it was postulated that at this age the tests measure different neural mechanisms. Alternatively the discrepancies could have been due to the fact that three year olds had difficulty in holding their heads in the correct position in the original version of the test, while in the modified version, the position of the head was controlled. The author acknowledged that the small sample size limited the validity of the findings in terms of general application.

The following conclusions can be drawn from studies reviewed on the reliability and validity of the SCPNT.

- 1 Polatajko's studies (1981, 1983, 1985) comparing results of an ENG with those of the SCPNT, do not support the hypothesis that the majority of learning disabled children have hyponystagmus. In fact she found no difference in the nystagmus responses of normal and learning disabled children.
- 2 The duration of postrotatory nystagmus obtained in the SCPNT and an ENG show some correlation in adults and in normal girls, but not in learning disabled girls. There was no correlation in excursion scores in any of the samples. (Keating, 1979)
- 3 The duration of postrotatory nystagmus differs in light and

- dark conditions, but subdued light does not affect the response. (Nelson et al, 1984)
- 4 The use of this test with learning disabled children appears to be unreliable. (Morrison and Sublett, 1983; Polatakjo, 1981, 1983, 1985)
 - 5 Punwar (1982) and Stillwell et al (1978) agreed, with Ayres' norms. Norms were found to be different from those in Ayres' study (1975) by Dunn (1981) and Kimball (1981) both of whom suggested a higher cut-off point for the diagnosis of labyrinthine hyper-responsivity.
 - 6 Separate postrotatory nystagmus norms are necessary for children under three years of age. For children over the age of three standardised norms may be used (Kaufman, 1978). Crowe et al (1984) however, suggested different norms for male and female four year olds. Kimball (1981), Punwar (1982) and Royeen (1980) found no significant difference between males and females.
 - 7 Results did not differ in different geographical areas. (Kimball, 1981 and Crowe et al, 1984)
 - 8 Time of day and sex does not affect the test-retest validity of the SCPNT. (Royeen, 1980)
 - 9 Test-retest validity holds good for children four years and over, but not for three year old children. The suitability of this test for three year olds is questioned (Deitz et al, 1981). Test re-test reliability was found to be high with normal children (Punwar, 1983, Kimball, 1981)
 - 10 In a revised version of the SCPNT (Kennedy 1984), results did not differ significantly from those of the original test except in the three year old group.

11 Polatajko (1981, 1983, 1985) proposed that the SCPNT is an invalid test of vestibular function and should be abandoned. Other investigators urged that further research be conducted into the validity of this test. (Keating, 1979, Morrison and Sublett, 1983, Kimball, 1981, Crowe et al, 1984)

NYSTAGMOGRAPHY

All tests described up to this point involve the stimulation of semicircular canals in order to induce nystagmus. There are various methods of recording nystagmus most of which Torok (1969) feels are inexact. Kosey (1977) mentions the following:

a Direct observation

This is the simplest method, but fixation may inhibit nystagmus.

b Frenzel's glasses

These are +20 dioptre lenses that inhibit fixation, magnify nystagmus and provide good illumination.

c Mechanical kymographic records

These are direct recordings from a device implanted into the cornea. Disadvantages of this method are the complexity and potential complications.

d Cine photography

This provides a permanent record useful for future analysis.

e Photoelectric nystagmography (PENG)

This method is based on the differing reflective properties of the iris and sclera in response to an infrared light beam. Specially designed goggles house the light source and sensor. This method is useful when the corneo-retinal potential necessary for an electro-nystagmogram is absent.

f Electronystagmography

This is the most widely used technique for recording nystagmus. It makes possible the measurement of the slow

and fast phases, the amplitude of the beats, and the total number of beats per second.

ELECTRONYSTAGMOGRAHY (ENG)

Much has been written on this subject. The literature most pertinent to this study will be reviewed.

Theoretical basis of an ENG

The ENG records the changes in corneo-retinal potential (CRP) which occur as the eyes move (Brodal, 1962). It was originally believed that the differences in potential were caused by the activity of the oculomotor muscles, but later it was shown that these were generated within the eyeball (Coats, 1975).

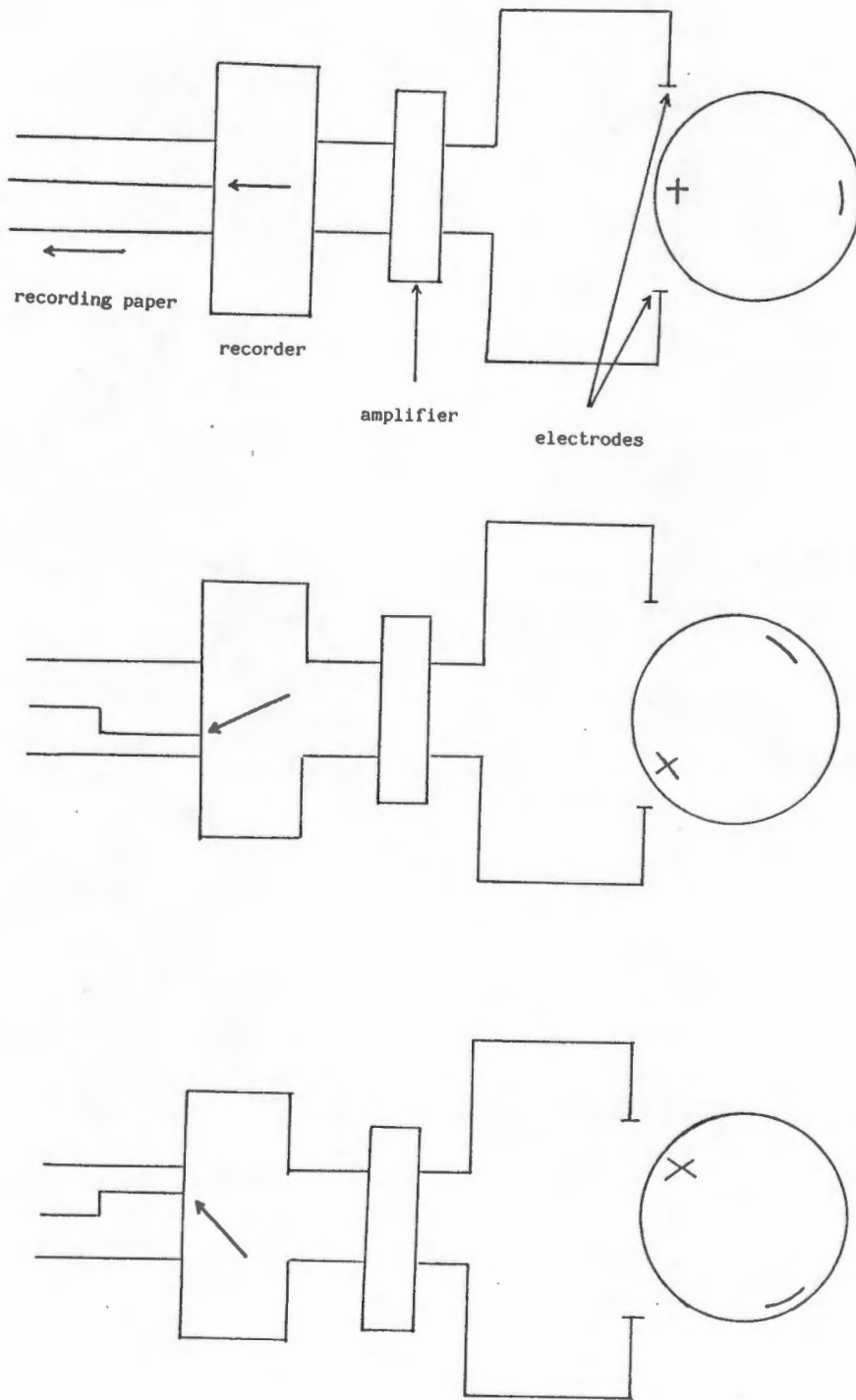
Coats (1975) and Kosey (1977), describe this process as follows:

The CRP causes the eyeball to act as an electrical rotating dipole. The cornea is positively charged, while the retina is negatively charged. Rotation of this dipole creates a voltage difference which can be detected by electrodes placed on the surface of the head. The ENG reflects this voltage difference between the two electrodes. This is amplified and made to drive a pen recorder. The ENG electrodes will record movement in the plane of the electrode pair. A baseline potential is recorded with the eyes in a neutral position. Gaze to the right produces a shift in CRP resulting in a deflection of the pen recorder. By convention right gaze is designated positive potential which is recorded as upward

deflection of the pen. Left gaze produces negative potential and a downward shift of the pen. This is illustrated in the following figure.

Figure 7

THE PRINCIPLE OF ELECTRONYSTAGMOGRAPHY (from Kosey)



CRP varies from person to person and is affected by visual acuity and illumination. The CRP dipole permits simple electrical recording of both spontaneous and induced nystagmus.

The nystagmogram is a sawtooth wave. As the eyes rotate at one speed in one direction, the electrodes record a steady voltage increase. When maximum angular rotation is reached, the direction of rotation is reversed. The eyes return to the neutral position at a faster speed, recording a rapid drop in voltage. The sawtooth raw tracing thus clearly indicates slow and fast components. (see appendix J p.183)

Advantages of ENG (Kosey, 1977)

- 1 It greatly facilitates the quantifying of results.
- 2 It permits indepth analysis of nystagmus parameters.
- 3 It allows for the exclusion of eye movements other than nystagmus.
- 4 It eliminates fixation influences.
- 5 It is possible to detect spontaneous and positional nystagmus which are otherwise not easily detectable.
- 6 It provides a permanent record for printing, comparison and teaching.
- 7 It makes possible the recording of nystagmus during rotation.
- 8 It may be performed with the patient's eyes closed, or in darkness. (Brodal,1962)

Disadvantages of ENG.

- 1 It records only final eye movements and does not consider

factors such as the effects of drugs and muscular fixation.

- 2 It requires special equipment and space.
- 3 It records nystagmus in only one plane, usually the horizontal.
- 4 Patients may voluntarily inhibit nystagmus, and must therefore be distracted by mental tasks.
- 5 A doctor rather than a technician may be required to evaluate the responses.
- 6 It has a limited clinical significance as it measures only the physical sign of nystagmus.

From the above discussion it can be concluded that the ENG, despite a few disadvantages is the most efficient and practical means of recording nystagmus.

Analysis of nystagmus

Nystagmus can be evaluated according to various parameters: latency, duration, frequency, amplitude or height of beats, velocity (speed) of the slow component, velocity (speed) of the fast component, symmetry of response and interbeat interval. There is controversy amongst authors about the accuracy of these and so a review of literature on the use of the different parameters will be presented.

1 Latency

This is the time from onset of stimulus to onset of nystagmus. Kosey(1977), Mulch(1978) and Hamersma(1957) agree that latency is the least informative parameter as its duration is largely a measure of the thickness of the

mastoid process.

2 Amplitude or height of beats

The total amplitude is the sum of the amplitudes of all the nystagmus beats. It represents the total deviation of the eye if it had not been interrupted by fast phases. According to Hamersma (1957) many feel that total amplitude is an important measure of nystagmus which corresponds closely to velocity of the slow slope, frequency of beats and duration. In Kosey's (1977) opinion total amplitude is closely related to frequency and velocity of the slow component but is not as direct a measurement as these.

Hamersma (1957) cites Mittermaier as stating that the mean amplitude of beats (total amplitude divided by total number of beats) shows differences in response better than frequency, but is of less diagnostic value than total amplitude.

Since the amplitude is determined by the point at which the slow phase is interrupted by the centrally induced fast phase, it is considered to be a centrally evoked nystagmus parameter. The high amplitude observed in young children may reflect a low central reactivity to vestibular impulses. (Tibbling, 1969.)

3 Duration

In measuring duration it is necessary to define the precise beginning and end points of the nystagmus response, (Kosey,

1977, Hamersma, 1957). When caloric stimulation is used duration extends from the beginning of irrigation to the end of nystagmus. Hamersma (1957) notes that nystagmus resulting from thermal stimulation usually lasts much longer than postrotatory nystagmus even when the latter stimulus is strongly applied.

Duration is among the least variable of parameters and at one time was a well accepted measure of nystagmus. However Hamersma (1957), Bradford (1975) and Mulch (1978) have observed that duration of nystagmus is an indicator of directional preponderance only and not a good indicator of hyper-responsivity of the vestibular system.

According to Corvera and Romero (1964) duration of post-stimulation nystagmus is an artificial measurement since the sustained stimulation required to elicit such a response is never encountered under normal conditions.

In her study Polatakjo (1983) reported that duration is now regarded as an invalid measure of vestibular function, and recommendations have been made that this parameter is not used in vestibular clinics in Toronto.

Tibbling's study (1969) demonstrated that a short duration can be combined with a high maximum speed of the slow component. He therefore considers it a poor parameter of strength of vestibular activity in children.

The duration of postrotatory nystagmus is the parameter measured in the Southern California Postrotatory Nystagmus Test (Ayres, 1975).

3 Frequency

This is the sum of all the beats during the period of nystagmus, or in the course of a chosen period of time. The use of the total number of beats is not widely accepted as a reliable parameter of nystagmus (Hamersma, 1957, Kosey, 1977) for the following reasons: determination of end points is difficult; frequency varies with alertness; there is considerable individual variation from person to person and counting is tedious. Mulch (1978) on the other hand, feels that the total number of beats is a good measure of nystagmus as it shows a close relationship with the velocity of the slow phase. Both measures correlate linearly with the intensity of the stimulus.

Frequency of beats per unit time appears to be the more accurate measure. Here the number of beats is counted in a given time at the peak of response. Hamersma (1957) recommends ten seconds. A more accurate measure is obtained by counting the sum of the number of beats during two time intervals at the peak of the response. The number of beats is counted by gross observation through Frenzel's lenses, using a stopwatch, or by ENG. Frequency of beats during peak response may show wide inter-subject variability, but little or no right-left variability. This is considered an accurate measure of vestibular function by Kosey (1977)

because it is easy to determine and standards for frequency counts are available.

Tibbling (1969) explains that nystagmus frequency per ten seconds is decreased by an increase in amplitude or by a reduction in speed of the slow component. This accounts for the low frequencies found in children in whom amplitude is high. He believes that nystagmus frequency cannot be used to measure vestibular activity when there is a variation in amplitude.

4 Velocity/speed of the slow component

This is the time taken for the eyes to move from a central position to the point at the periphery where it is interrupted by the fast phase which returns the eyes to a central position.

Kosey (1977) explains that the slow component represents the cupular deflection in the semicircular canals and is therefore the reaction of greatest physiological importance. Most investigators agree that the slow phase represents the vestibular phase of nystagmus (Hamersma, 1957). Indeed some writers stated that measurement of the slow component with the eyes closed, is the only valid measure of vestibular function (Kosey, 1977; Torok, 1969). Corvera and Romero (1964) however argue that measurement of the slow component is artificial since the vestibule needs to know the direction of an abrupt acceleration to prepare the body and limbs for probable impact, and the angular

displacement of the head in order to make compensatory eye movements to prevent the image slipping off the retina. The method of recording the ocular response to vestibular stimulation should therefore include the degree of response which equals the angular displacement of the eyes in relation to the skull, and the degree of stimulation which equals the angular displacement of the skull.

Speed of slow slope is the parameter most closely related to the stimulus inducing nystagmus. Mulch (1978) points out that the maximum velocity of the slow phase is the parameter which exhibits linear relationship to the stimulus intensity in both caloric and rotatory induced nystagmus.

Torok (1967) reports a study examining what he considers to be the two most widely used and accepted parameters of nystagmus - frequency count per time unit and the velocity of the slow component. Both parameters were measured from the same nystagmic response evoked by rotatory and thermal stimulation. These were applied in series in five graded intensities. Frequency and velocity of slow phase of nystagmus were measured over a ten second time period at peak intensity of response. Results of the study indicated that there is a relationship between the strength of the stimulus and both frequency and slow phase velocity, although the physiological basis of these two parameters differs. Torok concluded that both frequency count and slow phase velocity are valid measurements of nystagmus.

Kosey (1977) writes that the velocity of the slow phase correlates better than duration with the intensity of the stimulus and is therefore a better parameter to use than duration.

5 Velocity/speed of the fast component

According to Kosey (1977) velocity of the fast phase of nystagmus can also be used as a measure of vestibular function but is not as accurate a measurement as the slow component as it reflects central rather than vestibular function. A decrease in the speed of fast phase corresponds to suppression of central activity. (Tibbling, 1969)

6 Symmetry of response /directional preponderance

This parameter indicates the difference in nystagmus induced by stimulation of one labyrinth as opposed to the other. According to Corvera and Romero (1964), the criteria of abnormality in ocular response to vestibular stimulation have been based mainly on symmetry of response. Polatajko (1983) noted that since there is a wide inter-subject variability in parameters measuring nystagmus, a clinical assessment of vestibular function usually compares parameters within the subject himself. Examples of measures of symmetry are: unilateral weakness which indicates difference in function between the two labyrinths, and directional preponderance which indicates the difference in left beating nystagmus and right beating nystagmus.

Hamersma (1957) however, reported that asymmetry also

occurs in normal people, and is only considered significant when the difference between the two sides is 20 % or more.

In a study carried out by Eviater and Wassertheil (1971) it was concluded that, although asymmetry can be associated with central nervous system disease, the degree of association is too small to make it a specific pathological sign.

7 Interbeat interval

Sayers (1978) carried out a study to compare two parameters of measurement - slow phase slope of nystagmus and interbeat interval. He concluded that interbeat interval is a more stable measure than speed or amplitude of nystagmus beats and is just as sensitive a measurement of vestibular abnormalities as other parameters. This parameter of measurement was not mentioned in any other studies reviewed.

As a result of research on normal subjects, Mulch (1978) concluded that maximum speed of the slow phase over a ten second peak period and frequency of beats during the same period, measured by ENG are the most suitable indices of vestibular excitability. Other measurements are very time consuming and not as accurate. Eviater and Eviater (1979) agreed with his findings.

It must be concluded from this review of literature on parameters used to measure the nystagmic response that

maximum speed of the slow slope of nystagmus and frequency of nystagmus beats during peak response are the most direct, practical and reliable measures of induced vestibular nystagmus.

Other factors which are taken into account during an ENG examination of nystagmus, are the presence or absence of spontaneous and gaze nystagmus, and the quality of eye tracking (pursuit).

Normative Data on Nystagmus Parameters

There are few papers giving norms for ENG parameters. Polatajko (1981) points out that norms are not readily available due to inter-subject variability and different testing methods. From her literature review it was evident that 25 % difference in response between left and right rotation was considered normal. This figure was reached by accepting limits of normality of 2 standard deviations. These data applied to adult populations. Studies have shown that parameters do change with age (Mulch et al, 1978) and Eviater and Wassertheil (1971) suggest that in patients under 30 years, asymmetry in excess of 18 % be regarded as abnormal.

In a study by Vesterhauge and Larsen (1977) spontaneous, positional and induced nystagmus were measured by ENG in 50 normal subjects. Hot and cold stimulation was given and results were evaluated for duration and for maximum speed of slow slope of nystagmus. Subjects were tested twice and the

mean of the two results was calculated. Normal was determined as being the mean value plus/minus twice the standard deviation. Results indicated that 30 % of the subjects had spontaneous nystagmus and 26 % had positional nystagmus. There was no significant difference between single and double examinations. The study showed that hypofunction on one side may be normal, and that duration and maximum speed of the slow phase reflect different aspects of vestibular function.

Eviater and Eviater (1979) conducted a study to provide normative information for the nystagmic responses of infants from birth to two years. They found that once per-rotatory nystagmus had been elicited, its quality remained unchanged regardless of age and level of central nervous system maturation. They also studied the number of beats per revolution to the right and to the left and found these to be virtually identical. Thus any deviation from this pattern may be considered abnormal and suggestive of asymmetry.

With a sample of twenty normal individuals of various ages and both sexes Brask and Falbe-Hansen (1974) attempted to define normal responses for spontaneous, positional and caloric nystagmus using electronystagmography. A pendulum test was also performed to measure eye tracking. Results for the 20 normal subjects were as follows:

- a. 3 had spontaneous nystagmus, with a 3.5 degree per second maximum slow phase velocity. This remained unchanged in various positions.
- b. 6 subjects had positional nystagmus in up to four

positions, the maximum angular velocity of the slow phase being 7.5 degrees per second.

c. 3 had slightly irregular sinus curves in the pendulum test.

d. The recorded data following caloric stimulation indicated that there was no statistically significant difference between right and left values. No correlations between sex, age and the measured data could be found. Of the parameters measured, duration showed the least standard deviation. It was therefore considered the most appropriate parameter for expression of the normal range.

e. The measured data for all three parameters (maximum velocity of slow phase, maximum frequency and duration), showed a marked inter-subject variability.

Corvera and Romera (1964) described a study in which the compensatory eye movements (CEP) caused by vestibular and optokinetic stimuli were measured in normal individuals and in patients with labyrinthine and brain stem disease.

Abnormality was determined by:

1 A decrease or increase of the optomotor reaction.

Arbitrarily the CEP were considered abnormal when the value fell outside $\pm 30\%$ of the mean value obtained.

2 Asymmetry of response.

The ocular response to the left was compared with that to the right. It was considered abnormal if the smaller value measured less than two thirds of the larger. Results indicated that the CEP was proportional to the angular displacement of the chair, and that variation was linear when displacement was kept between 40 and 280 degrees. The

standard deviation was small.

Tibbling (1969) studied nystagmus in children from birth to fifteen years of age. The children sat on a rotation chair either alone or on the knees of an assistant. Their heads were fixed with the lateral semicircular canals oriented in the horizontal plane. The test was performed in total darkness. The angular acceleration was 120 degrees per second per second for 1.8 seconds. After 1.8 seconds, the velocity was constant and rotation continued for one minute. From the per-rotatory recordings, the following parameters were measured:

speed of slow and fast components, amplitude of nystagmus, nystagmus frequency per 10 seconds of rotation and duration of per-rotatory nystagmus.

Findings were as follows:

- a) The youngest children had a higher maximum speed of slow component than the older children which indicates a more intense vestibular response. In some cases the speed of the slow phase was even greater than the speed of rotation. The maximum speed of the slow phase diminished with increasing age.
- b) The speed of the fast component was found to fall with increasing age.
- c) Nystagmus amplitude was found to decrease with increasing age. By ten years of age however amplitude is relatively unaffected by decrease in vestibular response as determined by the speed of the slow component. There was an increasing correlation between amplitude and speed of fast component

as vestibular response diminished in the older age groups. This supports the hypothesis that these parameters are associated with central function.

- d) There was a highly significant difference in nystagmus frequency between the youngest and oldest age group. The mean nystagmus frequency during the first 10 seconds rose with increasing age from 15 to about 23 beats.
- e) The three to twelve month old age group was found to have a significantly lower duration of nystagmus than the one to three year group. The duration of nystagmus did not differ significantly between the groups of more than one year old.

Tibbling concluded that nystagmus intensity may be classified according to: 1) the peripheral activity reflected by the maximum speed of the slow component, and 2) the central activity reflected by the amplitude. Using these criteria the nystagmus response of the younger children was characterised by a higher peripheral and a lower central nystagmus intensity than the older children.

Hamersma (1957) describes four main patterns of ocular pursuit:

- 1 A smooth sinusoidal curve.
- 2 A few intermittent non-nystagmic movements superimposed on the sinusoidal curve.
- 3 Many rapid saccadic movements superimposed on the sinusoidal curve.
- 4 Loss of sinusoidal curve.

Types 1 and 2 are found in normal individuals. 65% of cases

of type 3 are found in CNS disease. The other 35% are due to peripheral lesions. Spontaneous nystagmus of central origin may be superimposed on the response. Acute spontaneous nystagmus of peripheral origin may or may not come through on the curve. Inner ear disease rarely disturbs tracking.

It can be seen from the above discussion, that certain factors complicate the determination of normative data. There are no standardised methods of testing vestibular function. There is a difference both in the type of stimulation administered and in the way it is applied. Although there is general agreement that the maximum speed of the slow phase of nystagmus and frequency of beats during peak response are the most appropriate measurements of vestibular function, there is no consistency in the ways these scores are calculated in the studies examined. Comparisons between studies can therefore not be made. Lastly it is generally acknowledged that the nystagmic response varies considerably from one normal individual to another, which makes difficult the determination of a cut-off point at which the response should be considered abnormal. Two standard deviations above and below the mean of the control sample, is commonly used as this cut-off point.

Added to these problems, are the many factors which affect the nystagmic response. These will be discussed in the next section.

FACTORS AFFECTING NYSTAGMUS

1. Light

The corneo-retinal potential increases with light intensity to a maximum which is reached in seven minutes. This is followed by a gradual decrease to a stable level which is attained in fifteen minutes. Toglia (1976) therefore suggests that when tests are to be performed in the dark the patient should be dark adapted for fifteen minutes prior to the first test.

Frequency of nystagmus beats may diminish in total darkness and also in light in proportion to its intensity (Toglia, 1976).

2. Visual Fixation

Toglia (1976) discusses the effect of visual fixation on nystagmus. Nystagmus may be inhibited or enhanced by visual fixation. If inhibited, it is usually of peripheral origin, while if increased, it is of central origin.

Fixation may be prevented by:

- passively closing the eyes,
- active closure of the lids,
- covering the eyes with pads,
- the use of Frenzel's glasses,
- darkening the room.

Each of these methods influences nystagmus by means of a different physiological mechanism.

Kalinovskaya (1970) noted that in healthy subjects, shutting the eyes weakened rotatory nystagmus and intensified caloric nystagmus. He also noted that preventing fixation by the use of Frenzel's lenses affected amplitude of nystagmus less than did closing of the eyes.

Levy et al (1977) concluded from his study, that failure to eliminate visual fixation opportunities can result in depressed, disrhythmic or absent responses. He recommended the clinical use of blackout goggles.

In 1974, Ornitz et al studied the effect of visual input on postrotatory nystagmus. Twenty five normal children were studied over three sessions. The Bárány procedure was used. The children were rotated ten times in twenty seconds, first in a clockwise and then in a counter-clockwise direction, followed by an abrupt stop. The horizontal semi-circular canals were maintained in the correct position by an occipital brace. The children were tested under six different conditions of light and fixation.

Conclusions from this study were:

- a) That nystagmus differs significantly under different conditions, ($P < 0.001$).
- b) That the duration of postrotatory nystagmus is significantly longer in total darkness than in all other conditions.
- c) That there is a significant reduction in the duration of postrotatory nystagmus and the total number of beats

when visual fixation is precluded, but some light impinges on the retina.

- d) That the greatest suppression of postrotatory nystagmus occurs in the presence of visual fixation and good light. Thus fixation and light appear to have additive effects in the suppression of vestibular nystagmus.

3. Position of the Eyes

According to Toglia (1976), nystagmus may be modified by the position of the eyes. Deviation of the eyes towards the side of the slow phase of nystagmus decreases its intensity, whereas deviation of the eyes to the side of the fast phase increases intensity.

4. Position of the Head and Neck

Different positions of the head can also affect nystagmus. Toglia (1976) suggests that this may be due to several factors including changes in the endolymphatic flow in the semicircular canals, utricular stimulation by gravity and the influence of neck proprioceptors. It is therefore important to take note of the relationship between head and neck when nystagmus is being assessed.

5. Mental Alertness

Nystagmus may be inhibited by drowsiness and enhanced by mental alertness. Mathematical calculations and conversations are often used to keep the patient at a constant level of alertness (Toglia, 1976). Kalinovskaya and Yusevich (1970), consider the increase in nystagmic

response during mental activity to be associated with a weakening of suprasegmental regulation of vestibulo-oculomotor reactions. Eviater and Eviater (1979) maintain that drowsiness or sleep may completely inhibit nystagmus. Once nystagmus has been elicited however, state of consciousness does not affect the quality or duration of the response.

McCabe and Rya (1980) reported their findings regarding the effect of two types of attention-requiring tasks on vestibular nystagmus elicited by caloric stimulation. The tasks were mental arithmetic and a short conversation. The subjects were divided into four groups according to the stimulus and the task. The two parameters used to assess nystagmus intensity under the various experimental conditions were beat frequency and average slow phase velocity for a five second time interval.

The results were as follows:

- There was a statistically significant increase in slow phase velocity following the initiation of conversation. In most cases beat frequency was not affected.
- Stimulus repetition resulted in a statistically significant decline in slow phase velocity. There was recovery of the response to former level following resumption of conversation.
- A change of mental task from arithmetic to conversation increased the velocity of the slow phase of nystagmus.

- When conversation was used as the predominant alerting method during the administration of repeated stimuli, the slow phase velocity remained constant. However when mental arithmetic was used as the predominant alerting method stimulus repetition brought about a decline in slow phase velocity.
- Beat frequency was constant throughout the trials.

Strauss and Gottesberge (1978), reported the effect of mental activity on thermally induced nystagmus under different test conditions. Subjects tested in a dark room with their eyes open and performing arithmetical calculations showed a statistically significant increase in nystagmus response. The greatest change was noted in total amplitude. Illuminating the eyes with Frenzel's glasses and thereby eliminating fixation did not alter amplitude, but further increased duration and frequency of nystagmus. Visual fixation in good illumination brought about a decrease in all parameters of nystagmus and under these conditions mental arithmetic further decreased the intensity of the response.

It was concluded that an ENG should be carried out in a dark room with the patient's eyes open and that arithmetical exercises should be given only when the response was so small that evaluation would be very difficult without amplification.

Montgomery and Rodal (1982), carried out a study to

determine the effect of mental state on the duration of nystagmus following the administration of the Southern California Postrotatory Nystagmus Test (SCPNT). The purpose of their study was to determine the influence of mental state on nystagmic response. The SCPNT was administered to 24 normal children. All children were tested in three states of arousal:

- 1 Alert state - here the child was given no special instructions before administration.
- 2 Aroused state - the child was asked to run 100 meters, quickly assume the test position, and perform arithmetical problems while rotating.
- 3 Relaxed state - the child was seated on the board and approximately one minute was spent helping him to relax. For example, the examiner said, "Try to relax your arms and legs. Think how you feel when it's bedtime." Silence was kept between verbal instructions. The child was then asked to open his eyes and the test was administered.

Results showed that although there were moderate correlations among total duration scores for the three sessions, wide individual differences were apparent. This suggests either that nystagmus can be affected by varying conditions or that individual variability from one test session to another is large. The authors observed that solving mathematical problems appeared to stop the eyes moving and suggested that solving problems may have increased visual fixation and that the aroused state should have been produced by physical exercise only.

They recommended however that in any studies of nystagmus, the therapist must consider the relationship between nystagmus and the state of mental alertness, especially when there are no other signs of vestibular dysfunction.

6. Drugs

Toglia (1976) recommends that the patient should avoid alcohol, sedatives and all other non-essential medicine for at least three days prior to an ENG examination.

7. Habituation

Habituation does occur in caloric induced nystagmus according to Sayers (1978). Kalinovskaya and Yosovich (1970) also found that with repeated stimulation of the semicircular canals the latent periods increased and the beat frequency and duration of nystagmus decreased. These authors believe that this is due to decreased sensitivity of the receptors in the semicircular canals.

McCabe et al (1973) found that the normal response of vertigo and nystagmus could not be elicited by caloric or rotatory stimulation in highly proficient skaters. Novice figure skaters had a normal response at the beginning of the study, but by the end of the study responses were reduced. Evidently those semicircular canals with axes the same as the axis of rotation are the first to decrease in response. This effect eventually spreads to all the canals. After a few weeks without spinning skilled subjects noted moderate dizziness upon rotation, but this disappeared

after a few days of resumed spinning. These findings were obtained in experienced skaters. Ballet dancers show a normal nystagmic response after spinning, whilst blindfolded skaters have no nystagmus after rotation. This is because figure skaters do not fix their eyes on a stationary spot during spinning, whereas dancers do.

McCabe believes that central suppression is the primary mechanism causing habituation, since higher neurone arcs must be involved in order for suppression to spread to the entire vestibular labyrinth. She points out that these findings have implications for occupational therapy.

8. Emotional Response

The corneo-retinal potential is affected by the emotional response which often develops after the first test. If the patient becomes apprehensive the corneo-retinal potential will increase thus amplifying the nystagmic response. (Toglia, 1976)

9. Latent Spontaneous Nystagmus

Latent nystagmus may not be detected at the beginning of the vestibular examination, but may become evident at the end of the examination. When present the resulting nystagmus can be considered the algebraic summation of the latent and induced nystagmus. Latent nystagmus must therefore be taken into consideration when assessing ENG's. (Toglia, 1976)

10. Strength of Stimulus

Fluur and Mendel (1969) investigated the relationship between the strength of acceleration and the duration of postrotatory nystagmus. Twenty two healthy subjects were rotated at acceleration strengths of one, two, four, and eight degrees per second per second. Duration of post acceleratory nystagmus was measured after each acceleration. The duration tended to be longer with increased strength of stimulus although a relatively small increase was noted in the acceleration range of four to eight degrees per second. On average the duration was approximately the same after both clockwise and counter-clockwise directions. Large individual variations were found in normal subjects.

From the above discussion it is apparent that nystagmus is affected by many factors. Some of these can be controlled while others cannot. Effects vary considerably from subject to subject and thereby complicate the establishment of norms.

OTHER TESTS OF VESTIBULAR FUNCTION

Tests of physiological vestibular nystagmus have been discussed. A brief mention of other tests of vestibular function follows.

1 TESTS OF OTOLITH FUNCTION

Kosey (1977) describes three tests of otolith function:

- i) The Parallel Swing which tests the reactivity and sensitivity of the otolith organs by producing linear acceleration which stimulates the maculae.
- ii) The Oculographic Illusion Test in which an illusion of object displacement is produced by linear acceleration which is measured.
- iii) The Ocular Counterrolling Test in which the rolling motion of the eyes in response to lateral inclination of the head is noted.

The otolithic organs may be functioning normally when the semicircular canals are not. Therefore an investigation of their function may be warranted.

2 VESTIBULO-SPINAL TESTS OF VESTIBULAR FUNCTION

Man maintains his spatial orientation by integrating afferent impulses from the vestibulo-ocular and proprioceptive systems. The CNS integrates these sensations to effect appropriate righting reflexes. Vestibulo-spinal tests evaluate various parts of this reflex system. The Romberg, gait, posturography, walzing, rails, lateropulsion and

laterotorsion tests evaluate the trunk or righting system as a whole. Past pointing and vertical writing evaluate function in the upper extremities; the stepping test evaluates the lower extremities and the tilt test combines responses of the upper and lower extremities. (Lee and Chasin, 1975; Kosey, 1977; Kaptein and de Wit, 1972; Fakuda, 1959)

One disadvantage of these tests is that they do not isolate labyrinthine function from proprioceptive and cerebellar function as well as do those tests involving stimulation of the semicircular canals and the otoliths. Another is that standardisation and the establishment of norms are difficult because of large inter-subject variability. An advantage is that the tests involve more natural stimulation than laboratory examinations do and require less equipment and specialised knowledge in their administration.

3 THE IDENTIFICATION OF VESTIBULAR BASED DYSFUNCTION ACCORDING TO AYRES' CRITERIA

In this section the criteria for the identification of vestibular based disorders suggested by A. J. Ayres and others who have continued to develop and research her theories will be discussed. Then following tests have been suggested for the identification of this type of disorder: (Ayres, 1972, 1979; Kimball, 1982)

a) The Southern California Postrotatory Nystagmus Test.
(1975)

A description of this test is given on p. 106, and validity studies discussed on p. 49. This is considered by Ayres (1975) and Kimball (1981) to be one of the most important screening tests for vestibular dysfunction.

b) Clinical Observations

This is a set of clinical tests which Ayres (1972) suggested could aid in the diagnosis of the different syndromes defined by her. (see appendix G, p. 179)

Dunn (1981) carried out a study which led to tentative norms in these observations for five year old pre-school children. The results of her study have been published in the form of a manual. Other therapists have published studies which have attempted to standardise the administration and scoring of the "clinical observations" on different age groups (Harris, 1981; Longo-Kimber, 1984; Bundy and Fisher, 1981; Parmeter, 1975, 1983; Zemke, 1983; de Gangi et al, 1980).

In 1984 the Research Committee of the South African Institute of Sensory Integration produced a videotape in an attempt to standardise these "Clinical Observations". A manual which contains instructions for the administration, scoring, and interpretation of each test is in the process of being produced for use with the videotape.

Those "Clinical Observations" which aid in the diagnosis of

vestibular based sensory integrative disorders and which were used in this study are described on p. 107.

c) The Southern California Sensory Integration Tests, (Ayres, 1980).

Certain scores in this battery of tests are taken into consideration in the identification of vestibular based sensory integrative problems. A description of these tests will be found on p. 101.

Studies on the identification of vestibular based disorders using Ayre's test criteria.

Ottenbacher (1978) attempted to identify neuro-behavioural functions of the vestibular-proprioceptive systems that would assist in identifying vestibular processing dysfunction in learning disabled children. The study included 92 children between the ages of 53 and 120 months, all of whom had evidence of learning disability, minimal brain dysfunction, or perceptual-motor disorders. Nine variables were identified and subjected to a multiple regression analysis. This showed that prone extension posture, standing balance with eyes closed, muscle tone and standing balance with eyes open were the variables most closely related to SCPNT scores and it was suggested that these should be routinely included in the evaluation of the vestibular-proprioceptive system.

De Gangi et al (1980) investigated the measurement of vestibular based functions in preschool children. A 21 item test entitled, "Assessment of sensorimotor integration in

pre-school children" was developed. The subtests fell under three headings: 1. Postural control, which was subdivided into flexion, extension, tonic labyrinthine integration and cocontraction; 2. Reflex integration; 3. Bilateral Motor Integration. Actual test items were not described fully, but were based on the observations suggested by Ayres (1972). The samples consisted of 113 normal and 23 developmentally delayed children from three to five years of age. It was concluded that:

- The test items validly measure vestibular based functions.
- The six component sub-tests provide strong discriminative power and a high degree of accuracy in classifying children as normal or developmentally delayed.
- The tests could be administered with a high degree of objectivity by therapists with little or no experience in sensory integration testing.
- Findings should be regarded as tentative until further studies on cross validation and construct validity have been conducted.

The relationship between the Southern California Sensory Integration tests, the Southern California Postrotatory Nystagmus Test, and Ayres' Clinical Observations and tests used in otolaryngology, ophthalmology and audiology was investigated by Royeen et al (1981). Only two children with vestibular based sensory integrative dysfunction were included in the study. Results revealed no agreement between the SCPNT and the otolaryngological examination. The authors concluded that there is a need for continued research, and

that norms and operational procedures should be defined in conjunction with otolaryngologists.

Short, Watson, Ottenbacher and Rogers (1983), obtained normative data for 156 four year old children on certain of Ayres' clinical observations. A regression analysis was done to determine the relationship between these observations and results of the SCPNT. It was found that the single best predictor was cocontraction, but this only accounted for 7 % of variance of SCPNT. The remaining variables in order of contribution to the prediction of postrotatory nystagmus duration were: prone extension posture, flexed supine posture, asymmetric tonic neck reflex, standing balance with eyes open, sex and muscle tone. Standing balance with eyes closed, contributed so little that it wasn't included in the regression. Together, the variables only accounted for 13.5 % of variance of SCPNT. An additional regression was conducted to predict postrotatory nystagmus in subjects who scored less than 1 standard deviation below the mean on the SCPNT. For these subjects the independent variables in order of contribution to the regression were: prone extension posture, standing balance with eyes open, muscle tone, sex, supine flexed posture, cocontraction and asymmetrical tonic neck reflex. All of these variables accounted for 50 % of the variance of SCPNT. Low muscle tone was found to accompany short duration nystagmus in agreement with Ottenbacher (1978) and Ayres (1975). Further studies were recommended to determine the relationship between "clinical observations" and vestibular function.

This discussion on the identification of vestibular disorders according to Ayres' test criteria leads to the following conclusions:

- 1 Most studies agree that the test items selected by Ayres are able to identify vestibular disorders; their validity however is measured against the SCPNT assuming this to be an accurate measure of vestibular function.
- 2 There is disagreement about the weighting of different variables with regard to their discriminative ability.
- 3 The validity of the SCPNT as a pure test of vestibular function is questioned.
- 4 There is no correlation between an ENG investigation of vestibular function and criteria suggested by Ayres.

CHAPTER 111

METHODOLOGY

3.1 HYPOTHESES

The following nul (H_0) and alternate (H_1) hypotheses were formulated in pursuit of the aims of this study as outlined in Chapter 1.

HYPOTHESIS 1

H_0

There is no correlation between the results of the Southern California Postrotatory Nystagmus Test and an electronystagmographic (ENG) investigation of vestibular function.

H_1

There is a correlation between the results of the Southern California Postrotatory Nystagmus test and an electronystagmographic investigation of vestibular function.

HYPOTHESIS 2

H_0

Mean maximum speed of slow phase, frequency, symmetry of nystagmus and duration of postrotatory nystagmus measured on an electronystagmogram, do not discriminate between normal and abnormal vestibular function as do the test criteria suggested by Ayres.

H 1

Mean maximum speed of slow phase, frequency, symmetry of nystagmus and duration of postrotatory nystagmus measured on an electronystagmogram do discriminate between normal and abnormal vestibular function as do the test criteria suggested by Ayres.

No hypothesis was formulated for Aim 3, since this is an exploratory aim.

3.2 VARIABLES

The following independent and dependent variables were identified:

INDEPENDENT VARIABLE H 1:

Vestibular function measured by an ENG.

DEPENDENT VARIABLE H 1:

Vestibular function measured by the Southern California Post-rotatory Nystagmus Test.

INDEPENDENT VARIABLE H 2:

Vestibular function according to Ayres' test criteria.

DEPENDENT VARIABLE H 2:

Vestibular function measured by an ENG.

INDEPENDENT VARIABLES AIM 3

Components of Ayres' test criteria.

DEPENDENT VARIABLE AIM 3

Mean maximum speed of slow phase of nystagmus measured on an ENG during clockwise and counter-clockwise rotation.

CONTROLLED VARIABLES

Age: 6 to 8 years.

Sex: Samples matched.

Ethnic group: White English speaking.

Socio-economic status: Social class 1, 11, and 111
(Classifications of Occupations H.M.S.O. 1960)

Medical history: No clinical evidence of :-

emotional maladjustment;

cerebral palsy;

neurological dysfunction;

impairment of vision or hearing.

Geographic area: All children attended Government schools in the Southern Suburbs of Cape Town.

3.3 INTER-TESTER RELIABILITY

All the Southern California tests were administered by the author (Certified tester of the Southern California Sensory Integration Tests).

All ENGs were administered by the same audiometrist, Mrs. Rogers, assisted by the author.

3.4 SAMPLE SELECTION

EXPERIMENTAL GROUP

Twenty three children were selected from those referred by paediatricians to the Red Cross Children's Hospital for an occupational therapy assessment.

The purpose and procedure of the research was explained to the parents in the course of an interview, and permission

obtained to involve their children in the study. Parents who consented were asked to respond to the questionnaire (see appendix A, p. 172). Each child who fulfilled the criteria for inclusion in the study was assessed using the Southern California Sensory Integration Tests (Ayres, 1980), the Southern California Postrotatory Nystagmus Test (Ayres, 1975) and Ayres' clinical observations (1972). These are described in detail below.

Those children who, according to Ayres' criteria (see p.89) had vestibular based sensory integration dysfunction were included in the study.

CONTROL GROUP

Twenty three children were selected in the following manner: Letters were sent to all parents in the Sub A, Sub B, and Std. 1 classes at a Junior School explaining the nature of the research project (see appendix B, p. 173). They were asked to give permission for their children to participate in the study, should they be selected. Parents who consented were asked to fill in the same questionnaire as did parents of children in the experimental sample. Teachers were asked to fill in the Teacher's Rating Scale (see appendix C, p. 175) to eliminate the possibility of learning or other sensory integrative problems. Children who appeared to be suitable according to the Teacher's Rating Scale were then assessed with the same test battery as the experimental sample of children and, if found to have normal sensory integrative function according to the Ayres' test criteria, were

included in a list of possible controls. Children from this list were matched to children in the experimental sample in sequential order according to age (within six months), and sex. (see appendix D, p. 176)

3.5 ASSESSMENT TOOLS

In the following section, all the tests and other research apparatus used are described.

THE QUESTIONNAIRE (See appendix A, p. 172)

The parent questionnaire was designed by the author to detect emotional maladjustment, neurological dysfunction, visual impairment and hearing loss. Evidence of any of these would according to the selection criteria applied eliminate a child from the study. When answers to the questions on school performance and emotional problems were in the affirmative, further details were obtained to ascertain whether the problems could be regarded as "normal", or should serve to eliminate the child from the study.

THE TEACHER'S RATING SCALE (see appendix C, p. 175)

The Rhode Island Pupil Identification Scale (RIPIS) (Novack, Bonaventura and Merenda, 1973) was used to identify scholastic difficulties which might indicate a disorder in sensory integration. This test consists of forty items, each of which is scored on a 1 to 5 point scale. Part 1 reflects general behaviour observed in the course of classroom activities. Part 2 reflects the child's written work. The scale was standardised on 851 pupils drawn from seven schools

in Rhode Island.

The score relates directly to predicted likelihood of learning difficulties. In order to establish predictive validity, teachers were asked to rate pupils in June and again in October. Children were classified into four categories according to score obtained. Category 1 consisted of children with the lowest scores, in whom there was little likelihood of learning difficulty. Category 4 consisted of children who were likely to experience considerable learning difficulty and fail to achieve the desired standard by the end of the year.

In this study the mean of the two scores (June and October) for children falling into category 1. was taken as the cut-off score for children eligible for the control sample. Such children according to the scale used should experience little or no learning difficulty.

Two questions were added to the rating scale:

Has this child ever required remedial help?

Has this child ever repeated a year?

An affirmative answer to either of these questions eliminated the child from the study.

This rating scale was chosen because it made minimum demands on the teachers' time. In addition relatively little training was required in its usage and interpretation.

THE SOUTHERN CALIFORNIA SENSORY INTEGRATION TESTS

(Ayres, 1980) (see appendix E, p. 177)

The Southern California Sensory Integration Tests (SCSIT), consist of the following sixteen sub-tests listed in order of administration:

1. Space visualisation

In this test use is made of two plastic formboards, one egg-shaped and one diamond-shaped, four egg shaped blocks and four diamond shaped blocks. The examiner presents the child with a series of problems each consisting of one formboard and two blocks. He is required to choose the appropriate block. In order to do this, he must perceive spatial stimuli and in the more advanced items mentally manipulate spatial relationships. No motor response is required. A score which reflects the child's ability to cross the midline of his body is also derived from this test. It is termed the Space Visualisation Contralateral Hand Usage (SVCU) and is based on the number of ipsilateral and contralateral responses the child makes when picking up the forms.

2. Figure-Ground Perception

This test was designed to determine the child's ability to focus attention on a foreground figure without being distracted by a rival background. The test booklet contains forty eight test items. The child is required to select from figures depicted at the bottom of the page those three which are embedded or superimposed in the picture at the top of the page. Performance of this test may be impaired by anxiety and

results obscured by guessing. No motor skill is involved.

3. Position in Space

This test was designed to measure the child's ability to discriminate the same geometric form in different orientations. The thirty test items are divided into three sections. In the first section the child is assisted so that he can learn from his mistakes; in the second section, no help is given and the time taken is recorded, and in the third section visual memory is required to choose the correct form.

4. Design Copying

This test was designed to measure a combination of visual perceptual skills. It requires the perception of a geometric design made by joining dots, and the reproduction of that design by joining the same dots duplicated on the test sheet. The test consists of thirteen items graded for complexity. Performance can be influenced by practice effect.

5. Motor Accuracy

This test was designed to measure the accuracy of a visually directed pen. The child is required to draw a line on top of a solid printed line. His performance is timed and the accuracy of his drawing is measured with a line measure. A score is obtained for both left and right hands.

The Space Visualisation, Figure-Ground perception, Position in Space, Design Copying and Motor Accuracy Tests are

standardised for children from four to ten years of age.

The following six tests, assess somatosensory perception. They are easily understood and require no verbal response from the children. The tests are standardised for children from four to eight years.

6. Kinesthesia

This test requires the child, without the aid of vision, to replace his finger on a particular spot on a test chart where it had previously been placed by the examiner. The test is intended to measure the child's perception of joint position and movement. The distance of the child's finger from the original point is measured.

7. Manual Form Perception

This is a test of inter-sensory integration and is based on well known tests of stereognosis. The child is given a plastic geometric form under a cardboard shield and without the help of vision is required to point to the picture on a printed sheet representing the same form.

8. Finger Identification

Here the child is required with vision occluded to point to the finger or fingers touched by the examiner.

9. Graphesthesia

In this test the examiner draws a design on the dorsum of the child's hand with the eraser end of a pencil while occluding

his vision. The child is required to draw the same design in the same place with the index finger of the other hand.

10. Localization of Tactile Stimuli

The child is required with eyes occluded to place his finger on a spot on his arm previously marked by the examiner's pen. Unlike the previous three, this test does not include the perception of form.

11. Double Tactile Stimuli

Two stimuli (pencil erasers) are applied by the examiner to the child's hand, cheek or hand and cheek simultaneously. After each application the child is asked to touch the same place/places. The results may be influenced by anxiety and distraction.

The following tests were designed to evaluate some of the higher levels of sensory integration involving several modalities. They are standardised for children from four to eight years of age.

12. Imitation of Postures

Here the child is required to assume a series of positions demonstrated by the examiner. This requires the motor planning of a skilled, non-habitual motor act.

13. Crossing the Midline of the Body

In this test the child is asked to imitate the examiner as she points to one or other of her ears or eyes with one of

her hands. Half the items involve pointing to the ipsilateral eye or ear and half to the contra-lateral eye or ear. A weakness of this test is that an intelligent child may work out the movements cognitively rather than perceptually.

14. Bilateral Motor Coordination

This test requires the child to imitate the examiner in executing smooth coordinated bilateral movements of the upper limbs. Both motor planning and the integration of movements of the two sides of the body are involved. The execution of this test will be affected by upper motor neurone lesions. An advantage is that it cannot be performed cognitively.

15. Right-Left Discrimination

In this test the child is required to identify left and right on his own body, on the examiner and in extra-personal space.

16. Standing Balance with Eyes Open and with Eyes Closed

These two tests assess the ability of the child to balance on one leg, first with his eyes open and then with eyes closed. In both tests a record is made of the length of time the child is able to maintain the position.

All these tests are scored by comparing the child's raw score with that of a normal child of the same age. A standard score is obtained by consulting the charts in the manual. A score less than one standard deviation below the mean indicates a problem in the area tested, while a score more than one

standard deviation above mean indicates above average function. Ayres (1980) recommends that the scores of all test items be considered before a conclusion regarding sensory integrative function is drawn.

THE SOUTHERN CALIFORNIA POSTROTATORY NYSTAGMUS TEST (SCPNT)
(Ayres, 1975) (see appendix F, p. 178)

This test provides a standard procedure for measuring postrotatory nystagmus. The child's response can be gauged by comparing results with those of a normal population.

During testing the child sits cross-legged on a board which turns freely on a ball bearing device attached to another board. Using an angle measure, the child's head is tilted downward to a 30 degree angle in order to ensure stimulation of the horizontal semicircular canals during rotation. The child is told to remain seated in this position with his eyes open while the board is rotated ten times first to the left and then to the right. The second series of rotations is started only after the effects of the first have subsided. Each revolution takes two seconds so that the total period of rotations in each direction is twenty seconds. At the end of the period the board is stopped abruptly and the child is asked to look at a blank wall without focussing on anything in particular. The maximum excursion of the eyeball during nystagmus is noted and the total duration of postrotatory nystagmus is timed on a stopwatch. The examiner's hand remains on the child's knee after rotation has ceased in

order to prevent his falling.

The raw score which is the sum of the duration of postrotatory nystagmus following rotation to the left and to the right, is converted into a standard score by referring to a table. The difference in standard scores following rotation to either side is also calculated.

Certain observations are made and recorded following rotation. These are: balance while turning; head control; and presence of vertigo, dizziness, nausea, alarm, distress or pleasure as a result of rotation. These additional observations aid interpretation of the test.

As this test stimulates only one part of the vestibular system an abnormal response does not necessarily mean dysfunction of other vestibular processes.

This test was standardised on a sample of 111 boys and 115 girls aged five to nine years living in Los Angeles, California.

Since the reliability of this test is questioned in the present study, it was administered and scored without any modifications according to the manual (Ayres, 1975).

AYRES' CLINICAL OBSERVATIONS (see appendix G, p. 179)

Only those clinical observations which according to the literature reflect vestibular function will be described,

although the full battery was administered to children in both samples. Various modifications in the administration and scoring of these tests have been suggested. In this study Ayres' (1972) instructions have been adhered to in most cases.

1. Muscle tone

This tests the quality of muscle tone in the upper limbs.

This test is administered as follows:

The arms are extended forwards at right angles to the body, with forearms supinated, and wrists fully extended. Biceps and triceps are palpated, and the degree of hyper-extension (beyond 180 degs.) in the elbow joints is noted. Observations of general movements made by the child during the test contribute to the assessment of muscle tone.

2. Cocontraction

This tests the child's ability to contract simultaneously the muscles around the elbow and shoulder joints and then the neck joints, while stabilising the trunk.

Administration of the test:

The child is seated on a chair opposite the examiner. He is not allowed to stabilise himself against the back of the chair. He is asked to grasp the examiner's thumbs with his elbows flexed while she alternately pushes and pulls on his hands in an arc-type motion saying, "Don't let me push you, don't let me pull you." The child is given an opportunity to build up tone.

To test cocontraction of the neck muscles the examiner places

her hand on top of the child's head and attempts to move his head back and forth and from side to side while pushing down slightly. He is instructed to, "Freeze like a statue".

If the child flexes and extends his arms in response to the therapist's push and pull, or if his trunk is unstable, the response is considered inadequate. Similarly if he cannot stabilise his head against the movements of the therapist's hand, cocontraction around the cervical joints is considered deficient.

3. Prone extension

This tests the child's ability to assume and to maintain a position requiring the simultaneous raising of the head, chest and arms from the floor.

Administration of the test:

The child is asked to lie prone and assume a position with his arms abducted 90 degrees at the shoulders, elbows flexed to 45 degrees and hips and knees extended, with knees off the mat. The position is demonstrated to the child and if necessary he is placed in the position at first. After a rest he is asked to assume the position independently and hold it for as long as possible to a maximum time of 30 seconds. While holding the position the child is asked to count aloud in order to prevent him from holding his breath. The examiner's fingers are slipped under the child's knees to ensure that they do not touch the floor. She records with a stopwatch the length of time the child is able to maintain the position.

According to Ayres (1972) normal children aged six and older can usually hold this position with moderate exertion for 20 to 30 seconds. A shorter period can be anticipated in children under six years, while children between four and five years of age may not be able to assume the posture or may sustain it for only a very short period.

The quality of this posture is as important as the time the child is able to hold it. A well integrated child will assume the posture, lifting both ends of his body simultaneously, in a smooth co-ordinated manner and will be able to hold it without great effort. A child who has sensory integration problems will assume the posture with each limb moving independently of the rest of the body and hold the position only with great effort.

4. Primitive postural reflexes

A. The Assymetrical Tonic Neck Reflex (ATNR)

This tests the degree to which the ATNR is integrated.

Administration of the test:

The child is placed in a quadruped position with his elbows slightly flexed to prevent locking. The examiner rotates his head 90 degrees so that the chin and shoulder are in line. She notes the degree of elbow flexion on the occiput side, and any resistance on the part of the child to having his head turned. The child's head is then rotated to the opposite side, and the degree of elbow flexion is again noted. A resistance to head rotation is assumed to indicate an attempt by the child to avoid the disorganising effect of the ATNR.

A test involving the assumption of a posture opposite to that of the ATNR is also administered. The child is asked to turn his head to the side, place his hand on the hip on the side to which the face is turned, and then lift the leg on the opposite side.

The effect of the ATNR is also assessed in Schilder's arm extension test. Here the child stands with his feet together, arms extended in front of him, fingers abducted and eyes closed. The therapist slowly rotates the child's head from side to side while observing the degree of resistance to head turning, changes in arm posture comparing the two limbs, the degree of trunk rotation, any tendency to lose equilibrium, and negative emotional reactions. If the ATNR affects the arms, changes in muscle tone may result in convergence or divergence of arms or raising of one arm and lowering of the other. If the ATNR is affecting the legs the child's equilibrium will be disturbed, and head turning will be resisted.

B. The Symmetrical Tonic Neck Reflex (STNR)

This test determines the degree of integration of the STNR.

Administration of the test:

The child is again placed in the quadruped position with his head in the mid-position. Hips, knees and shoulders are flexed to 90 degrees, and the elbows remain unlocked. The examiner moves the child's head into extension and then into flexion. She observes whether, with the head extended, there is extension of the elbows and a tendency to sit back on the

heels, and whether there are any changes in elbow, shoulder, hip and knee position with the head flexed.

5. Extraocular muscle control

This test determines the child's ability to establish and maintain visual contact with a target.

Administration of the test:

The child is asked to keep his eyes on the rubber of a moving pencil. The pencil is held thirty centimeters from the child's face and moved in an arc equi-distant from the eyes in all planes - horizontally, vertically and diagonally. The child's head is stabilised when necessary. The following are noted: dissociation of eye movements from head movements; coordination of eye movements; ability to cross the midline smoothly, retain the target when losing it and to converge when it is moved towards the eyes.

6. Postural and equilibrium responses

The quality of the equilibrium reactions is observed in different positions on a tilt board. The following points are observed:

amount of trunk rotation, elongation of weight-bearing side, any difference between the responses of either side, the point at which protective extension is exerted and quality of the response including the shift in body alignment.

To test for protective extension, the child is asked to kneel upright on the floor. The examiner then pushes him briskly on the back. The quality and speed of the response is noted.

7. Postural Background Movements

The child's postural background movements are observed during the administration of the Southern California Sensory Integration Tests, especially the Kinesthesia and Motor Accuracy tests, and also throughout the Clinical Observations. These postural background movements are assessed according to the ease with which the child adjusts his posture in order to complete a given task, the degree of resistance or floppiness of the arm during the Kinesthesia test, difficulties in crossing the midline of the body and difficulties in dissociating arm movements from trunk movements.

8. Postural insecurity

This tests the child's response to being placed supine on a moving surface.

Administration of the test:

The child is placed supine on a tilt board. The examiner supports the child at first, then gradually removes this support, while moving the board gently from side to side. The child's facial expression, changes in muscle tone, equilibrium reactions, abnormal movements, voiced responses and attempts to clutch the board or therapist are noted.

In all these "clinical observations" the child's response is graded according to a three point scale: 3 denotes normal function; 2 slight deficiency and 1, poor performance or definite deficiency. (see appendix G, p. 179)

THE ROTATING CHAIR

After a fruitless search for a suitable alternative, a decision was made to construct an electrically driven rotating chair to produce the vestibular stimulation necessary to induce nystagmus for the ENG examination. The chair had to meet the following requirements:

1. Constant rotatory acceleration of a seat platform in the horizontal plane.
2. Constant speed for a specified period. This speed should not exceed one rotation in two seconds. One rotation in three seconds is considered to be the most comfortable speed for the patient.
3. Constant deceleration.
4. The ability to rotate in both a clockwise and counter-clockwise direction at the above speeds and variations of speeds.
5. Complete stability for six to eight year old children, giving confidence at all times during the test.
6. The seat to be fully adjustable and fitted with a safety harness.
7. The apparatus to be completely safe with no drive belts, pulleys, gears, switches or electrical connections accessible to young fingers.

The assistance of an expert in the fields of mechanical engineering, Mr. Bill Bettsworth, and electronics, Mr. Owen Penberthy, was sought in the design and construction of this chair.

Construction of the chair (see figs. 8, 9 and 10 ps.127-129)

Meeting the precise requirements regarding acceleration and deceleration would have required an alternating current motor with electronic controls. This was considered rather complicated and expensive and was not readily available. Thus it was decided to install a constant speed alternating current (AC) "fractional horse power" motor delivering rotary motion through a conventional Vee-belt drive and a reduction gear box.

A reconditioned 0.25 KW AC induction motor with capacitance start was purchased. This motor was capable of 1425 revolutions per minute. In order that the chair be capable of both clockwise and counter-clockwise rotation, it was necessary to change the polarity of one of the coils of the motor. This was achieved by wiring in a double pole double throw switch so that in one position of this switch the chair rotated clockwise, and in the other counter-clockwise. The switch was connected to the motor by a flexible cable of approximately one meter length thus enabling the operator to stand clear of the chair.

To create a base giving suitable stability and adjustability, a typist's swivel chair was obtained which proved to be ideal in all respects. The seat, castors and vertical shaft were removed during construction. On the upper surface of the truncated chair was mounted a worm and worm wheel reduction gear box which was salvaged from a derelict Defence Force radar antenna installation. It had to be mounted at right

angles to the surfaces originally provided in order to bring the worm wheel shaft into a vertical position for rotating the seat. This was achieved by making and fitting a substantial right angle bracket, the back of which served as a base onto which the motor was bolted.

Although the gear box reduced the speed of the vertical shaft considerably ($\pm 75 : 1$), it was found necessary to provide a further 2 to 1 reduction. This was achieved by fitting suitable Vee-pulleys on the motor spindle and worm shaft and connecting these with a conventional half inch Vee-belt. Provision was also made for adjustment of the position of the motor relative to the gear box in order to allow for adjustment to the tension of the belt.

The original padded seat from the typist's chair was then converted in order to have suitable adjustments for height and angle of backrest, and re-fitted to the vertical drive shaft of the gear box.

The castors were not replaced as it was thought that the child would feel more secure on a stable surface. To render the pulleys, drive belt, gears, and electrical connections safe from the child, a 24 inch diameter hardboard disc, which was non-rotating, was interposed between the chair and the "works", as a foolproof safety screen.

Two pairs of velcro straps were attached to the chair, one on the seat to be fastened around the child's waist and the

other on the backrest to be fastened around his chest.

The development and construction of this chair took place over a period of about five months. Both the mechanical and electrical components of the apparatus functioned in a highly successful manner.

THE ADAPTED CERVICAL COLLAR AND GOGGLES (see fig. 15, p.134)

A standard cervical collar was obtained to hold the child's head at a 30 degree angle during rotation thereby ensuring stimulation of the lateral semicircular canals. The section of the collar lying over the sternum was shortened and the curve of the shoulder pieces was narrowed to accommodate a child's body. The section which rests at the base of the skull was removed, and the curve of the chin rest was altered to allow for approximately 30 degree flexion of the neck when the child's chin was resting on it. Fine adjustments were made possible by sliding this section up or down depending on the length of the child's neck. By using an angle guide an exact 30 degree angle could be obtained. A velcro strap was attached to the chin rest which held the child's head in the correct position during and after rotation.

In order to cut out light and to prevent visual fixation during and after rotation, a pair of adjustable swimming goggles was used. The lenses were "blacked out" by painting them with dark nail varnish.

THE ELECTRONYSTAGMOGRAPH (ENG) (See fig. 11, p. 130)

A Tracoustics RN - 260 electronystagmograph was used in this study. This instrument permits an objective evaluation of vestibular function. It graphically records eye movements based on the corneo-retinal potential of the eye. With it the clinician can record an intensity of nystagmus too low to be noticed by the naked eye.

For calibration purposes eye movements are induced by following the activity of three lights attached to a horizontal bar 1.5 meters above the patient with the mid-point directly over his nasion. The calibration light switch activates either right, left or centre light, or selects a flash rate of two seconds alternation between left and right lights.

The chart speed switch selects paper speed of five or ten millimeters per second. The latter speed was selected for this study as this permits easy calculation with a ruler of the velocity of the slow phase.

3.6 TESTING AND SCORING PROCEDURES

Southern California Sensory Integration Tests (SCSIT);
Southern California Postrotatory Nystagmus Test (SCPNT) and
Ayres' Clinical Observations (see figs. 12 and 13 p. 131-132)

- 1 This test battery was administered either in the assessment room of the Occupational Therapy Department at the Rondebosch Cottage Hospital, or in the study at the author's home.
- 2 The child was seated at a table on a chair of appropriate size placed to the left of the author.
- 3 The complete S C S I T battery was administered first, according to the Manual (1980).
- 4 Ayres' clinical observations were completed next, according to instructions (see p.107).
- 5 The child was then positioned on the rotating board, and the S C P N T was administered. This assessment took place at the end of the session as recommended, to avoid any adverse effects on the other assessments.
- 6 The full assessment was completed in one session lasting approximately two hours. This time included a short break of about ten minutes for a cooldrink and biscuit, usually taken at the end of the somatosensory section of S C S I T.
- 7 As this assessment was carried out some days before the ENG assessment, use was made of the opportunity to describe the latter procedure to the child. To make him look forward to this investigation with pleasure, the analogy of "an astronaut training session " was used.

8 Mothers were asked to withhold Methyl Phenidate (Ritalin) for two days before and on the day of the ENG examination, if this drug had been prescribed.

Electronystagmographic Investigation of Rotatory Nystagmus

(See fig. 15 and 16 ps. 133-135)

- 1 This investigation took place in the Audiometry Outpatients Department of Groote Schuur Hospital.
- 2 The author was assisted throughout the study in carrying out this investigation by the same audiometrist.
- 3 The child's mother in most cases remained in the room throughout the test.
- 4 The room was darkened and the child was asked to lie supine on a plinth with his nasion directly below the midline of the bar to which the calibration lights were attached.
- 5 Before placing the electrodes, care was taken to remove skin oils with alcohol swabs in order to establish good skin contact.
- 6 Beckman's silver chloride electrodes were used. The ground (white) electrode was placed in the middle of the forehead immediately above the bridge of the nose. The right electrode (brown) was placed on the flat part of the outer edge of the bony rim of the eye socket in line with the bisector of the eyeball. The left electrode (red) was placed in a similar position adjacent to the left eye (see fig. 14 p. 133). Before placement, the electrodes were covered with Beckman's electrode electrolyte paste. The electrodes were immobilised with Johnson's micropore tape.

7 Calibration procedure

Five minutes were allowed for dark adaptation inclusive of the time taken to place the electrodes. The recorder, pre-amplifier and the velocity coupler were calibrated by having the child shift his gaze between left and right lights without moving his head. This provided him with alternating visual stimuli 20 degrees on either side of the midline. The preamplifier gain was adjusted to provide one centimeter deflection as indicated on the chart recording for ten degrees of eye positional displacement.

8 Measurement of spontaneous and gaze nystagmus

The child was asked to fixate on a small red ball suspended 45 centimeters above him in the centre of his visual field. He held his gaze for approximately 30 seconds and was then asked to close his eyes keeping them in the same position for a further 30 seconds. After this he was asked to fixate on the author's thumbnail held 30 degrees to the right for 15 seconds and then to close his eyes keeping them in the same position for a further 15 seconds. This procedure was repeated with the thumbnail held 30 degrees to the left. Extreme lateral gaze which can produce nystagmus was avoided.

9 Measurement of ocular pursuit (pendulum vision)

The basis of this test is the visual pursuit of a stimulus that moves back and forth in a sinusoidal pattern across the visual field. A small red ball was pulled approximately 30 degrees from the midline and then released to initiate a pendular swing. The child was asked to follow the ball smoothly with his eyes, without moving his head. If

necessary the child's head was stabilised.

Nystagmographic recordings were made during the tests for gaze and spontaneous nystagmus and ocular pursuit.

10 Vestibular Nystagmus

The child was asked to climb off the plinth, and to sit cross-legged on the electrically driven rotating chair (see fig. 15 p. 134-135). He was secured into the chair by means of 2 velcro straps, one around the waist and one around the chest. The adapted cervical collar was placed in position and the chin rest was adjusted so that his head was held at a 30 degree angle. The velcro strap held the child's head in this position. Blacked out swimming goggles were worn to cut out visual stimulation. The child was asked to avoid blinking if possible and to keep his eyes open throughout the test. The box into which the electrodes were plugged was held by the author above the child's head to avoid tangling of the wires. Her other hand was on the switch so that the chair could be stopped immediately should any problem arise. After a warning to the child, the chair was switched on and allowed to rotate 10 times to the right (clockwise). This took 30 seconds, after which it was stopped abruptly (within one quarter of a revolution of being switched off). The child was asked to remain in this position until postrotatory nystagmus had ceased. During a 5 minute pause, the goggles and cervical collar were removed. They were then replaced and the chair was again switched on and allowed to rotate 10 times to the left (counter-clockwise). The room remained dark throughout the test. In order to keep him mentally alert the child was

asked to count the number of turns with the author during rotation, and in the postrotatory phase he was asked questions about his school and family. Recording of nystagmus on the ENG continued during and after both clockwise and counter-clockwise rotation.

11 The goggles, electrodes and neck brace were then removed and the child was released from the chair. He was given a small reward for having "passed the astronaut test", and allowed to leave.

12 The total testing and scoring time for this assessment was approximately 45 minutes.

Scoring the ENG recordings (see appendix H & I ps. 181-182)

After reviewing the literature it was decided to measure the following parameters:

- (i) Mean maximum speed of the slow slope during the five second period at the peak of response.
- (ii) Frequency of nystagmus beats during the same five second peak period.
- (iii) Symmetry of response during clockwise and counter-clockwise rotation.
- (iv) Duration of postrotatory nystagmus.

The peak period of nystagmus during rotation was determined as follows:

The mean maximum speed of the slow slope of nystagmus during clockwise and counter-clockwise rotation was calculated for consecutive five second periods from five seconds after the

start of rotation to cessation of rotation. The first five second period was not taken into account as the start of the recording was often unclear. This calculation was completed on the recordings of six of the control subjects and six of the experimental subjects. The results of this preliminary investigation showed that the peak period of the nystagmic response occurred between five and ten seconds after commencement of rotation. This five second period was therefore chosen for the calculation of the mean maximum speed of the slow slope and the frequency of nystagmus beats.

To measure the mean maximum speed of the slow slope, a ruler line was drawn through all the slow slope tracings of the nystagmus beats during this five second period (see appendix J, p. 183) Using this line, the speed of the slow slope of nystagmus was calculated and the mean of the three largest measurements was taken. The total number of beats during this same five second period was calculated.

Observations of the child's behaviour during rotation were the same as those in the Southern California Postrotatory Nystagmus Test (1975).

3.7 DATA ANALYSIS

A descriptive analysis of the ages and sexes of children in the control and experimental samples was completed.

In order to achieve the first aim of this study: to ascertain whether the results of the Southern California Postrotatory Nystagmus Test (SCPNT) correlate with results of an electronystagmogram (ENG) in measuring vestibular function, a correlation matrix of the variables making up these tests was generated (N = 46). Measures in the ENG were correlated with those in the SCPNT using scores of all the children in both samples. The purpose of this analysis was to determine the validity of the SCPNT as a measure of vestibular function assuming the ENG to be the most accurate measure.

To achieve the second aim of this study: to discover whether there is a significant difference between the ENGs of children identified as having vestibular based sensory integration problems and normal children, results of the ENG in the control sample were compared with those in the experimental sample using the Student t Test. By comparing the means and standard deviations of the two samples on scores for mean maximum speed of slow slope of nystagmus, symmetry of response, frequency of beats during peak response and duration of postrotatory nystagmus measured on the ENG, one could determine whether the difference between them was significant. Results would lead to conclusions regarding the validity of criteria used by occupational therapists to identify vestibular dysfunction.

The number of children with spontaneous and gaze nystagmus in the two samples was determined, and the quality of ocular pursuit in the samples was compared using the Chi-square test. This exercise was undertaken to determine whether there was a significantly greater incidence of spontaneous and gaze nystagmus and abnormal ocular pursuit in the experimental sample.

The third aim of this study was to discover which of Ayres' test criteria, single or in combination discriminate best between normal and abnormal vestibular function. To achieve this a multiple linear regression analysis was applied. The mean of the clockwise and counter-clockwise measurements of the maximum speed of the slow slope of nystagmus (dependent variable) was regressed against all the test scores (27) which are taken into consideration in identifying vestibular based dysfunction according to Ayres' test criteria (independent variables). The purpose of this analysis was to determine whether these variables made a significant contribution to the variance of mean maximum speed of slow slope of nystagmus, and what percentage contribution each made.

The statistical analysis was carried out by Mr. S. Isaacs, the statistician in the Department of Medical Informatics, Groote Schuur Hospital. Mr. Isaacs wrote the statistical programmes used and analysed the data on a Sperry computer.

Figure 8

CONSTRUCTION OF ROTATING CHAIR (A)



Figure 9

CONSTRUCTION OF ROTATING CHAIR (B)



Figure 10

THE COMPLETED ROTATING CHAIR



Figure 11

THE ELECTRONYSTAGMOGRAPH

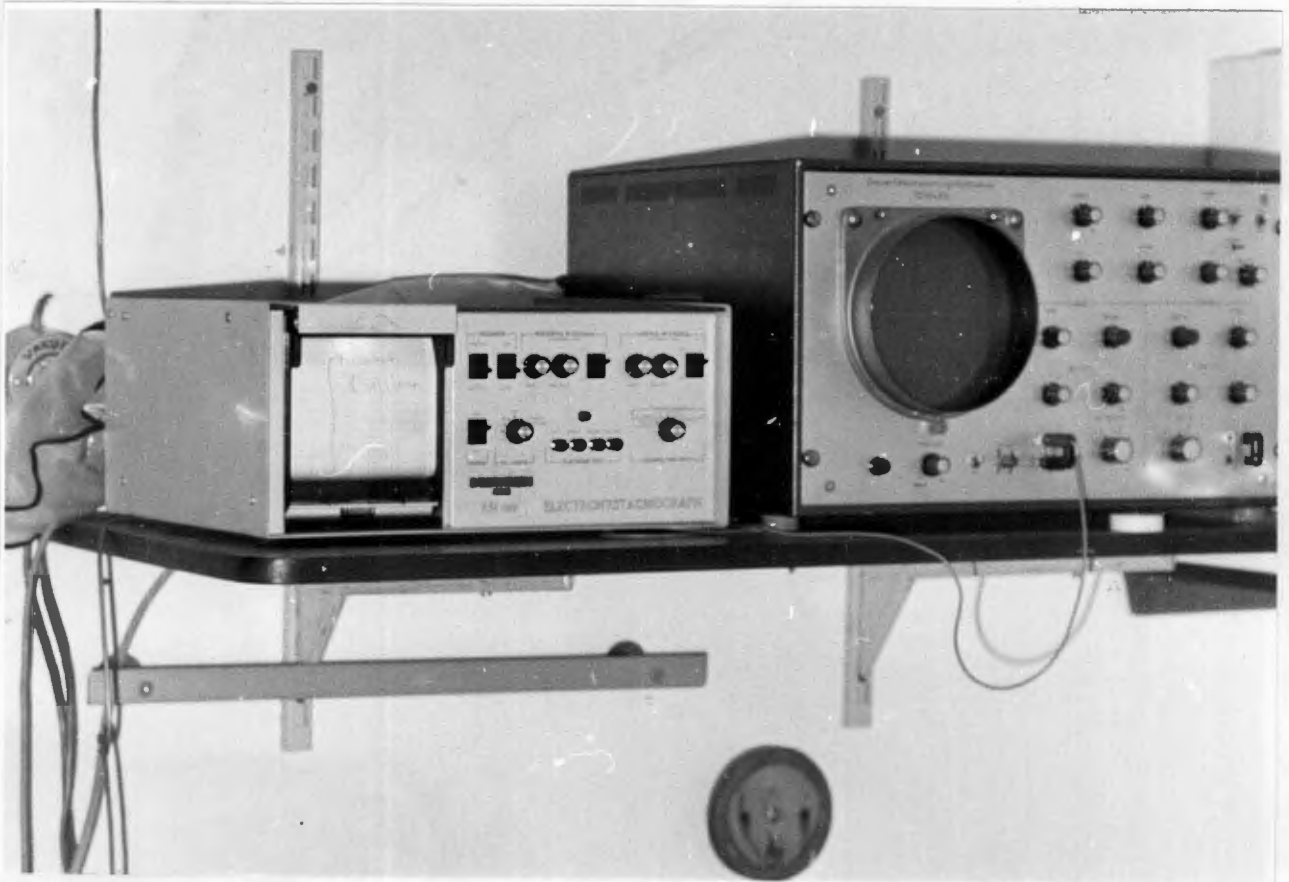


Figure 12

ADMINISTRATION OF SCSIT



Figure 13

ADMINISTRATION OF SCPNT



Figure 14

CHILD ON PLINTH SHOWING ELECTRODE PLACEMENT



Figure 15

CHILD READY FOR START OF ROTATION (A)



Figure 16

CHILD READY FOR START OF ROTATION (B)



CHAPTER 1V

RESULTS

Forty six boys were studied. The experimental group consisted of twenty three with vestibular based sensory integration problems identified according Ayres' test criteria. The control group consisted of twenty three who showed no evidence of sensory integration or learning problems.

The fact that there were no girls in the samples was coincidental. Two girls were tested, but did not meet selection criteria. The age range in both experimental and control samples was 6 years 0 months - 8 years 11 months and the median age in both samples was 6 years 10 months. (see appendix D p. 176)

RESULTS PERTAINING TO AIM 1 OF THE STUDY

Results of the correlation matrix test are given in Table 1. (p. 137). At the 0.05 level of confidence only two measures show significant correlation. These are symmetry of response and duration of postrotatory nystagmus in the ENG which correlate with mean standard score in the SCPNT. There is no correlation between the mean maximum speed of the slow slope of nystagmus or frequency of nystagmus beats with any of the SCPNT scores.

Table 1

CORRELATION MATRICES OF ENG MEASURES AND SCPNT MEASURES

S C P N T

	Postrotatory nystagmus	Standard score	Symmetry
E Speed of slow slope	0.18	0.27	0.15
N Symmetry	0.20	*0.32	0.22
G Frequency	0.10	0.19	0.21
Postrotatory	0.23	*0.34	0.18

n = 46

r significant at $p < 0.05$ if $r > 0.29$

* = positive correlation

4.2 RESULTS PERTAINING TO AIM 2 OF THE STUDY

Results of the Student t test comparing the experimental and control samples on five ENG measurements are expressed in tables 2 to 6. Examples of ENG tracings from which measurements were made can be found in the appendix J, p.183.

At the 0.05 level of confidence the critical level of t was equal to 1.68. (df = 44)

Table 2

Comparison of Mean maximum speed of slow slope during clockwise rotation (SSSX CW)

	CONTROLS	EXPERIMENTALS
Number	23	23
Mean (degs. per sec.)	78.68	74.55
Standard deviation	22.89	18.90
t = .66 (N.S.)		

Table 3

Comparison of Mean maximum speed of slow slope during counter-clockwise rotation. (SSSX CCW)

	CONTROLS	EXPERIMENTALS
Number	23	23
Mean (degs. per sec.)	69.86	67.60
Standard deviation	25.69	20.36
t = .32 (N.S.)		

The difference between the scores of the experimental and control samples for mean maximum speed of slow slope during clockwise and counter-clockwise rotation was not statistically significant. ($p = 0.05$)

Table 4

Comparison of Symmetry of response during clockwise and counter-clockwise rotation. (SYM)

	CONTROLS	EXPERIMENTALS
Number	23	23
Mean (% diff.)	12.83	14.08
Standard deviation	11.68	10.52
t = .38 (N.S.)		

There was no statistically significant difference in symmetry of response between the two samples. (P = 0.05)

Table 5

Comparison of Frequency of nystagmus beats during peak period of response (FREQ)

	CONTROLS	EXPERIMENTALS
Number	23	23
Mean (no. beats)	22.86	17.60
Standard deviation	5.49	4.21
t = 3.64		

There was a statistically significant difference ($p < 0.0005$) in the scores of the two samples measuring frequency of nystagmus during peak response.

Table 6

Comparison of Duration of Postrotatory Nystagmus (PRN)

	CONTROLS	EXPERIMENTALS
Number	23	23
Mean (secs. duration)	19.26	21.47
Standard deviation	6.28	5.50
t = 1.27 (N.S.)		

Although there was a difference between mean scores of the two samples for duration of postrotatory nystagmus, this difference is not statistically significant. ($p = 0.05$)

The only statistically significant difference between experimental and control samples with regard to ENG measurements was in frequency of nystagmus beats during the five second peak period. The mean score of the control sample was higher than that of the experimental sample. ($p = 0.05$)

It is interesting to note that the control sample had a marginally higher mean maximum speed of slow slope than the experimental sample. The difference in mean scores for symmetry indicated a higher incidence of asymmetry in the experimental sample. The mean duration of postrotatory nystagmus in the experimental sample was slightly higher than in the controls. These differences were not however statistically significant. ($p = 0.05$)

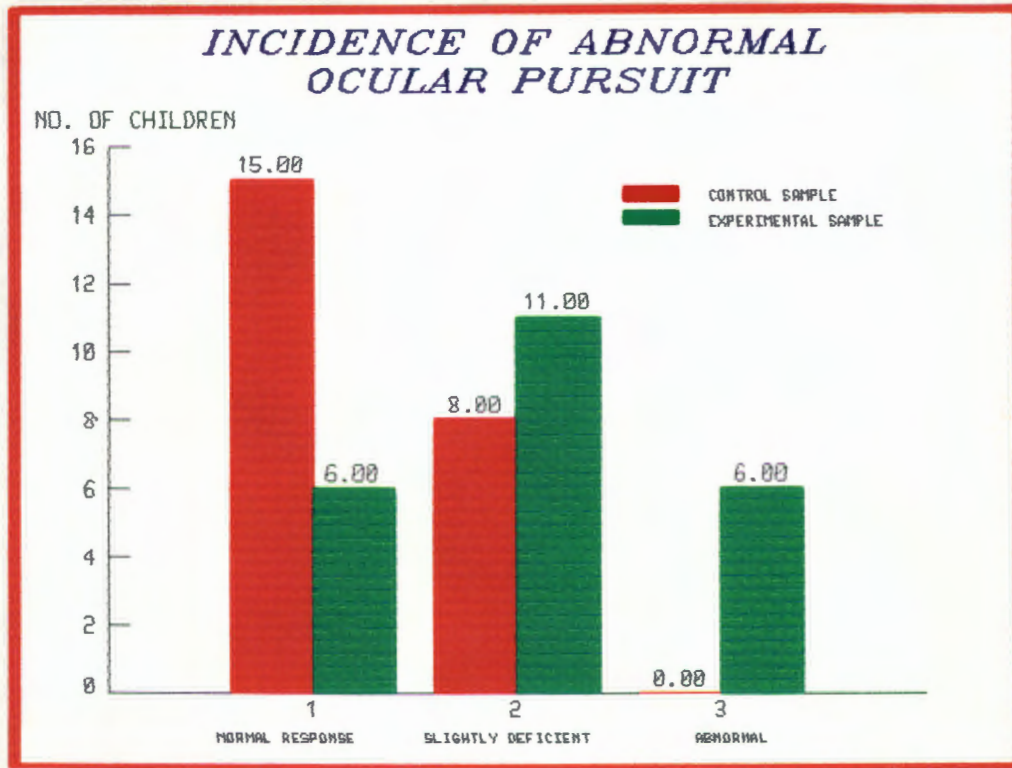
In all measures the standard deviation was smaller in the experimental sample than in the control sample.

Only one child in the control sample exhibited gaze nystagmus with eyes closed, and one child in the experimental sample exhibited gaze nystagmus with eyes open. No spontaneous nystagmus on forward gaze with eyes open or closed was found in either sample. Examples of A, B, and C type ocular pursuit can be found in the appendix K, p184.

Results of the chi-square test which was applied to compare the incidence of abnormal ocular pursuit in the two samples is given in Table 7 (p. 142).

The experimental sample exhibited a greater incidence of abnormal ocular pursuit than the control sample. This difference was statistically significant. ($p = 0.05$)

Table 7

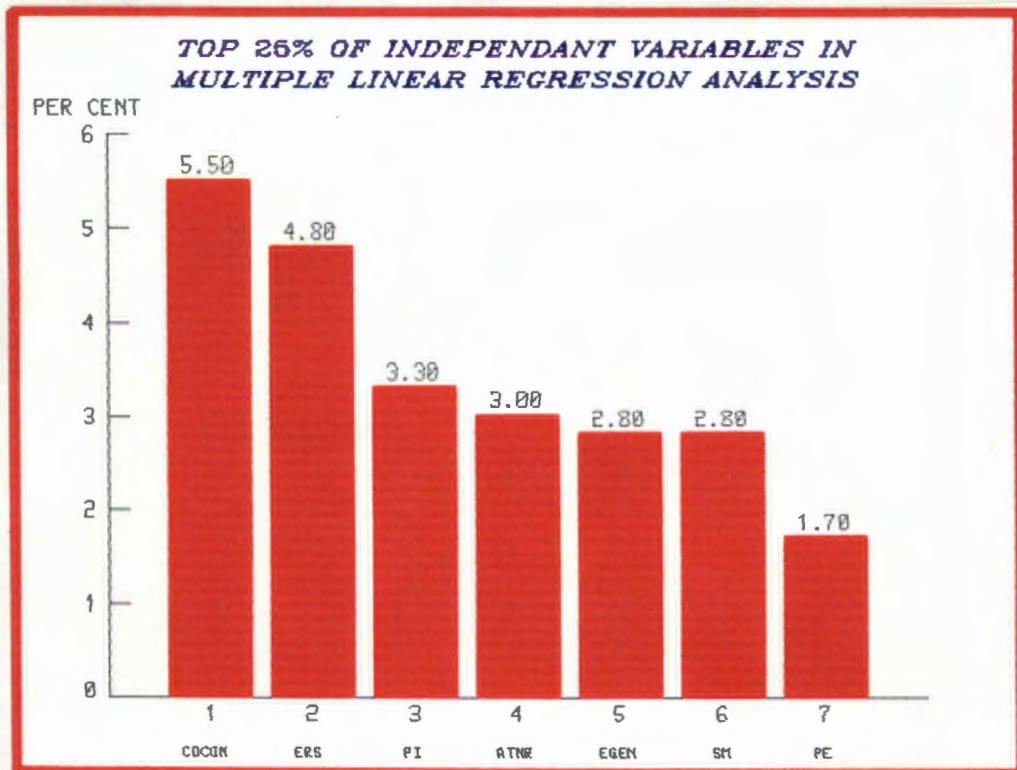


chi-square value = 7.16 df = 2 0.02 < p < 0.05

4.3 RESULTS PERTAINING TO AIM 3 OF THE STUDY

The twenty eight variables considered when identifying vestibular dysfunction (independent variables) were subjected to a multiple linear regression analysis. A summary of the results is expressed in Table 8. The full analysis can be found in the appendix L (p. 185) .

Table 8



$F = 1.44$ $DF = 28, 17$ not significant at $p < 0.05$

Abbreviations:

COCON = cocontraction; ERS = equilibrium reactions; PI = postural insecurity; ATNR = assymetrical tonic neck reflex; EGEN = general eye movements; SM = slow movements; PE = protective extension.

The order of the contribution of the independent variables to the prediction of mean maximum speed of slow slope of nystagmus (dependent variable), was as follows:

Cocontraction 5.5 %

Equilibrium reactions 4.8 %

Postural insecurity 3.3 %
Asymmetric tonic neck reflex 3.0 %
General eye movements 2.8 %
Slow movements 2.8 %
Protective extension 1.7 %
Space visualisation contralateral hand usage score 1.0 %
Hand dominance .98 %
Resistance in Shilder's arm extension test 0.8 %
Crossing the Midline test 0.6 %
Postural changes in Shilder's arm extension test 0.5 %
Prone extension posture 0.4 %
Reflex inhibiting position 0.4 %
Bilateral Motor Coordination 0.4 %
Symmetrical tonic neck reflex 0.3 %.

The following variables counted for less than 0.3 % of the variance of the dependent variable: muscle tone, Crossing the Body Midline, localisation and convergence of the eyes, thumb finger touching, postural background movements, Standing balance with eyes open and closed, difference in the Motor Accuracy Test scores, Crossing the Midline of the Body crossed items only, Right Left Discrimination and the Southern California Postrotatory Nystagmus Test.

In total only 53 % of the variance of mean maximum speed of the slow slope of nystagmus was accounted for by measures used by occupational therapists to identify vestibular based disorders. This leaves 47 % not accounted for. According to these results, components of Ayres' test criteria are not

sufficient to predict mean maximum speed of slow slope of
nystagmus measured on an ENG.

CHAPTER V

DISCUSSION

5.1 CORRELATION OF RESULTS OF THE SCPNT AND AN ENG AS MEASUREMENTS OF VESTIBULAR FUNCTION

Only two parameters show significant correlation in tests of vestibular function. Symmetry of response and duration of postrotatory nystagmus measured by ENG both correlate with the standard score of the SCPNT.

The positive correlation between symmetry of ENG response and SCPNT standard score is difficult to explain as symmetry of ENG response is judged according to differences in mean maximum speed of nystagmus slow slope scores during clockwise and counter-clockwise rotation. In the multiple linear regression analysis, the SCPNT standard score accounted for only 0.2 % of the variance of mean maximum speed of slow slope.

A positive correlation between the standard score of the SCPNT and duration of postrotatory nystagmus measured on the ENG is of more consequence as they both involve measurement of the same parameter. This correlation becomes less significant however when it is noted that there was no correlation between the raw postrotatory nystagmus duration scores in the two tests. This could be accounted for by the

involvement of the optokinetic reflex in the SCPNT, and the inconsistencies in administration and measurement discussed in Chapter 1 (p.2).

There was no correlation between mean speed of slow slope of nystagmus and frequency of beats with any of the SCPNT measurements.

It is interesting to note that there is no correlation between the two tests in measurements of symmetry of response to left and right rotation. This could be explained by the fact that symmetry in the SCPNT reflects the duration of postrotatory nystagmus, while symmetry of ENG response is judged according to differences in mean maximum speed of slow slope.

The results obtained preclude clear-cut acceptance or rejection of Nul Hypothesis 1, which states that there is no correlation between the results of the SCPNT and results of an ENG investigation of vestibular function. A correlation has been demonstrated between two parameters which as noted cannot be considered important in the light of insignificant correlations between the two tests in related measurements. There is no correlation between mean maximum speed of slow slope and frequency (which are considered to be the most direct and valid measurements of vestibular function according to Kosey, 1977; Hamersma, 1957 and Torok, 1969), and measurements in the SCPNT. Nul Hypothesis 1 would have been accepted had these alone been included in the

correlation calculation. Symmetry of response and duration of postrotatory nystagmus were included as they are measured in the SCPNT, and the study afforded an opportunity to test their validity when compared with findings on ENG. It can be concluded from these results that the SCPNT is not an accurate or valid measure of vestibular function.

This conclusion supports the findings of those authors who have demonstrated a need for further research into the SCPNT (Keating, 1979; Morrison and Sublett, 1983; Kimball, 1981 and Crowe et al, 1984) and it supports Polatajko's contention (1981, 1983, 1985) that the test is invalid and should no longer be used. It also confirms the author's own reservations expressed in Chapter 1 (p. 2).

It should be born in mind when comparing results of the SCPNT and ENG that neither is a complete investigation of vestibular function. Both examine the action of only one component of the vestibular apparatus i.e the horizontal semicircular canals. A complete assessment of vestibular function should include tests of anterior and posterior semicircular canal function, tests of otolithic function and an examination of vestibulo-spinal reflexes (see p. 88). As noted by Rose (1978) vestibular testing is not as sophisticated or advanced as auditory testing.

Consideration must also be given to the many factors discussed on p. 79 which influence the nystagmus response. Although most of these were controlled during the ENG

examination in this study, it was not possible to eliminate all the effects of the child's emotional response or to allow for the wide range of individual differences.

5.2 COMPARISON OF ENG MEASUREMENTS IN NORMAL CHILDREN AND CHILDREN WITH ABNORMAL VESTIBULAR FUNCTION

A comparison of scores achieved by the experimental and control samples in five parameters measured by ENG revealed that there was no statistically significant difference in mean maximum speed of slow slope (clockwise or counter-clockwise), symmetry of response or duration of postrotatory nystagmus. There was a statistically significant difference between scores measuring frequency of nystagmus beats during peak response.

As mean maximum speed of the slow slope of nystagmus, which is accepted as the most accurate and valid measurement of vestibular function, does not identify the same children as do Ayres' criteria, it may be concluded that Ayres' criteria do not accurately discriminate between normal and abnormal vestibular function.

Although children in the experimental sample obviously do have a neurologically based disorder as demonstrated by their presenting problems which led to referral, results of The Southern California Sensory Integration Tests and Ayres' clinical observations, these problems are not the result of vestibular dysfunction. This conclusion is in agreement with

Polatajko (1981) who proposed that the clinical manifestations of learning disabilities have a cortical rather than a sub-cortical basis.

The statistically insignificant difference in symmetry of response between the two samples is not surprising since symmetry is based on the mean maximum speed of the slow slope which did not discriminate normal from abnormal as did Ayres' criteria. It is interesting to note that neither mean symmetry scores would be considered abnormal according to figures quoted in the literature reviewed. This also applied in Polatajko's study (1981). Hamersma (1957) observed that significant asymmetry is considered present only when there is a difference between the two sides greater than 20 %. In Polatajko's study a difference of more than 18 % was considered abnormal. In the present study the percentage difference was 12.8 % in the control sample, and 14 % in the experimental sample. In both samples the mean maximum speed of the slow slope was less after the second rotation (see tables 2 and 3). Ayres (1975) and Polatajko (1981) suggested that a reduced response following the second rotation might indicate good adaptation in a well integrated brain.

The frequency of nystagmus beats during peak response differed significantly in the two samples (see table 5) and so gave support to Ayres' hypothesis of vestibular dysfunction. Some authors feel that frequency of nystagmus does reflect labyrinthine activity (Hamersma, 1957; Kosey,

1977) and shows a close relationship to the slow phase of nystagmus (Mulch 1978). Tibbling (1969) has observed that the frequency of nystagmus is decreased by a reduction in the speed of the slow component and by an increase in the amplitude. The fact that the mean number of beats during the 5 second peak period was lower in the experimental sample could thus have been due to the fact that the speed of the slow slope was less in the experimental sample during both clockwise and counter-clockwise rotation, although not significantly so. However frequency count is also related to the fast component of nystagmus which reflects central rather than vestibular function (Kosey, 1977, Tibbling, 1969). It is proposed that the identification of children according to the frequency of nystagmus beats, points to the fact that their problems stem from a common central disorder rather than vestibular dysfunction.

There was no significant difference between the two groups with regard to duration of postrotatory nystagmus. This is contrary to the findings of Ayres (1975, 1978), de Quiros (1976); Frank and Levinson (1975) and Ottenbacher (1980). The mean score for duration of postrotatory nystagmus was longer in the experimental sample than in the control sample, although this difference was not statistically significant. This is in direct conflict with Ayres' (1975, 1978) hypothesis which states that 50 % of learning disabled children have reduced duration of postrotatory nystagmus. Ottenbacher (1978) put this figure at 46 %. Polatajko (1981) suggested that the short duration nystagmus demonstrated in

these studies can be explained by failure on the part of children in the learning disabled sample to refrain from fixating when rotation ceased. Their fixation then served to inhibit nystagmus. She pointed out that although 77 % of the studies she reviewed claimed to support Ayres' hypothesis that vestibular dysfunction was the underlying cause of many learning problems, discrepancies in methodology rendered most of these studies invalid. Polatajko's own results showed no difference in vestibular function between normal and learning disabled children. Her study differed from the present study in that the selection of her experimental sample was made according to the results of academic achievement tests and an intelligence test. Ayres' tests did not form part of her selection procedure. She concluded that vestibular dysfunction does not correlate with academic achievement and should not be considered a causal factor. In the present study, sample selection was made according to Ayres' selection criteria, and the experimental sample consisted of children identified in this way as having a vestibular based sensory integration problem. It must be concluded from the results that vestibular dysfunction is not the underlying cause of the children's problems. As Ayres' own criteria were used, this finding casts even greater doubt on her hypothesis than did Polatajko's work. Results of the multiple linear regression analysis confirm this conclusion. (see p. 143)

The gaze nystagmus recorded in one child in each sample could have been induced by directing gaze too far to the side. If this was the case nystagmus should be considered a normal

phenomenon and not an indication of vestibular dysfunction. There was a statistically significant difference in the incidence of abnormal ocular pursuit in the two samples. (see table 7, p 142). According to Hamersma (1957) a definitely abnormal response is the result of CNS disease in 65 % of the cases and peripheral lesions in the other 35 %. Polatajko used the same criteria as were used in the present study and found that only 37.5 % of her normal sample had normal smooth ocular pursuit. She suggested that the criterion for normal pursuit be reduced to "B" (less than three but at least one good sinusoidal wave. See appendix I p. 182), in which case 100 % of her control group could be considered normal. In the present study 35 % of the controls and 74 % of the experimental sample had abnormal ocular pursuit. If Polatajko's modified criterion is applied all controls fall within normal limits. As a percentage of the control group did not have normal ocular pursuit according to criteria used, which applies to adults, it can be concluded that eye control has not fully developed in the 6 - 8 year age group.

According to Ayres (1972), abnormal ocular pursuit could indicate vestibular dysfunction. Other possible causative factors such as poor concentration and CNS dysfunction or immaturity should however also be considered.

Results of the study thus indicate that Nul Hypothesis 2 may not be rejected out of hand or accepted as it stands. Mean maximum speed of the slow phase, symmetry of response and postrotatory nystagmus measured on an ENG do not discriminate

between normal and abnormal vestibular function as do the test criteria suggested by Ayres, but frequency of nystagmus beats does.

Sampling Procedure

The initial sampling procedures in dividing the children into those with no sensory integrative or learning problems, and those with vestibular based sensory integrative problems may be questioned. A discussion of measures used follows:

Myklebust (1971) has claimed in the light of his investigations that classroom teachers can detect and classify learning problems and therefore replace a psychometrist in initial screening procedures. Wallace and Larsen, (1978) also reported that accurate and useful assessments can be expected from experienced teachers.

With this in mind a decision was made to use "The Rhode Island Pupil Identification Scale" (RIPIS). The reliability of this scale was established by obtaining Pearson product-moment correlations for teachers' observations over a nine month period (Novack et al, 1973). The reliabilities between adjacent months were high, ranging from .755 to .988. At the end of the school year, teachers were asked to classify their pupils according to the following categories:

- "1 Promoted to next higher grade; will experience little or no difficulty.
- 2 Promoted to next higher grade; will experience some difficulty.
- 3 Promoted to next higher grade; will experience considerable difficulty.
- 4 Not promoted."

These categories established criteria against which to validate the RIPIS and it was shown that the higher the score a pupil receives the more likely is he to experience learning difficulties. These data were considered adequate justification for the use of this test in the present study.

The parent questionnaire used effectively eliminated from the study children suffering from conditions other than sensory integration problems which could have influenced results.

Ayres' test battery was administered to both samples. She points out that reliance on a group of test scores rather than on individual scores increases the accuracy of the diagnosis. She gives detailed guidelines and criteria for interpreting the test scores and reaching a differential diagnosis according to the syndromes defined by her. She gives examples of numerous case studies to illustrate her diagnostic technique (Ayres, 1976, 1980). She stresses the need for a thorough knowledge of neurobiology, and training and experience in the use of her tests before a valid interpretation can be made. As mentioned earlier, the author holds a certificate of competence in the administration and scoring of these tests.

The ENG Assessment

The stimulus used to induce nystagmus was based on Bárány's method. It has been noted on p. 43 that certain objections have been raised to this method. However a more sophisticated method of inducing rotatory nystagmus was not possible given

the circumstances of the present study. Caloric tests were ruled out because of their unsuitability for use with children (see p. 41). It is felt that as this test was administered to both samples in exactly the same way, disadvantages of the method used would not alter the results.

5.3 DO AYRES' TEST CRITERIA DISCRIMINATE BETWEEN NORMAL AND ABNORMAL VESTIBULAR FUNCTION ?

In order to achieve the last aim of this study the scores of the twenty eight tests and observations used to identify vestibular based sensory integration disorders were compared with the mean maximum speed of the slow slope measured on an ENG. The contribution of these variables to the variance of mean maximum speed of the slow slope was not statistically significant either individually or in combination. Therefore, if it is agreed that the mean maximum speed of the slow slope of induced vestibular nystagmus is the most accurate and valid measure of vestibular function, Ayres' test criteria should not be used to identify vestibular dysfunction. Occupational therapists should consider the use of other tests reviewed in the literature to identify vestibular problems. Vestibulo-spinal tests appear to be particularly suitable. Perhaps a combination of these tests measuring the effect of vestibulo-spinal reflexes on the trunk, the upper limbs and the lower limbs should be used e.g. the Romberg test, the Vertical Writing Test, and the Stepping Test (see p. 88). The tests mentioned do not require sophisticated equipment and have the advantage of being easy and quick to

administer. These are not pure tests of vestibular function as they involve other sensory receptors including tactile, pressure and proprioception, and other areas of the CNS including the cerebellum and basal ganglia. This does not pose a problem in light of the previous discussion however, which questions the importance of isolating vestibular function in child integration problems.

5.4 IMPLICATIONS OF THIS STUDY FOR OCCUPATIONAL THERAPISTS

The policy statement on testing and treatment of sensory integrative dysfunction by occupational therapists which was published by the American Occupational Therapy Association (Hinojosa et al. 1982), may need to be reconsidered in the light of results of this study. The following statement was made:

"Occupational therapy is based on the belief that purposeful activity may be used to prevent and remediate dysfunction, and elicit maximum adaptation toward achieving optimum functioning. Fundamental to a person's ability to interact with the environment is the ability to process sensory information. The theories and research related to sensory integration have provided the basis for the development of a therapeutic model used by occupational therapists in their efforts to help individuals reach their potential for productive purposeful lives."

This statement stresses the need for extensive evaluation when treating sensory integrative disorders. While the Southern California Sensory Integration Tests (Ayres, 1980) and the Southern California Postrotatory Nystagmus Test (Ayres, 1975) were specifically designed to assess sensory integrative dysfunction, other tests contribute further

information to the total assessment. The occupational therapist assesses individual sensory systems in the course of an evaluation, concentrating mainly on components of vestibular, tactile, proprioceptive and visual systems. The relevance of assessing separate systems is questioned in the light of the present study which showed no difference in vestibular measurements (apart from frequency) between experimental and control samples. This suggests that vestibular dysfunction is not a specific feature in children with sensory integrative disorders. Neurological signs such as poor balance, hypotonia and problems in ocular pursuit, should be regarded as "neurological soft signs". This is in agreement with Polatajko (1981).

The American Occupational Therapy Association statement (1982) further recommends that treatment should provide selected sensory input primarily through vestibular, proprioceptive and tactile channels. It is claimed that through the use of equipment, therapeutic handling and motivating activities adaptive responses are facilitated. The validity of this approach in children with disorders in sensory integration, particularly with regard to use of vestibular channels, must now be questioned.

It must be conceded however that sensory integrative therapy in which vestibular stimulation is an important component does undoubtedly have positive results. This is evident from the literature (Weeks, 1979; Ayres, 1978; Bhatara et al, 1978; Montgomery et al, 1977; and Price, 1982), and from the

exceptional demand for sensory integrative therapy in South Africa. In this country it has become the major field of private occupational therapy practice and its value is unquestioned by parents and many of those who deal with learning disabled children.

CHAPTER VI

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The SCPNT is not a valid test of vestibular function and should be abandoned.

There is no difference in vestibular function between children identified according to Ayres' criteria, as having a vestibular based sensory integrative disorder and normal children.

The test battery presently being used by occupational therapists does not discriminate between children with normal and abnormal vestibular function.

There can be no doubt that Ayres' tests do identify problems which have a neurological basis but such problems cannot be attributed solely to vestibular dysfunction and should be regarded as "neurological soft signs".

The results of this study call into question a) the relevance of evaluating vestibular function in children with sensory integrative problems; and b) the validity of using vestibular stimulation in therapy.

Evidence does exist that children with sensory integrative problems respond to therapy which includes vestibular

stimulation. Therefore it cannot be recommended that sensory integrative therapy be discontinued, but rather that the reasons for its positive results be established.

The results of this study, and the questions which arise from them emphasise the need for further research into Ayres' vestibular dysfunction hypothesis, and the testing and treatment methods which have arisen from it. This need becomes more evident when consideration is given to the popularity and wide use made of sensory integrative therapy both in South Africa and other parts of the world.

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A P P E N D I C E S

QUESTIONNAIRE FOR STUDY INVOLVING RESEARCH WITH
LEARNING DISABLED CHILDREN

NAME OF CHILD:

DATE OF BIRTH:

PHONE NUMBER:

CHRONOLOGICAL AGE:

Please answer the following questions by putting a tick in the appropriate box.

Was your pregnancy with this child normal? YES / NO

Was your child's birth uncomplicated? YES / NO

Has your child ever had a head injury? YES / NO

Has he/she had meningitis? YES / NO

Has he/she had encephalitis? YES / NO

Has he/she ever had a fit? YES / NO

Has your child any visual or hearing problem? YES / NO

Do you consider your child to be free of
emotional problems? YES / NO

In your opinion, does he/she appear to be
coping well with all aspects of school life? YES / NO

Reason for referral:.....
.....

Marie Penberthy

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Bergvliet 7800.

Phone: 72-4835

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Department of Occupational Therapy,
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UNIVERSITY OF CAPE TOWN

(WITH WHICH IS INCORPORATED THE SOUTH AFRICAN COLLEGE)



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Hospital Connection: 47-3311 ext. 3130

DEPARTMENT OF OCCUPATIONAL THERAPY
MEDICAL SCHOOL
370B MAIN ROAD
OBSERVATORY, C.P.
7925

1st June 1983.

Dear Parent,

I am a full-time lecturer in the Department of Occupational Therapy and have registered this year for the degree M.Sc. Occupational Therapy.

The research I am doing involves the investigation of vestibular function in children with learning problems. The vestibular sense organs detect the pull of gravity and movements of the head and are concerned with the maintenance of balance. Vestibular dysfunction has been related to learning problems in previous studies.

My study aims firstly, at improving the identification of vestibular problems and, secondly, ascertaining the incidence of vestibular based learning problems.

The results of this study will have important implications as far as the assessment and treatment of learning disabled children by Occupational Therapists is concerned.

In order to carry out this research, I will need approximately 30 children between the ages of 6 and 8 years who have no learning problems. This group will be used for comparison with the learning disabled group.

The children selected will be assessed after school hours at my home in Bergvliet. The assessment will include standardised tests which evaluate the recognition of visual, tactile and movement sensations, as well as certain movement skills. This assessment will take approximately 2 hours.

The children will also have an electronystagmogram - a laboratory controlled test of vestibular function. This investigation is harmless and will cause the children no pain or discomfort. It will be administered by a qualified technician at Red Cross Hospital, assisted by me, and will take approximately 15 minutes.

.../2

Will you give permission for your child to take part in this study if selected?

Yes/No

If so please answer the attached questionnaire, and return it to your child's class teacher as soon as possible. I will phone you and make arrangements if your child is selected for the study.

I thank you for your interest and co-operation.

Yours sincerely,

Marie Penberthy (Mrs.)

Rhode Island Pupil Identification Scale
H. Novack/E. Bonaventura/P. Merenda

Observation period: from _____ to _____

Observer _____

Name _____ Age _____ years _____ months

Sex _____ Grade _____

School _____

Instructions: For each item on this form, rate the pupil being evaluated according to the following scale:

1 = never 2 = rarely 3 = occasionally 4 = frequently 5 = always

If during any observation period no opportunity has arisen for the task to be performed, leave the item blank.

Part I refers to behavior which can normally be observed in the classroom. Part II deals with behavior which is most readily observable through written work.

Part I

- ___ a. Has difficulty cutting.
- ___ b. Has difficulty pasting.
- ___ c. Bumps into objects.
- ___ d. Trips over self.
- ___ e. Has difficulty catching a ball.
- ___ f. Has difficulty jumping rope.
- ___ g. Has difficulty tying shoes.
- ___ h. Has difficulty buttoning buttons.
- ___ i. Breaks point of pencil.
- ___ j. Has difficulty sitting still.
- ___ k. Has difficulty standing still.
- ___ l. Has short attention span.
- ___ m. Gives the appearance of being tense.
- ___ n. Has difficulty remembering what is seen.
- ___ o. Has difficulty remembering what is shown.
- ___ p. Cries.
- ___ q. Fails to take reprimands well.
- ___ r. Has difficulty understanding directions.
- ___ s. Tends to be discouraged.
- ___ t. Tends to give up.
- ___ u. Tends to avoid group activity.
- ___ v. Has difficulty completing assignment in allotted time.

___ PART I SCORE

Part II

For items with an asterisk (*) indicate item and describe the error on the back of the page. Record any additional errors not indicated on check sheet.

- ___ a. Has difficulty staying within lines when coloring.
- ___ b. Produces work which varies in quality.
- ___ c. Demonstrates poor handwriting on papers.

- ___ d. Erases on papers.
- ___ e. Turns in papers which are dirty.
- ___ f. Has difficulty writing within lines.
- ___ g. Starts writing in the middle of the paper rather than from the left margin.
- ___ h. Mirrors and/or reverses letters, numbers, words, or other forms in copying.*
- ___ i. Mirrors and/or reverses letters, numbers, words, or other forms when visual stimulation is not provided.*
- ___ j. Runs words or parts of words together in copying.*
- ___ k. Runs words or parts of words together when visual stimulation is not provided.*
- ___ l. Omits or substitutes letters, words, and/or numbers in copying.*
- ___ m. Has difficulty with the names of letters and/or numbers.*
- ___ n. Omits or substitutes letters, words, and/or numbers when no visual stimulation is provided.*
- ___ o. Has difficulty completing written work in the time allotted.
- ___ p. Has difficulty grasping number concepts.
- ___ q. Has difficulty arranging numbers vertically.
- ___ r. Has difficulty with addition and subtraction.
- ___ s. Makes omissions, substitutions, or reversals of letters, numbers, and/or words in reading.*

___ PART II SCORE

___ TOTAL SCORE FOR PARTS I & II

Has this child ever required remedial help?

Has this child ever repeated a year?

MATCHING GROUPS

<u>EXPERIMENTAL GROUP</u>			<u>CONTROL GROUP</u>		
<u>NAME</u>	<u>DATE</u>	<u>OF BIRTH</u>	<u>NAME</u>	<u>DATE</u>	<u>OF BIRTH</u>
1 S. B.	04.12.75		1 M. V.	04.10.75	
2 C. R.	17.07.75		2 M. C.	21.05.75	
3 M. B.	24.12.76		3 A. R.	05.08.76	
4 P. G.	21.09.76		4 C. H.	23.09.76	
5 N. R.	16.05.76		5 P. W.	22.10.76	
6 S. M.	20.12.75		6 B. S.	08.01.76	
7 M. O.	15.06.77		7 R. S.	20.06.77	
8 N. V.	02.10.74		8 D. T.	03.10.74	
9 S. M.	02.10.75		9 D. S.	28.08.75	
10 T. H.	11.11.74		10 J. L.	23.11.74	
11 D. E.	02.10.75		11 J. H.	30.12.75	
12 N. S.	11.04.75		12 G. P.	11.03.75	
13 G. B.	23.09.77		13 C. J.	08.04.77	
14 G. F.	23.09.77		14 M. B.	08.08.77	
15 V. H.	17.07.77		15 S. M.	03.06.77	
16 R. H.	09.06.77		16 S. L.	21.09.77	
17 R. L.	18.09.77		17 M. Q.	17.06.77	
18 B. A.	02.12.77		18 K. S.	13.07.77	
19 N. S.	05.03.78		19 J. C.	01.02.78	
20 J. G.	18.02.78		20 R. N.	30.09.77	
21 R. B.	04.04.78		21 C. D.	03.04.78	
22 K. A.	17.04.77		22 S. G.	10.12.76	
23 J. S.	01.10.77		23 C. D.	24.08.77	

Southern California Sensory Integration Tests

Standard Deviation (S.D.) Scores

by A. Jean Ayres, Ph.D.

Published by

WPS	WESTERN PSYCHOLOGICAL SERVICES
	PUBLISHERS AND DISTRIBUTORS 12031 WILSHIRE BOULEVARD LOS ANGELES, CALIFORNIA 90025

A DIVISION OF MANSON WESTERN CORPORATION

Name _____ Test Date Yr. _____ Mo. _____ Dy. _____
 Examiner _____ Birth Date Yr. _____ Mo. _____ Dy. _____
 Preferred Hand: L R ; Preferred Eye: L R _____ Chron. Age Yr. _____ Mo. _____ Dy. _____

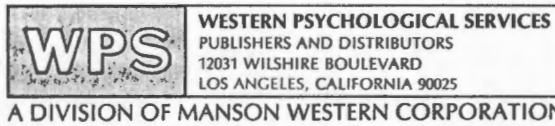
	Raw Score	Time	Adj. Score	S.D. Score	Left		Right	
					Raw	S.D.	Raw	S.D.
Visual Perception								
Space Visualization	_____	_____	_____	_____				
Figure-Ground Perception	_____			_____				
Position in Space	_____			_____				
Design Copying	_____			_____				
Somatosensory Perception								
Kinesthesia	_____			_____				
Manual Form Perception	_____			_____				
Finger Identification	_____			_____				
Graphesthesia	_____			_____				
Localization of Tactile Stimuli	_____			_____				
Double Tactile Stimuli Perception	_____			_____				
Motor Performance								
Imitation of Postures	_____			_____				
Bilateral Motor Coordination	_____			_____				
Standing Balance: Eyes Open	_____			_____				
Standing Balance: Eyes Closed	_____			_____				
Motor Accuracy: Right	_____			_____				
Motor Accuracy: Left	_____			_____				
Other								
Crossing Midline of Body	_____			_____				
CML: Crossed Items Only	_____			_____				
Right-Left Discrimination	_____			_____				
Postrotary Nystagmus	_____			_____				

Appendix F
Southern California Postrotary Nystagmus Test

RECORD SHEET

by
A. Jean Ayres, Ph.D.

Published by



Name _____	Test date: Year _____ Month _____ Day _____
_____	Birth date: Year _____ Month _____ Day _____
Examiner _____	Chronological age: Year _____ Month _____ Day _____

Duration of nystagmus following rotation to left _____ seconds = _____ SD

Amount of excursion: barely perceptible _____

about one millimeter _____

two millimeters or more _____

Duration of nystagmus following rotation to right _____ seconds = _____ SD

Amount of excursion: barely perceptible _____

about one millimeter _____

two millimeters or more _____

Total number of second _____ = _____ SD

Difference in standard deviations between left and right _____

with lesser duration following rotation to: left _____ right _____

Observations following rotation:

1. **Balance while turning:** maintains; tends to lose; falls from board
2. **Head control:** steady; slight loss; head rolls about
3. **Vertigo:** no indication; mild experience; prolonged experience
4. **Dizziness:** none; mild; severe
5. **Nausea:** none; slight; definite
6. **Alarm or threat:** none; slight; severe
7. **Pleasure from rotation:** none; slight; definite
8. **Other**

Unable to complete test because:

CLINICAL OBSERVATIONS

Adapted from A. Jean Ayres, 1972

Name: _____

Test Date: year _____ month _____ day _____

Parents: _____

Birth Date: year _____ month _____ day _____

Address: _____

Chron. Age: year _____ month _____

Telephone: _____

Familial handedness: _____

Referred by: _____

Dominant Hand: R.L.

1. Hyperactive/distract

- 3 - normal activity
- 2 - slight hyperactive
- 1 - def. hyperactive

2. Tactile defensiveness

- 3 - no response
- 2 - 1 or ? response
- 1 - 2 responses or def.

3. Muscle tone

- 4 - hypertonic
- 3 - normal
- 2 - slight hypotonic
- 1 - def. hypotonic
- R/L differences

4. Eye preference:

S's eye through ring of Ex's finger at 6" R L R L

S's eye through hole in paper R L R L

S's eye through different objects
i.e. cone, telescope, kaleidoscope R L R LIndependent eye closure (optional)
circle if adequate R L

5. Eye movements:

Across midline

Pursuits in general

Convergence

Quick localisation

- 3 - normal
- 2 - slightly irr.
- 1 - def. poor

- 3 - normal
- 2 - slightly irreg.
- 1 - def. poor

- 3 - normal
- 2 - slightly irr.
- 1 - def. poor

- 3 - normal
- 2 - slightly irreg.
- 1 - def. poor

R/L Differences:

6. Ability to perform slow motions:

- 3 - smooth
- 2 - slightly irregular
- 1 - jerky, too fast

7. Diadokokinesia: Number of times palms slap thighs in 10 seconds:

Right _____ times

Left _____ times

Both simultaneously

- 3 - normal
- 2 - slightly defic.
- 1 - definitely poor

- 3 - normal
- 2 - slightly defic.
- 1 - definitely poor

- 3 - normal
- 2 - slightly defic.
- 1 - definitely poor

8. Thumb-finger touching:

Right	Left	Both Simultaneously
3 - normal	3 - normal	3 - normal
2 - slightly irreg.	2 - slightly irreg.	2 - slightly irreg.
1 - definitely poor	1 - definitely poor	1 - definitely poor

9. Tongue to lip movement

Upper Lip	Lower Lip	Sides
3 - normal	3 - normal	3 - normal
2 - slightly irreg.	2 - slightly irreg.	2 - slightly irreg.
1 - definitely poor	1 - definitely poor	1 - definitely poor

10. Co-contraction:
arm, shoulder, neck

- 3 - normal
- 2 - slight deficiency
- 1 - definite deficiency

11. Postural insecurity
supine position

- 3 - normal
- 2 - slight deficiency
- 1 - definite deficiency

12. Postural background
movements:

- 3 - normal
- 2 - slight deficiency
- 1 - definite deficiency

13. Equilibrium reactions:

Prone	Quadruped	Sitting
3 - normal	3 - normal	3 - normal
2 - slt.def.	2 - slt. def.	2 - slt. def.
1 - def. def.	1 - def. def.	1 - def. def.

14. Protective extension:

- 3 - normal
- 2 - slt. def.
- 1 - def. def.

15. Schilder's arm extension posture:

Choreoathetosis:	Postural changes	Trunk rotation	Head resist.	Discomfort
3 - normal	3 - normal	3 - normal	3 - normal	3 - normal
2 - slight	2 - slight	2 - slight	2 - slight	2 - slight
1 - definite	1 - definite	1 - definite	1 - definite	1 - definite
R/L Differences:	Arms raised R L	Elbow hyperextension R L		

16. Prone Extension Posture:

- 3 - holds 20 or more seconds with moderate exertion
- 2 - holds to 10 seconds, or 20 with great exertion
- 1 - unable, or holds 0 - 9 seconds

17. Asymmetrical TNR

- (a) quad position
 - 3 - no flexion on passive head turning
 - 2 - slight flexion on passive head turning
 - 1 - definite flexion on head turning
- (b) reflex inhibiting posture
 - 3 - can assume and maintain balance
 - 2 - can assume only with great difficulty
 - 1 - cannot assume

18. Symmetrical TNR

- 3 - no change in joint position
- 2 - slight change
- 1 - definite change

19. Flexed Position Supine

- 3 - holds 20 or more seconds with moderate exertion or holds with slight resistance
- 2 - holds to 10 seconds, or up to 20 seconds with great exertion, or holds but unable to take resistance
- 1 - unable, or holds 0 - 9 seconds

ELECTRONSTAGMOGRAPHY

NAME:

DATE OF TEST:

DATE OF BIRTH:

CHRON. AGE:

MEDICATION:

		Present	Absent
Spontaneous nystagmus	(Centre eyes open		
	(eyes closed		
Gaze nystagmus	(30° Left eyes open		
	(eyes closed		
	(30° Right eyes open		
	(eyes closed		
		Normal	Abnormal
Ocular Pursuit (Pendulum)			
<u>Vestibular nystagmus Per-rotatory</u>			
Intensity	C.W. SSSX		°/sec
	C.C.W. SSSX		°/sec
Symmetry	$\frac{SSSX (C W) - SSSX (C C W)}{SSSX (C W) + SSSX (C C W)} \times 100$		% diff.
Frequency			beats
<u>Postrotatory nystagmus</u>			
Duration C.W.			secs
Duration C.C.W			secs
Total duration			secs

Child's response during rotation: (Ayres 1972)

- 1 Balance while turning: maintains; tends to lose; falls from board
- 2 Head control: steady; slight loss; head rolls about
- 3 Vertigo: no indication; mild experience; prolonged experience
- 4 Dizziness: none; mild; severe
- 5 Nausea: none; slight; definite
- 6 Alarm or threat: none; slight; severe
- 7 Pleasure from rotation: none; slight; definite
- 8 Other

KEY: SSSX = Mean Max. Speed of Slow Slope; C.W. = Clockwise
C.C.W. = Counter Clockwise

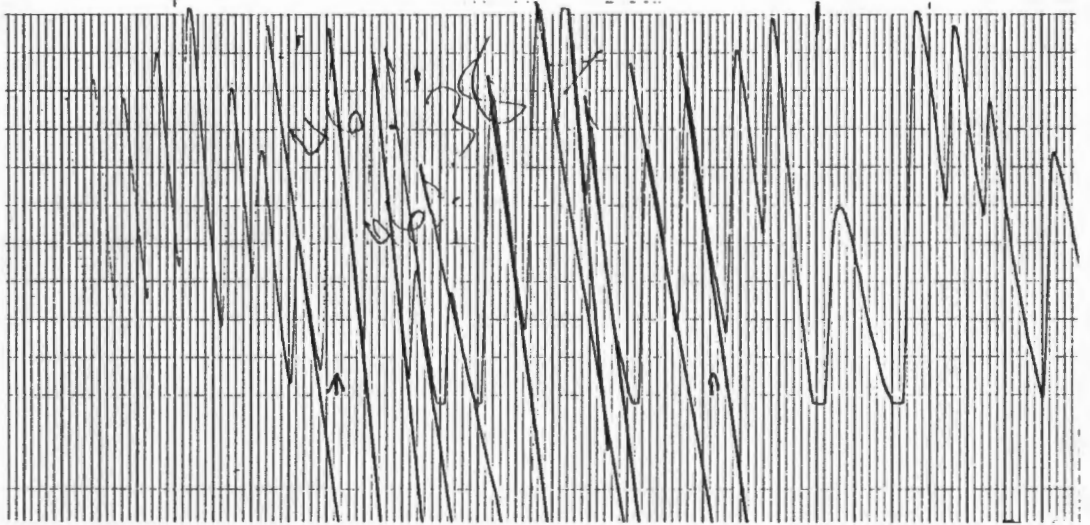
ELECTRONYSTAGMOGRAPHIC SCORING CRITERIA

Component	Characteristic	Rating	Operational Definition
Spontaneous Nystagmus	Presence	SSSX Measured in degrees per second	3 good nystagmus beats required to be con- sidered present.
Gaze Nystagmus	"	"	" "
Smooth Ocular pursuit	Wave form	A	3 good sinusoidal waves in a row
		B	Less than 3 but at least 1 good sinusoidal wave
		C	Consistently abnormal sinusoidal waves
Per-rotatory vestibular nystagmus	Intensity	Max SSSX Measured in degrees per second	Mean speed of slow slope of 3 max nystagmus beats in period 5 to 10 secs after commencement of rotation (peak period)
	Symmetry	percentage difference between CW & CCW rota- tion	$\frac{\text{SSSX (CW)} - \text{SSSX (CCW)}}{\text{SSSX (CW)} + \text{SSSX (CCW)}} \times 100$
	Frequency	Number of beats	Total number of beats taken over same 5 sec period as max SSSX
Postrotatory Nystagmus	Duration	Seconds	Total time period following C W plus C C W rotation

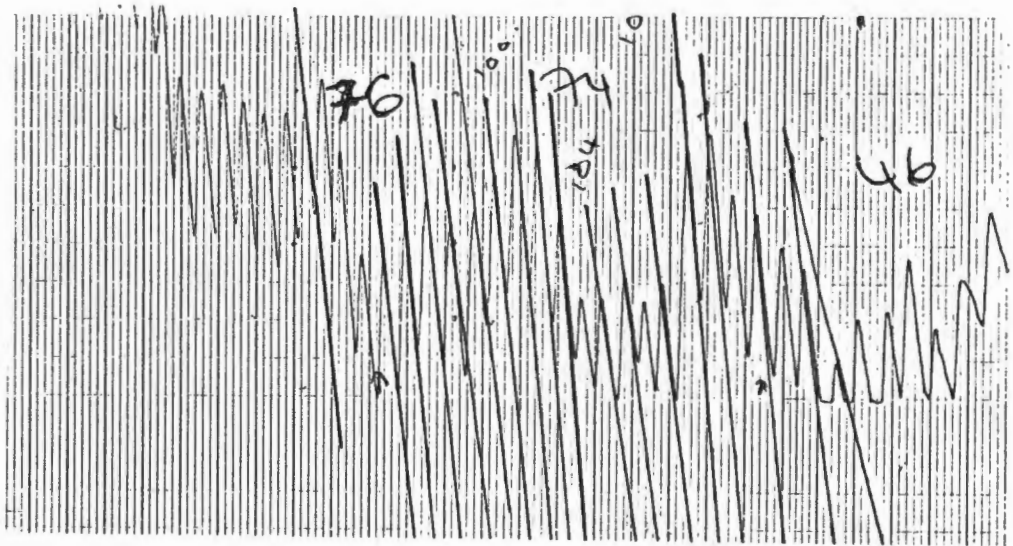
KEY: SSSX = Mean speed of slow slope
 C W = Clockwise
 C C W = Counter clockwise

EXAMPLES OF ENG TRACING

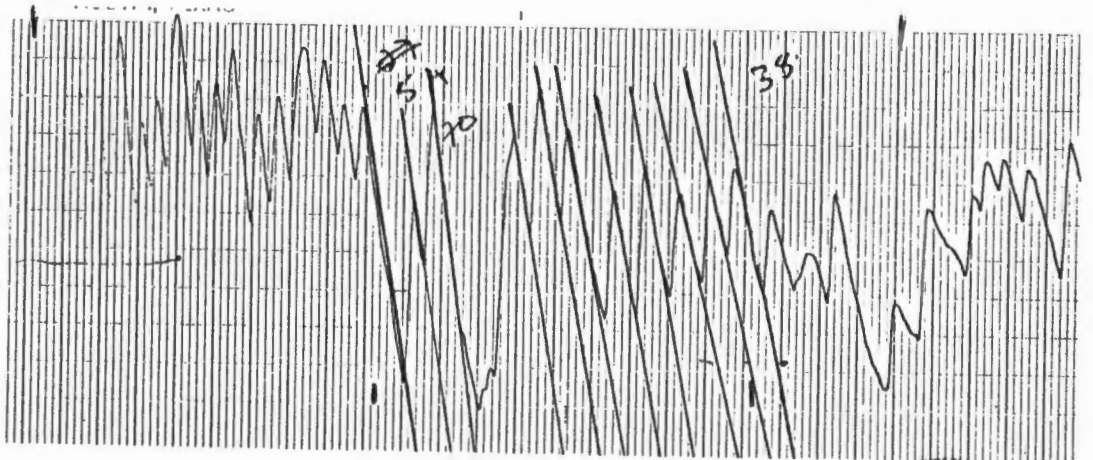
1) Average Response



2) Intense Response

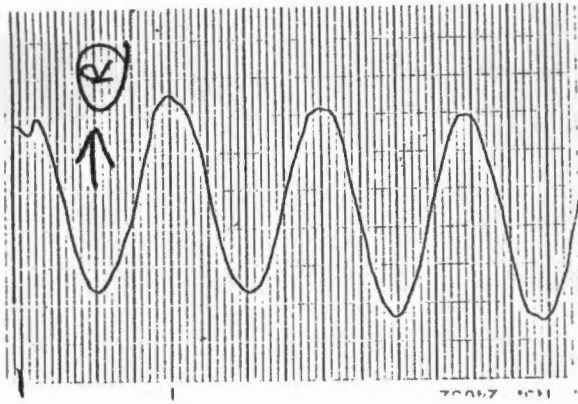


3) Intense Response

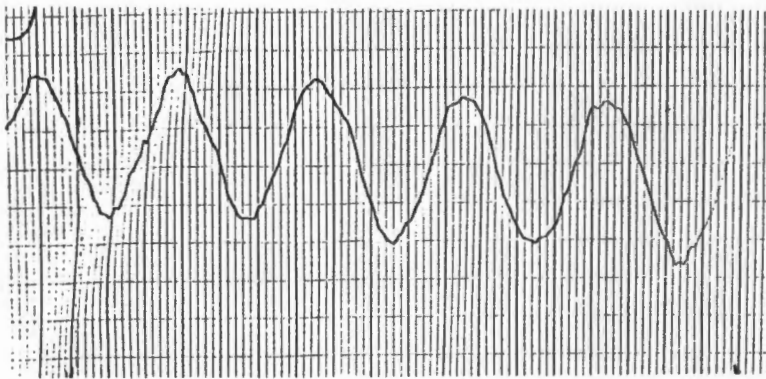


EXAMPLES OF OCULAR PURSUIT TRACING

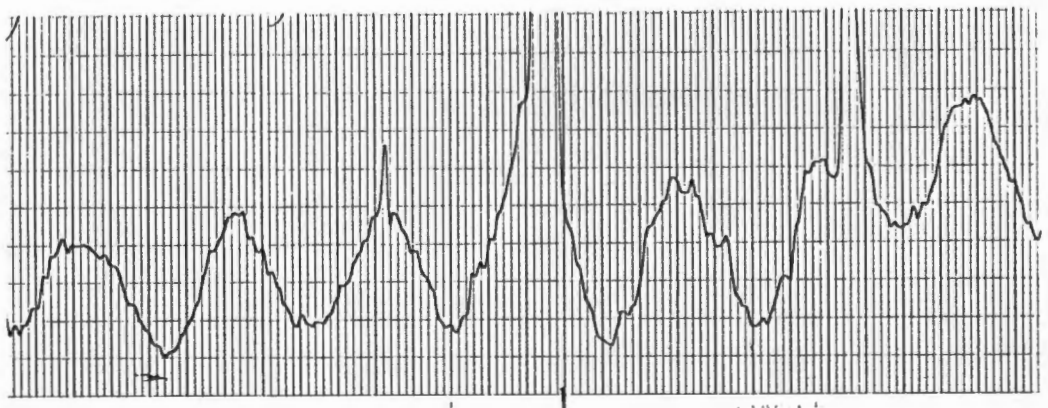
A type Response



B type Response



C type Response



MULTIPLE LINEAR REGRESSION

TERM	COEFFICIENT	STD. ERROR	T-STATISTIC	PART. CORR	CONTR R - SQ
Dominance	7.82	13.07	.59	0.14	0.00
S V C U	-1.21	1.97	-.61	-.14	0.01
Muscle Tone	-.36	13.94	-.02	-.00	0.00
Eyes Crossing Midline	-1.09	16.12	-6.79	-.01	0.00
General Eye Movement	- 13.02	12.79	-1.01	-.23	0.02
Eye Convergence	2.29	11.59	.19	0.04	0.00
Eye	-2.59	12.98	-.19	-.04	0.00
Slow Movements	-11.87	11.61	-1.02	-.24	0.02
Thumb Finger Touching	-.81	13.54	-6.02	-.01	0.00
Cocontraction	-14.93	10.54	-1.41	-.32	0.05
Postural Insecurity	16.58	14.95	1.10	0.25	0.03
Postural background movement	4.56	14.53	.31	0.07	0.00
Equilibrium Reactions	17.77	13.33	1.33	0.30	0.04
Protective Extension	-12.43	15.76	-.78	-.18	0.01
Shoulders - postural changes	5.67	12.24	.46	0.11	0.00
Shoulders - Resistance	6.31	11.62	.54	0.13	0.00
Prone extension posture	-4.22	10.71	-.39	-.09	0.00
Asymmetric Tonic Reflex	-9.69	9.19	-1.05	-.24	0.03
Reflex inhibiting Posture	6.06	14.56	.41	0.10	0.00
Symmetric Tonic Neck Reflex	-12.15	10.83	-1.12	-.26	0.03
Bilateral Motor Coordination	11.82	9.43	1.25	0.29	0.04
Standing Balance, eyes open	-.52	6.39	-8.21	-.01	0.00
Standing Balance, eyes closed	1.98	5.92	.33	0.08	0.00
Difference in Motor Accuracy	-.83	1.51	-.54	-.13	0.00
Crossing Body Midline (CML)	16.75	11.23	1.49	0.33	0.06
CML Crossed Items	-11.43	15.29	-.74	-.17	0.01
Right Left Discrimination	-4.41	7.31	-.60	-.14	0.01
S C P N T	5.00	5.06	.98	0.23	0.02

	<u>SUM SQ</u>	<u>DEG FR</u>	<u>MEAN SQ</u>
DUE TO REGRESSION	8701.45	28	310.76
ABOUT REGRESSION	7635.28	17	449.13
TOTAL	16336.73	45	363.03
R-SQUARED	.53	CORRECTED R-SQUARED:	-.23
F-TEST	.69	STD ERROR OF REG:	21.19