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The need for evidence based practice.

Orthoptics, like all allied health fields, faces increasing pressures for its continued development from both the limited funds within the health system and for recognition from other professions. In this current climate, the issue of evidence based practice has become a catch-cry. This is not at all surprising. As funds decrease, it becomes even more important that proven effective methods of treatment be undertaken. The assumptions of historical precedence can no longer be taken for granted. It is often easier to continue with practices with which we have become comfortable, rather than to question these practices. Inherently questioning our methods makes sense. No professional wishes to have clients engage in treatments without the promise of a positive outcome.

At the same time, Orthoptics and other disciplines have moved into University based curricula. The research based nature of these institutions has lead to increased systematic questioning of both the techniques and the tools traditionally used. This move has met with resistance from students, who often struggle to see the need for research as an active part of their professional life. Research is often seen by both students and professionals, as an activity that is the exclusive domain of a small specialised group within their field. What is often missed is the realisation that evidence based practice, is in reality, another term for research. It is the questioning of all practices aiming for effective outcomes, which can, and should, be practiced by all.

Although at first this concept of research seems daunting, it is in practice occurring all the time. The simplest monitoring of a patient's progress is in itself a form of single case study. Other forms of systematic questioning also lend themselves readily to the clinic based professional, ensuring effective outcomes for patients.

Single Case Studies

As described, each individual patient is in themselves a study. From their measurable improvements, to their subjective comments. In particular, this mode of investigation provides a forum for the individual nature of most client's situations. Reporting both the positive and negative outcomes to the wider community can be of enormous benefit to the profession as a whole.

Group Based Studies

This traditional form of study provides a general outcome for a general problem. For example, is problem A best treated with Treatment B or Treatment C? For most common disorders this technique provides strong evidence for and against techniques and methods as used in the clinic.

Surveys

Often we forget that the best method of finding out information about our clients is to ask them themselves. A simply survey form can ascertain why patients may not be adhering to their treatment regime, or how they feel about the improvements, or lack thereof, that are occurring.

Retrospective Studies

Our filing cabinets are full of important information ready to be found. Though they can be difficult to undertake, due to inconsistent methods of recording, retrospective studies are often an excellent starting point for raising questions about treatment outcomes.

Quality Assurance

Quality assurance is the evaluation of strategies to determine the effectiveness of the clinical process, both as a whole and in parts, to achieve the best results for the patient. Often, though this evaluation is undertaken, the information is provided as an internal report, when in fact the outcomes have greater implications for the professional community.

Validity and Reliability Studies

Validity is how well a tool measures what it's supposed to measure, whereas reliability is the ability of a tool to give the same measure each time it is used. We often assume that the methods and techniques we use are both reliable and valid, when in fact, little may be known about these properties.

Literature Reviews

This can in itself form a study as such. The historical experiences from within and from without a field can often bare strongly on current practice. An historical review can reinforce your own decision making processes, giving you an insight into how others have approached, the same, or similar problems.

Consideration of the above strategies supports that many health professionals in actuality undertake research in their daily practice which often goes unreported. Changes in individual clinics can sometimes occur without formal reporting, leaving the community as a whole without knowledge of the antecedents of a technique or practice. The final step in any research is the writing and publishing of the work.

We encourage all professionals to submit their findings for publication.

Nathan D. Moss
Neryla Jolly

Congenital Esotropia - an overview

Robin Wilkinson

Abstract

This paper looks at congenital esotropia, its phenotypic expression and the current theories on the neural mechanisms underlying the disorder. The clinical spectrum of the disorder is outlined and current research on latent nystagmus, asymmetries of optokinetic nystagmus and defects in visual motion perception are discussed. The aetiology of the disorder is unknown but recent studies on the macaque monkey which has naturally occuring congenital esotropia provides the first neuroanatomic evidence for cerebral cortex maldevelopments associated with the disorder.

Key Words: congenital esotropia, nystagmus, motion processing, neuroanatomical defect.

Introduction

Congenital or Infantile Esotropia has been defined as esotropia occurring in the first 6 months of life[1]. The incidence of the disorder has in the past been reported as1%[2]. However recent studies have disputed this and put the incidence as low as 0.27%[3].The disorder has a variable phenotype but commonly there is a constant large angle of deviation with associated anomalies such as latent nystagmus, dissociated vertical deviation , asymmetry of pursuit and optokinetic nystagmus and poor potential for normal binocular vision to develop.

Aetiology-theories

There are two main theories on the aetiology of congenital esotropia and they largely shape the various terminologies used for the disorder.

Worth postulated the aetiology of congenital esotropia was a congenital defect of the fusion faculty and that restoration of normal binocular single vision was therefore not possible[4].Chevasse later postulated that congenital esotropia developed as a result of interference with the development of the conditioned reflexes which in normal development lead to binocular single vision[5].

In a sense both were correct for certain phenotypes of the disorder but neither explain the complete clinical spectrum of congenital esotropia. Worth's theory would explain congenital esotropia which fails to develop any signs of binocularity in spite of surgical intervention in early life. Chevasse's theory on the other hand would explain congenital esotropia which develops albeit imperfect binocular single vision after early surgical intervention.

Terminology : Congenital vs Infantile

There has been much discussion regarding the correct terminology for esotropia occuring early in life. Congenital esotropia is a term we are all familiar with and it implies the disorder is present from birth. Neonate studies dispute this; Nixon and co-workers examined 1219 neonates in an attempt to discover whether esotropia is truly present at birth and found that 49% were orthotropic, 33% were exotropic, 3% were esotropic, and 15% were not sufficiently alert to permit classification. None of the 40 esotropic neonates demonstrated typical signs of congenital esotropia but rather 17 had intermittent esotropia, 14 varied from esotropia to exotropia and 9 had variable esotropia[6]. Three infants did go on to develop infantile esotropia. Another study by Archer, Sondhi and Helveston came to similar conclusions that normal infants and those with congenital esotropia or exotropia could not be distinguished on neonatal examination[7].

Lang summarises the situation thus; "does the term congenital really mean the defect must be both present and visible at birth?" At birth the visual system is anatomically and functionally immature and birth in a way is a premature event for the visual system thus congenital esotropia only manifests itself when the visual system matures and the binocular system becomes functional at 4 to 6 months of age[8].

While the aetiology remains unknown the terminology will remain largely a debate of words.

Clinical Spectrum of Congenital Esotropia

There are several syndromes that fall within the spectrum of congenital or infantile esotropia and it may be that they are simply the same basic disorder varying in expression. These are:
Essential Infantile Esotropia
Lang's Congenital Esotropia Syndrome
Ciancia Syndrome
Adelstein -Cuppers Nystagmus Blocking Syndrome

Essential Infantile Esotropia(Von Noorden)[9].
Onset birth to 6 months of age
Large stable angle which exceeds 30 prism dioptres
Defective abduction
Overaction of the Inferior Obliques
Dissociated Vertical Divergence (DVD)
Manifest/Latent nystagmus
Asymmetry of Optokinetic Nystagmus (OKN)
AHP

Lang's Congenital Esotropia Syndrome - concentrates on the four characteristics of a condition he labelled "alternating sursumduction"[10].

Early onset
DVD
Nystagmus - latent in most cases
Excyclodeviation of the non fixing eye
Abnormal head posture (AHP)

Ciancia Syndrome - this emphasises nystagmus as the most crucial component characterising the syndrome[11].
Early onset
Bilateral limitation of abduction
Jerk nystagmus increasing in abduction and decreasing in adduction
AHP with the face towards the side of the fixing eye
DVD
Asymmetric optokinetic nystagmus

Nystagmus Blocking Syndrome. Adelstein and Cuppers - proposed that the esotropia resulted from hypertonicity of the medial recti caused by sustained adduction of each eye and that the convergence impulse dampens the nystagmus[12].
Nystagmus increases on abduction
AHP with the face towards the side of the fixing eye
There is a straightening of the eyes under general anaesthetic.

Thus the clinical correlation of early onset or congenital esotropia with DVD, asymmetry of OKN and latent/manifest nystagmus is well documented.The pathogenesis is unknown and as stated it may be that the various syndromes are simply phenotypic variations of the same basic disorder.

Before discussion of the current research on congenital esotropia, the following is a brief review of the visual pathway and the mechanism of fusion.

Visual Pathway

Axons from the ganglion cells of the retina group together and travel as the optic nerve to the optic chiasm where the nasal fibres decussate. From the chiasm the fibres then travel via the optic tract to the lateral geniculate nucleus (LGN).

The LGN is a six layered structure. It is divided into two ventral

magnocellular laminae and four dorsal parvocellular laminae. Magnocellular cells appear to be concerned with movement, while parvocellular cells are concerned with stereopsis, colour and form discrimination[13]. Lamina 1,4 and 6 receive axons from the ganglion cells of the retina of the contralateral eye and lamina 2,3 and 5 receive from the ipsilateral retina[14].

The LGN is a 'sorting station' and from here the highly organised fibres travel via the optic radiations to the visual cortex (Brodmans area 17) which is also referred to as visual area 1 or V1.

The axons of the LGN project essentially to layer IV of the cortex where there is an alternation of ocular dominance areas receiving fibres from left or right eye but not both[15]. In layers just above and below area IV about half of the cells are binocularly driven from corresponding regions in the two retinas. The striate cortex is layered into parvocellular and magnocellular recipient lamina. The axons of the corpus callosum link the cerebral hemispheres.

The Fusion Mechanism

In congenital esotropia fusion deficits range from impairment to total lack of fusion so it is important to understand the neural mechanism of fusion. Essentially there are two components, sensory and motor fusion. Sensory fusion results from the detection of two similar images, one with each eye, and interprets them as one. Motor fusion aligns the visual axes and ensures a single fused image during vergence movements[16]. The extent of the disparity that motor fusion can respond to is measured by prisms and is called the fusion amplitudes.

At the retina visual input as light energy is transformed into electrical energy and travels the visual pathway to the occipital cortex.

Following decussation at the optic chiasm the input from both eyes is sorted at the level of the lateral geniculate nucleus and relayed to the visual cortex. Here recognition of retinal image disparity generates two different responses to disparity - motor fusion and stereopsis (three dimensional perception).

Central stereopsis(fine) is a highly specific pattern matching process operating over a narrow range of horizontal spatial disparities. Peripheral stereopsis (coarse) is a much less specific process which uses retinal disparity cues outside Panum's area[17].

Current Research Relating to Congenital Esotropia

The Onset of Binocularity.

Current research has given us a clear insight into the anatomical and physiological events that take place postnatally in the development of binocular single vision. Anatomically the visual system is immature at birth in particular with regard to the retina, lateral geniculate nucleus and visual cortex.

A morphological study on an 8 day old normal full term infant has yielded important information on the retina in the immediate post natal period[18]. The study confirmed the maturity of the peripheral retina at this stage compared to the very immature macula.

The fovea is so poorly developed that the authors suggested neonatal visual acuity must be extra foveal.

The lateral geniculate nucleus undergoes a doubling of volume between birth and six months of age.after which it remains stable into adult life[19].

In the visual cortex synapse development, synaptogenesis, occurs rapidly between 2- 4 months.The total volume of striate cortex reaches adult size at 4 months.

There is evidence that binocular interactions appear during this period. Such interactions include stereopsis, equalisation of optokinetic nystagmus responses, and binocular summation of pupillary light reflexes[20].

In the visual cortex there is initially a massive growth spurt resulting in an over production and redundancy of synaptic connections which reaches a maximum between 4 and 8 months. The connections are unspecified in terms of their function. Neuronal circuits emerge in response to afferent stimulation and stabilise and persist. There is a subsequent 'pruning' of non utilised synapses. Synapse elimination occurs between the ages of 8 months and 11 years.

This evidence of initial exhuberant synaptic connections support the hypothesis of an anatomical substrate for plasticity in the developing cerebral cortex.

Animal Models for Congenital Esotropia

Macaque Monkey

The macaque monkey is considered the best non human model for investigation of the neural mechanisms of strabismus. Some macaque monkeys have been found to develop early onset esotropia with abnormal temporally directed horizontal pursuit and latent nystagmus similar to those documented in strabismic humans[21].

Tychsen and Burkhalter and others have investigated functional and structural abnormalities in the visual cortex of squinting macaque monkeys in a bid to provide an insight into human congenital esotropia. They have demonstrated that there is a structural anatomical basis for functional deficits in infantile esotropia. Macaques with early onset strabismus were found to have maldevelopment in connections in ocular dominance columns in the upper V1 layers of the visual cortex . Binocular horizontal connections were reduced an average of 50/60% in strabismic monkeys compared to normal monkeys. Ocular dominance columns also showed greater activity in nasally driven columns in each V1 area - that is the contra lateral neurons inhibited the ipsilateral neurons and this may explain alternate suppression[22,23]. This study provides the first neuroanatomic evidence for cerebral cortex maldevelopments in natural infantile esotropia. They postulate that the defect could be congenital or that the esotropia itself could cause excessive pruning of connections early in life because of abnormal binocular experience.

Siamese cat

The Siamese cat, like the macaque monkey, has a naturally occuring esotropia. Studies by Hubel and Wiesel have investigated the visual pathway in the Siamese cat and have found it to be abnormal[24].They showed that the temporal fibres also decussate at the optic chiasm. In turn the lateral geniculate nucleus has anomalous layering patterns which suggest that at this early level the substriates for fused binocular single vision have been largely lost. Hubel and Wiesel found that in the visual cortex of the Siamese cat the area that would normally receive inputs from central vision have projections from retinal areas up to 30 degrees from central vision. In addition they have found that the vast majority of striate cortex units investigated were only activated by monocular contralateral eye stimulation.

An experiment by Cool and Crawford conducted on Siamese cats involving three subgroups - orthophoric, moderate angle esotropia and large angle esotropia, yielded results that were interesting. Basically they found that none of the cats had binocular or ipsilaterally activated cells in the visual cortex. They hypothesised that as two cats were orthophoric this supported the theory that the squint is primary and does not develop from a central defect of coding mechanism for fusion[25].

The development of esotropia in Siamese cats mimics that of humans in that initially the eyes diverge in the neonate stage and converge at three months. Moreover the degree of misalignment varies greatly.

Siamese cats present a model that the abnormal pattern of decussation at the chiasm that is an abnormal anatomical condition can lead to anomalous projections in the geniculostriate pathway that prevent the development of normal binocular single vision[26].

Asymmetries of optokinetic nystagmus and motion perception.

Optokinetic Nystagmus (OKN) Asymmetry.

Optokinetic nystagmus is an oscillatory response to moving targets. It consists of a slow phase (pursuit) followed by a rapid refixation (saccade). The pretectal nucleus of the optic tract contains direction selective neurons that are believed to be involved in OKN responses.

In a normal neonate, monocular optokinetic nystagmus is asymmetrical; - the response to a stimulus moving in the nasal-temporal direction is significantly reduced compared to the response in the temporal - nasal direction[27]. This asymmetry decreases with age and becomes symmetrical at around 6 months of age when the binocular reflexes are established.

In congenital esotropia it has been found that the reduced temporally directed monocular horizontal OKN persists. Mein studied this asymmetric OKN and concluded that only patients with the triad of early onset strabismus, nystagmus and DVD consistently demonstrated asymmetry of uniocular OKN[28].

However a more recent study suggested that the OKN response was directly related to the age of onset of the strabismus. The earlier the onset the more likely the OKN response will be asymmetric[29]. This was confirmed in a study which found that OKN responses remained asymmetric in a group of congenital esotropes even though they were aligned before 5 months and went on to achieve good stereopsis[30].

A recent study by Westall and others looked at a group of 14 infants and toddlers with congenital strabismus and found none of them developed symmetric monocular OKN. However 45% did elicit sensory-cortical fusion. They concluded that

optokinetic nystagmus asymmetry may not be associated with a deficit in cortical fusion but rather with deficits in binocular pathways projecting to OKN control centres[31].

In summary, current research supports the theory that monocular optokinetic nystagmus asymmetry is related to the age of onset of strabismus and not to the potential for binocularity.

Defects in Visual Motion Processing

Recent work has shown that smooth pursuit movements are driven by visual inputs from the cortical pathways for motion processing.

Congenital esotropes have been found to have a number of abnormalities of ocular motor responses that imply asymmetry of the motion processing mechanism with nasal to temporal motion being defective.

These studies have found that in congenital esotropes:

1. Monocular OKN is defective in nasal to temporal direction, as previously mentioned.
2. Pursuit eye movements are defective with failure to track smoothly from nasal to temporal direction unioculary.
3 There is failure to judge velocity of targets moving in the nasal to temporal direction[32].

These deficits are considered to be due to maldevelopment in the motion processing of the visual cortex although whether the strabismus being present at a critical developmental period causes the defect or whether the strabismus is a result of an abnormal emphasis on nasally directed motion is not clear.

A study by Norcia, Hamer, Jampolsky and Orel-Bixter found that motion processing showed plasticity in the critical developmental period and the magnitude of directional bias improved after early surgery in a group studied[33]. They felt that there was a critical period for the development of binocular direction selective mechanisms during which accurate alignment may be effective in promoting recovery of response.

Latent Nystagmus

Latent nystagmus (LN) is a congenital jerk nystagmus which manifests on covering one eye or reducing image brightness in one eye. The term manifest latent nystagmus was introduced by Dell'Osso to describe manifest nystagmus with the same characteristics as latent nystagmus that is, the nystagmus increases on reducing input to one eye[34]. He felt this was the same as nystagmus associated with congenital esotropia and that it only appeared as latent nystagmus because the very low amplitude wiyh both eyes open was not observed clinically. Essentially the characteristics of latent nystagmus and manifest latent nystagmus are the same with a fast phase (jerk) to the temporal side on the fixing eye and a slow nasal movement or slip.

Kommerell has postulated that latent nystagmus is due to the same defect in naso-temporal symmetry that affects pursuit and optokinetic systems. Normals employ two controls to pursue, foveation or position of the image in relation to the fovea, and retinal slip. He hypothesised that the asymmetry of smooth pursuit and LN are due to maldevelopment of retinal slip He argues that the key factor in producing these asymmetries is the reduced binocularity rather than monocular or binocular deprivation.[35]

Current Genetic Studies

Strabismus Inheritance Study in Tasmania (SIST)

The SIST study is a genetic study looking for the genes that predispose individuals to congenital esotropia. The study hypothesises that congenital esotropia is a genetic disorder which results in anatomical changes which affect the development of the binocular reflexes and normal binocular single vision. The expression of the gene varies in severity and the milder phenotypes do have the anatomical structure to develop subnormal binocular vision if the eyes are aligned surgically at at an early age. The more severe phenotype will never have the structure in place to develop any form of binocularity.

The study is currently looking at several candidate genes looking for mutations that segregate with affected individuals in 25 sibling pairs with congenital esotropia. The initial candidate genes under investigation are genes that relate to the development of axonal direction in the visual pathway.

CONCLUSION

The aetiology of congenital esotropia is unknown. Current research on the clinical manifestations of the disorder and anatomical studies on the macaque animal model have done much to enlighten us on the neural mechanisms underlying the disorder.

ACKNOWLEDGEMENT

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The effects of age on Saccades made to Visual, Auditory and Tactile Stimuli

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Abstract:

Purpose

To investigate the effects of stimulus modality and aging on saccades in healthy human subjects.

Methods

Visual, auditory and tactile evoked saccades of young, middle aged and older healthy subjects with normal visual function, hearing and somatosensation were measured and analysed. The young group was comprised 12 subjects aged between 20 and 30 years of age, with a mean age of 23.7 (+ 2.9) years. The middle-aged group was comprised of 7 subjects ranging in age from 40 to 50 years with a mean age of 46.9 + 3.4 years. The older group was comprised of 7 subjects ranging from 60 to 70 years of age, with a mean age of 63.86 +3.0 years.

The visual stimuli were presented by light emitting diodes at 0, +5, 10, 15 and 19 degrees. The auditory stimuli were noise-emitting loudspeakers placed above the visual stimuli. The tactile stimuli were presented by bone vibrators driven at 250 Hz placed beneath the fingertips at corresponding angles.

Results

The latency of auditory saccades was significantly longer than tactile saccades, whose latencies were in turn significantly greater than visual saccades. Visual saccades were most accurate and least variable, followed by tactile saccades. Auditory saccades were found to be highly variable and grossly inaccurate. Age did not affect saccades to different sensory modalities.

Conclusions

The results suggest that non-visual stimuli undergo greater neural transformation than visual stimuli, and, specifically, auditory stimuli undergo more neural transformation than tactile stimuli for the generation of a saccade. The findings of this study provide the initial basis for eventual clinical applications of tactile stimuli in the evaluation and rehabilitation of persons with visual impairment.

Introduction

Sensory information about light and movement, sound and noise, taste, olfaction and touch (somatosensation) is constantly being transmitted to the human central nervous system (CNS). To give a better understanding to this sensory information the CNS initiates a rapid eye movement (saccade) to direct the visual axes to the point of the sensation, and then high acuity visual information about the object is obtained. This process of initiating saccades to the source of incoming sensory information gives better understanding and more meaningful interaction between humans and their surrounding environment. Based on this knowledge, studies have examined and found that saccadic eye movements can be made not only to visual stimuli but auditory and somatosensory (tactile) stimuli (1,2,3,4,5,6).

The superior colliculus (SC) of the midbrain (7) is the integral structure of the CNS involved in the generation of saccadic eye movements. Consisting of seven layers (7,8) the SC is divided into a superficial (dorsal) division (layers I to III) and a deep (ventral) division (layers IV to VII). The division is made on the basis of functional properties such as neuronal morphology, afferent-efferent projections, physiological properties and behavioural involvement (7). The superficial division of the SC serves as a sensory structure (9) receiving afferent input from the retina and visual cortex (8,9). The deep division of the SC receives afferent input from different sensory modalities and motor structures, and is involved in the transformation of sensory information into motor command (7). The cells of the SC may be specific to one sensory modality (10,11) or respond to multiple sensory modalities (7,10). Multimodal cells respond to either a combination of each sensation (ie visual and auditory or visual and tactile) or all three sensations. The sensory input into the SC enables the development of 'sensory maps' which locate the stimuli in relation to the surrounding environment. These sensory maps are retinotopic, or 'eye-centred' for visual (7) and somatosensory input (1). A craniotopic or 'head-centred' reference frame exists for auditory stimuli (12). The individual sensory maps of superior colliculus follow the same co-ordinates, but are then transformed into one sensory map. After the multimodal sensory map has been established by the superior colliculus, a small group of cells in the area of the afferent sensory input (7) code the direction,

amplitude and velocity of the saccade (13) required to drive the eye to the desired position.

The latency of visually evoked reflexive saccades has been shown to be approximately 200 milliseconds, with a standard deviation of 25 to 50 seconds (9). Santamaria (14) and Warabi et al (15) have found that target eccentricity prolongs saccadic latency, in contrast Versino et al (16) found no relationship between target position and saccadic latency. Increasing age has repeatedly been shown to prolong the latency of a saccade to a randomised target (14,16,17,18,19,20,21,22). Santamaria (149) showed that the combination of age and target eccentricity both prolong saccadic latency. Visual saccades are highly accurate, with hypometria of 10 percent considered to be within normal limits (14). Warabi et al (15), Sharpe & Zackon (20) and Santamaria (14) found that increased age results in a greater inaccuracy of saccadic eye movements; in contrast to these findings, Versino et al (16) found no relationship between increased age and saccadic accuracy.

Zahn et al (3,4) and Zambarbieri (5) have investigated auditory-evoked saccades, finding that auditory saccades have a longer latency than visual saccades. The latency of auditory saccades decreases with increased target eccentricity. Auditory saccades are less accurate than visual saccades, usually arriving within three degrees of the target position (3,5). Increased target amplitude causes decreased accuracy and a greater variability of responses for auditory saccades (5). Zahn et al (3) reported that neither the accuracy nor the latency of a saccade were affected by the frequency or intensity of narrow-band noise. Schik et al (6) examined predictable saccades to visual and auditory targets in young, middle-aged and older subjects and found increased latency and higher velocity of saccades in the older group. In contrast to the aforementioned studies by Zahn et al (3,4) and Zambarbieri (5), Schik et al (6) found shorter latencies for auditory targets. It is important to note that the study by Schik et al (6) used a very different method in his study, and these methodological differences make it difficult to compare this study to others by Zahn et al (3,4) and Zambarbieri (5).

Groh and Sparks (2) investigated the behavioural characteristics of saccades to somatosensory stimuli, using three monkeys and two human subjects. In this study subjects were requested to grasp a post which provided a pulse of vibration for 100 milliseconds, positioned 20 degrees either side of the midline. Different saccadic amplitudes were obtained by randomising the starting point for the saccade. The study found that the tactile saccades had longer latencies in comparison to visual saccades, which decreased as target eccentricity increased. It is interesting to note that when the hands were visible the monkeys often looked towards their hands and not the stimulus. Groh and Sparks (2) have demonstrated that when a large tactile stimulus is used the target can be localised by humans. It was not known whether the results could be elicited from a smaller surface area such as the fingers, and whether these responses would be more accurate. The fingers contain the largest density of tactile sensors in the human body, which would suggest that they could be localised with greater accuracy.

The present study aimed to investigate the latency, accuracy and variability of responses of saccades made to tactile stimuli presented to each of the fingers, and to compare the results with saccades made to visual and auditory targets that subtended the same angle. Subjects were divided into three different age groups to determine whether age also influences the characteristics of saccades.

Methods

Subjects

Twenty-six subjects were recruited on a voluntary basis and gave written informed consent for participation in the study. Inclusion / exclusion criteria were established to ensure volunteers could generate normal saccadic eye movements, had good general and ocular health, and had normal visual, auditory and vibrotactile sensation. These were tested using a questionnaire and various clinical tests. Potential participants with Alzheimer's disease, schizophrenia, dementia, (21,23,24,25,26,27), Parkinson's disease, progressive supranuclear palsy, Huntington's disease (27) and other psychological and neurological disorders were excluded from the study. Volunteers taking sedatives and hypnotics (including barbiturates and benzodiazepines), anti-convulsants and medications indicating the afore-mentioned disorders were excluded from the study. Volunteers were also asked to cease alcohol consumption 12 hours prior to testing.

Volunteers with nystagmus, neurogenic or mechanical extra-ocular muscle palsies, other disorders affecting eye movements, diseases affecting peripheral vision (such as glaucoma and retinitis pigmentosa) and volunteers with homonymous hemianopia (28) were excluded from the study. In addition to this, participants were required to have best corrected visual acuity of 6/12 or better in at least one eye (using Snellen's Acuity Chart), normal pupil reactions, a full visual field to confrontation testing, no strabismus and full ocular movements.

Volunteers with a known history of hearing loss and diabetes mellitus were excluded from the study. All potential participants were required to demonstrate the ability to hear a 30 decibel sound presented at three pitches (500Hz, 1000Hz and 2000Hz) in each ear, using a Beltone audiometer calibrated to 4000Hz, which is within the normal range of hearing for all age groups (29). Participants were required to demonstrate the ability to perceive the commencement and cessation of vibration on each fingertip, tested using a standard E tuning fork.

All 26 volunteers were eligible for participation with normal visual, auditory and somatosensation. A young group (aged between 20 and 30 years), a

middle-aged group (aged between 40 and 50 years) and an older group (aged between 60 and 70 years) were formed. The young group consisted of 12 subjects (8 female, 4 male) with a mean age of 23.7 (sd +2.9). The middle-aged group contained 7 subjects (4 female, 3 male) with a mean age of 46.9 (sd +3.4). The older group had a mean age of 63.9 (sd +3.0) and was comprised of 7 subjects (5 female and 2 male).

Procedure

The visual, auditory and tactile stimuli were purpose built for this study. The visual stimuli were light emitting diodes (LEDs). The visual stimuli were mounted onto an arc which was positioned 1.6 metres from the patient, and could be adjusted to eye level. At this distance, the visual stimuli were located at 5, 10, 15 and 19 degrees to left and right. An LED served as the zero point for visual stimuli, and was aligned with the visual axis.

The auditory stimuli were speakers that emitted narrow-band noise of 250Hz at 85 decibels. The speakers were positioned directly above the LEDs, therefore subtending the same angles as the visual stimuli. An audiometer was used to control the speakers.

The tactile stimuli consisted of Radioear B-7 bone transducers mounted into foam as a means of limiting the vibrations from spreading to the other fingers. The input was a 250 Hz sine wave. The transducers were placed such that one thumb served as the zero point when aligned with the visual axis of one eye. The other four fingers of each hand subtending angles of 5, 10, 15 and 20 degrees to the left and right when placed 34 cm from the eyes. The foam was then placed into a metal box for support and mounted to raise the structure to eye level. When testing was conducted, one thumb was aligned with the right visual axis to avoid the effects of convergence.

For all stimuli, positions to the left were deemed to be negative whilst positions to the right were categorised as positive.

Subjects were fitted with the Microguide eye tracker, which was adjusted for comfort and aligned with the visual axis of both eyes. Subjects were then positioned into a headrest mounted on the desk, and the head was stabilised using an adjustable chin height and forehead strap. The eyes aligned with the tactile stimuli and then the visual and auditory stimuli at the respective distances required, and the room darkened. Subjects were instructed to keep their head still whilst testing, and to look as quickly as possible at the stimuli, holding that position until the next stimulus appeared. An oscilloscope was used to view the eye movements from each eye, approximately calibrating the eye tracker by adjusting it for symmetrical output at +19 degrees. A calibration program presented visual stimuli at all nine target positions, the data from which was used to linearise the testing data via a cubic polynomial curve fit.

For each type of stimulus, programs written in the Viewdac programming environment were used to randomly present the stimuli in each of the eight target positions. A standardised method was used to present the stimuli for each stimulus type. Testing commenced with the presentation of the target at zero, followed by a stimulus at one of the eight target positions, and then again at zero and so forth. Each target position was tested eight times in a randomised order, with the interval stimuli randomised between 1.5 and 3 seconds. The order that the three stimulus types were presented was randomised between subjects. Eye movements recorded by the eye tracker travelled to an oscilloscope and digitised at 12-bit resolution at 400 Hz for subsequent analysis.

The data files were re-named by an independent source for blind analysis. Analysis was performed using a Matlab 5.2 program developed by one of the authors (LA), which was based on the Zoomtool interactive graphics package as modified by Jonathan Jacobs, Case Western Reserve University. For each subject the calibration data was matched to each of the nine target positions, so eye movements were accurately scaled. A cubic polynomial was fitted to these points and used to scale other recordings. Saccades that overshot the 20-degree point were saturated and hence excluded from analysis. Saccades that commenced prior to or at the same time as the presentation the stimulus were regarded as anticipatory saccades and were excluded from analysis. The data were then transformed into Microsoft Excel files. The codes were then broken and the data analysed using the program SPSS version 8.0.

The dependent variables in this study are latency, accuracy and variability of subject accuracy. The accuracy of a saccade was defined as the magnitude of error (measured in degrees) and the variability of accuracy was defined by the variability of the magnitude of error. The two independent variables of this study were age and stimulus modality. Post-hoc analysis was conducted using pair-wise comparisons. As the samples originate from three different families no Bonferoni adjustment was used. Statistical significance was set at 0.05.

Results

The study found that the latency of a saccade is affected by the stimulus used to initiate the saccade ($F(1.659)=73.845$, $p<0.001$). Visual saccades have the shortest mean latency of 0.193 + 0.047 seconds, followed by tactile saccades with a mean latency of 0.352 + 0.169 seconds. Auditory saccades have the longest mean latency of 0.528 + 0.267 seconds (see Figure 1). Post-hoc analysis showed that a statistically significant difference exists between all three types of stimuli ($p<0.001$). One-way analysis of variance (ANOVA) showed no difference no significant effects for age ($F(2)=0.645$, $p=0.534$). Two-way ANOVA revealed that there was no interaction effect between age and stimulus type for the latency of saccades ($F(3.319)=0.283$, $p=0.8550$). These results are demonstrated in figure

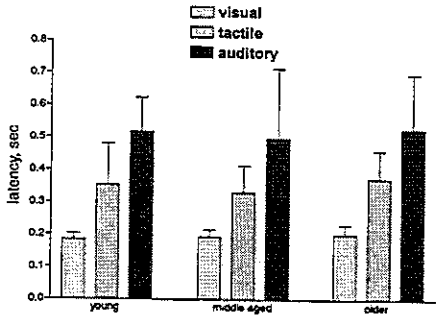

Figure 1: The effects of age and stimulus type on the latency of saccades.

The accuracy of a saccade was found to be influenced by the type of stimuli used to elicit the saccade (F (1.23)=269.248, p<0.001), with statistically significant differences existing between all three types of stimuli (p<0.001). The study did not find a significant effect for age (F (2)=0.626, p=0.543), or an interaction effect between the two variables of age and stimulus type (F (2.46)=0.235, p=0.835). See Figure 2.

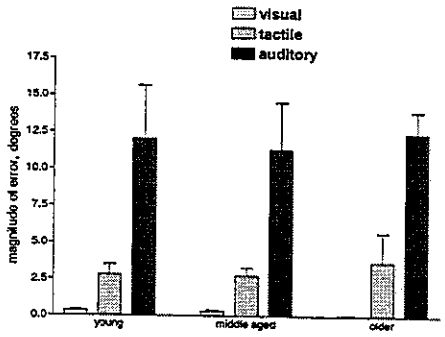

Figure 2. The effects of age and stimulus type on the accuracy of saccades.

The variability of subject accuracy was determined by the standard deviation of each subject's response to each stimulus type. One way ANOVA showed the type of stimulus used to elicit a saccade significantly influences the variability of the subject's accuracy (F (1.459)=370.321, p<0.001). Pair-wise comparisons confirmed that the differences between each of these stimulus types were statistically significant (p<0.001). Age was found to have no statistically significant influence on the variability of a subject's response (F (2)=0.770, p=0.475). No interaction effect was found to exist between the two independent variables (F (2.917)=0.197, p=0.893). See Figure 3.

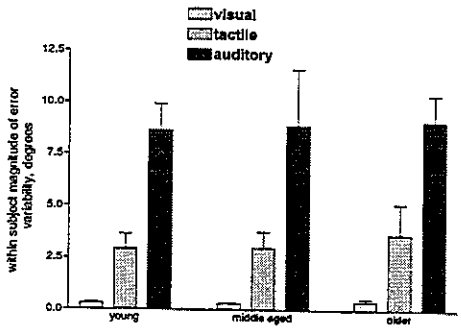

Figure 3. The effects of age and stimulus type on the variability of saccadic accuracy.

Discussion

Most previous studies have shown that auditory (3,5) and tactile (2) saccades have longer latencies than visual saccades. This study supports these findings, but furthermore establishes the relationship that exists between the latencies of all three types of saccades. This study's finding of shorter saccadic latency in visual saccades would suggest that visual information undergoes less transformation and/or processing than saccades to other auditory and tactile stimuli. Whilst Zahn et al (3), Zambarbieri (5) and Groh and Sparks (2) hypothesised that increased saccadic latency is the result of extra sensory processing of auditory and somatosensory stimuli. The results of the present study not only support this theory but suggests that the shorter latency of tactile saccades (0.355 + 0.169 seconds) compared to auditory saccades (0.528 + 0.267 seconds) suggests that tactile information undergoes less transformation and/or processing than auditory information for the generation of a saccade.

As was expected, the present study found that visual stimuli produce the most accurate saccades. Although not as accurate as visual saccades, the present study did establish that the eyes could localise some tactile stimuli presented to the fingers with relative accuracy. In this study the bone transducers used were broad and flat and provided vibratory stimulation to the entire fingertip, which subtended up to 3 degrees of visual angle. Therefore using these calculations, the endpoint of the saccade was on average only 1 degree either side of the finger. The study did not, however, examine if accuracy was dependent on the subjects' handedness, and it may be possible that saccades to the fingers of the 'dominant' hand yield a greater accuracy.

It was anticipated that tactile saccades would be much more accurate, and, upon debriefing subjects it was found that the foam did not always adequately dampen the vibrations from spreading from one finger to another. In future studies a better defined and isolated vibratory stimulus may improve accuracy. It is possible that after prolonged vibratory stimulation of the fingers, it became increasingly difficult to localise the location of the target.

In the present study the auditory saccades were highly inaccurate, with a mean error of approximately 12 degrees. Furthermore the variability of the accuracy of the auditory saccades was significantly higher than the other two types of saccades. During the analysis of these saccades it was noted that many of the subjects made saccades in the opposite direction to the target. This result is in contrast to the findings of Zahn et al (3), who found that an auditory saccade was relatively accurate, arriving within 3 degrees of the target. The result in this experiment may be explained by the close proximity and the small angular displacement of targets, meaning the auditory signals from each ear would arrive to the primary auditory cortices from each ear at very similar times, hence making localisation of the stimuli exceptionally hard.

The low numbers of subjects in each age group and large standard deviation of responses under each test condition may have led to the absence of a significant age effect. It is important to note that even when the middle-aged group was removed from the analysis, still no age effect was present. The analysis by Whitaker and his co-authors (13) showed that there is a decrease in saccadic latency during the eighth decade of life (71 to 80 years of age). The absence of a group of participants in the eighth decade of life may be a contributing factor in the absence of an age effect.

Using a normal population the present study found that saccades to a tactile stimulus displayed relatively high accuracy. Future studies could examine the accuracy of eye movements in patients with central vision loss from causes such as age-related macular degeneration, or childhood pathologies such as Stargardt's disease.

The high degree of saccadic accuracy creates many possible clinical applications for tactile stimuli. Visual field testing relies strongly on the patient's visual feedback to keep steady fixation, to allow accurate analysis of the visual field. In patients with central vision loss tactile stimulation could be used to promote steady central fixation as there is no visual feedback to promote central fixation. This vibrotactile stimulus system could also be used in clinical practice to maintain central fixation during A-scan biometry, keratometry, fundus photography and retinal laser treatment. The same technique may also be appropriately used to calibrate the recordings of the eye movements of patients with central vision loss to provide increased accuracy of test results. Central vision loss is commonly associated with visual disorders of aging such as macular degeneration, and the absence of an age effect indicates that vibrotactile sensation may lend itself to clinical applications easily.

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Negative Vergence Training and its Effect on the Divergence Range and Heterophoria Size

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Abstract

This study aimed to investigate the extent to which negative vergence training can influence the divergence range and the associated heterophoria size. Forty ocularly healthy participants (11 males & 29 females) with an age range between 17-64 years (mean age=26.6 yrs; SD=12.1 yrs) were included in the study. The participants were randomly allocated into four groups (n=10/Gp). The first group was trained using the diploscope treatment only, the second group was trained using the cat-stereograms card with additional modifications applied to it, the third group was trained using a standard cat-stereograms card without any modifications. Participants in these groups underwent training for 5 minutes, 3 times a day for 2 weeks. Lastly the control group did not undergo any training.

Results indicated that there was a significant change in the mean near heterophoria size post training in all groups. This significant change was attributed to chance occurrence and may not yield any clinical relevance. A close to significant interaction between the groups training the cat-stereograms card with modifications and the group training with the standard cat-stereograms card was also found, signifying a better treatment success with modifications applied to the standard cat-stereograms card. Single case analysis of three esophoric participants, pointed to a possible future study to examine the impact of treatment on this group.

Key words: Negative vergence, divergence, heterophoria size, diploscope, cat-stereograms card, additional modifications

Introduction

The ocular motor system is organized to integrate two independent major subsystems: versions and vergences1, 2. The former subsystem mediates conjugate eye movements, while the latter mediates disjugate (disjunctive) eye movements. Both subsystems operate to ensure bifoveal fixation when the eyes of the individual are directed at different directions (versions) and at different viewing distances (vergences).

It has been generally accepted amongst most eye care practitioners that the plasticity and the adaptability of the ocular motor system has enabled it to be freely trained with therapy3. The vergence subsystem has been one area where this plasticity has been shown to exist4. This has proven valuable in the therapeutic training of both the healthy asymptomatic individual and the symptomatic individual whom can present with measurable reduced vergence ranges5.

The vergence subsystem can be generally described according to three types: horizontal, vertical and torsional eye movements. The training of the horizontal vergences has been by far the most popular type of vergence to be trained clinically.

In 1893 Maddox6 classified four types of visual stimuli that can elicit horizontal vergences (i.e. both convergence and divergence). These visual stimuli are tonic, retinal disparity, accommodative and proximal stimuli6. Convergence has also been described as a voluntary response7. Maddox6 considered these visual stimuli are more or less independent additive components of the total horizontal vergence required to maintain any object on both fovea3.

Maddox6 also observed that the eyes under deep sleep, anaesthesia and death, tend to resume the normal anatomical resting position of divergence as a result of the lack of any neural activity keeping the eyes aligned straight ahead5. This resting position differs from the physiological resting position where the eyes resume an intermediate convergent position in the dark. That is, resume the normal anatomical resting position in the absence of any visual stimuli8.

It is pragmatic to assert that the amount of studies conducted on the positive vergence system or convergence outweighs by far the amount conducted on the negative vergence system or divergence in the literature. Studies such as those conducted by Daum1, 3,4,9, Vaegan10, 11 and Green12 demonstrated that the positive vergence system is easier to train, and a greater increase in its amplitude has been noted, when compared to the negative vergence system. Daum13 suggested that this difference observed between these two eye vergence movements, is possibly due to the

existence of two different control systems or neural centres13.

Different types of training methods have been investigated in these studies, such as 'push up' training, variable vectograms, synoptophore and an 'aperture-ruler' trainer. These methods were generally categorised into two types of training involving smooth, slow tonic activities and quick, stepwise, more phasic tasks13 .

In 1986, Daum14 conducted a study primarily involving the training of the negative vergence system. The study involved a training period of 7 consecutive weeks. Daum14 acknowledged that negative vergence training could indeed increase the divergence amplitude by substantial amounts (an increase of 5.0^ at distance and 9.0^ at near), however this magnitude of increase remains smaller than the magnitude of change shown to be possible following positive vergence training, observed in other studies 1, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15. Daum14 concluded that there must be a fundamental difference between both the positive and the negative horizontal vergence systems14.

Green12 similarly investigated the training of horizontal vergences as well as vertical vergences using a hand-held prism bar. Green's12 study demonstrated a mean divergence amplitude increase of 7.6^ (45%) at 1/3m and 1.2^ (18%) at 6m12. "The surprising element was revealed at the two-year follow up. There was no decline in the increases after two years, and there was a further increase of 117% after a further period of training"12. Green12 affirmed that this magnitude increase will be greater if the convergence amplitude is maximally trained prior to divergence amplitude training12. Green12 concluded that there is a possibility that divergence amplitudes could increase more readily with prism bar vergence training.

Despite the overall success and the numerous studies available on the therapeutic training of horizontal eye vergences, this area merits further study, particularly the negative vergence system. Therefore the current study aimed to establish the extent to which negative vergence training could influence the divergence range and the associated heterophoria size in a group of normal asymptomatic participants. Two different treatments not explored in previous studies were implemented: the traditional diploscope and the commonly used cat-stereograms. The level of effect of these two training treatments was evaluated using two outcome measures: the near (30cm) and the distance (6m) base-in range and the heterophoria size. The current study also aimed to ascertain if the cat-stereograms card was more effective in extending the two outcome measures with the application of additional modifications to the card. It was proposed that the treatments adopted in this current study would extend the range of divergence and influences the size of heterophoria present. It was also anticipated that the application of additional modifications to the cat-stereograms card would improve the treatment effect following training.

Method

Participants

Forty ocularly healthy participants were invited to participate in the current study on a voluntary basis. The participant's age ranged between 17-64 years with a mean age of 26.6 years, SD of 12.1 years. The inclusion requirements were based on participants passing a visual and an ocular motor assessment examination performed prior to random allocation into groups. The participants were required to have: corrected visual acuity of 6/6 or better for each eye; good general health and no history of any current or past ocular pathology, strabismus (intermittent or manifest) and retinal or ocular media disease. Any participants with a history of ocular surgery or regular medications were also excluded.

Design

The current study involved the use of a mixed experimental design consisting of a between groups and repeated measures. The participants were randomly assigned to one of four groups: the diploscope group, the cat-stereograms card with additional modifications group, the standard cat-stereograms card without any modifications group and lastly the control group, which did not undergo any training. Measurements of the base-in range and the heterophoria size for both near and distance were undertaken on (day 1) and (day 15) to ensure consistency of results. The treatments were given to participants to take home and perform for duration of 2-weeks (14 days) for 5 minutes 3 times a day (total of 15 minutes per day).

Apparatus

The measuring instruments included in the current study were: Snellen's 6m Visual Acuity chart (Clement Clarke International Ltd). A horizontal hand-held prism bar with increasing increments of 2^ (total of 40^) and a circular fixation target measuring 1.7cm. The treatments undertaken consisted of the 'diploscope' device and the 'cat-stereograms' card. A consent form, an information sheet about the study, a compliance daily calendar and a treatment instruction sheet, were all provided to each participant prior to commencing with training.

Testing Procedure

On day 1 a brief history was taken to select the suitable participants. A visual acuity test and a cover test were performed at both 6m and 1/3m distances. Once these preliminary measures were completed, the first initial measurements of both the divergence (base-in) range and the heterophoria size were commenced.

The divergence range measurement

A hand-held base-in prism bar was used to measure the divergence amplitude of participants. The examiner placed the prism bar before the participant's eye and asked them to fixate at the 6/60 letter 'A' on the 6m-vision chart when taking the distance measurement and at the fixation target held at 1/3m for the near measurement. The participants were asked to

report when the letter 'A' or the near target became horizontally displaced into two completely separated images as the examiner increased the strength of the base-in prism (i.e. this prism which caused the image separation was recorded). The distance and near measurements were taken three times and averaged for analysis.

The heterophoria measurement

The von Greaf subjective heterophoria technique was used to attain an accurate quantitative measurement of the participant's heterophoria size. Tracy16 observed this heterophoria measuring method to yield high test-retest reliability with a coefficient greater than 0.90, since it uses prism dissociation as a dissociating technique16.

This method consisted of a vertical dissociative base-up prism, which interrupted the participant's fusion. The strength of prisms needed to achieve full dissociation varied between 3^-6^, depending on the participant's vertical range.

A vertical prism bar was placed before the participant's right eye as they fixated at the 6/60 'A' letter on the 6m-vision chart. The prism vertically displaced the image before the subject's line of sight, which allowed them to appreciate two vertically, separated 'A' letters. Perfectly vertically aligned 'A' letters indicated that the participant was orthophoric and a measurement of '0' was recorded. Diagonally placed images, indicated the presence of a horizontal deviation. A second hand-held prism was used to align the diagonal images, until they were vertically aligned one above the other. The prism strength required to achieve this was recorded. Similarly, measurements were repeated at near (1/3m) using the fixation target.

The order in which the distance and near measurements for both the base-in and heterophoria size, were randomised between participants to control for any sequence effects. All measurements were performed and repeated in the same manner on day 15 following completion of the treatment period.

Home treatments

The Diploscope treatment

The diploscope principally teaches "the awareness to the patient of his visual axis, and in acquiring dexterity in directing the axes to a given point at will"17. There are four points of fixation to which the participant can direct their visual axis. However, as this current study was chiefly training divergence, the participants only exercised the "fourth position" of fixation, as it was the only position primarily concerned with divergence.

The training of the diploscope required the participants to place the instrument (Figure 1) on their nose and direct their eyes slightly above and beyond its card (with the letters DOG printed on it) into a 6m distance or into a far away distance such as outside a window. This distance fixation was a mandatory requirement, as divergence was ensured to take place. Participants were subsequently instructed to diverge their eyes until they were able to achieve the letters DOOG. The participants were able to train their divergence range by consciously increasing the distance between the middle 'OO' letters. In theory, as the distance continued to further increase between those two middle letters, the divergence amplitude would have simultaneously increased17.

Once the participants exercised their divergence range looking into the distance, they were asked to redirect fixation to the near metal septum before their eyes. Consequently, the middle 'OO' letters joined and became one letter 'O'. However when asked to exert control by diverging their eyes further, the participants were able to maintain the distance between the two letters and keep them apart. This part of training aimed at strengthening and sustaining the divergence capability, the participants had achieved when looking into the distance17.

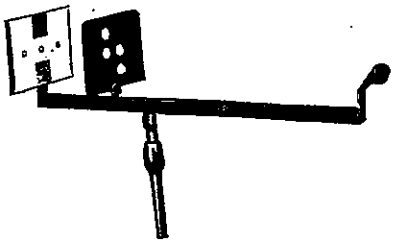


Figure 1. The diploscope treatment

The cat-stereograms treatment

In the clinical setting, a standard cat-stereograms card, which has two cat pictures distanced 6cm apart, is used to train relative fusion. The distance between the two cat pictures is specifically set at 6cm to be equivalent to the average individual's interpupillary distance (IPD).

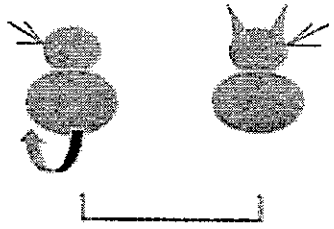
This card teaches "dissociation of accommodation from that part of convergence, which is variable, that is the metre angle minus the AC/A ratio"17. This principal was accomplished by the participant, via the movement of their visual axes into a position, which is either relatively convergent (positive relative fusion) or relatively divergent (negative relative fusion) with respect to the position of the card. Consequently, this visual axis movement resulted in one image of the cat pictures on the card, to fall on the fovea of the participant's right eye and the image of the other cat picture to fall on the fovea of their left eye17. Following, a bifoveal-fused image would have been perceived and projected straight ahead as a third complete cat picture in the centre of the card 8,17,18. Given that, divergence training was the primary aim of the current study, participants were encouraged to exercise the negative relative fusional aspect of the card, by holding the card at an arms length and looking slightly above and beyond it into the distance to achieve the picture of the third complete cat.

Clinically, this standard cat-stereograms card is not generally given with any additional modifications to assist the patient to adapt their eyes when they experience difficulties in achieving the third cat. The modifications applied to the cat-stereograms card in the current study, included the adjustment of the separation between the cats by further increasing the

distance by 0.5 cm to reach 8cm and by reducing the image separation, by 0.5 cm reaching 4 cm (Figure 2). The adjustment of the distance between the images, aimed at assisting the participant to achieve the third cat with ease (i.e. by training using a distance that they were comfortable with). The increase in the distance between the two cat pictures, aimed at providing the participant a range of distances on which they can exercise and extend their divergence range (Figure 2). The other type of modification applied in the current study, entailed the removal of the middle part of the two-cat pictures17, 18(open stereograms; Figure 3) to have the participant look through them into the distance. This modification also aimed at allowing the easier achievement of the third cat, by encouraging the participant to relax the proximal convergence that takes place as a consequence of the nearness of the card. The modification also relaxes accommodation, ultimately assisting in divergence to be instigated with more ease.

The participants in the cat-stereograms with modifications group, besides having their IPD measured on day 0, were given a set of cat- stereogram cards with the additional modifications applied to them. The set consisted of pairs of 9 cat-stereogram cards (total of 18 cards). Each pair of the cat-stereograms cards had the cat pictures set at a certain distance and included one open cat-stereograms card and one closed cat-stereograms card. For example, a pair that had it's cat pictures set at 4cm, would have one open cat-stereograms card and one closed cat-stereograms card, with both cards set at 4 cm etc. The participants were instructed to choose the pair of cards with which they could achieve the third cat, then to start each pair with the use of the open cat-stereograms card to assist them to achieve the third cat easily. Subsequently, they were to train using the closed cat-stereograms card. Once they achieved the closed cat-stereograms card, they were able to progress to a further set distanced pair of cards until they could accomplish the 8cm cat-stereograms pair of cards or until the two weeks period concluded.

The participants using the standard cat-stereograms card were only given the standard closed cat-stereograms card without any modifications applied to it. The IPD of participants was also assessed in that group on day 0.

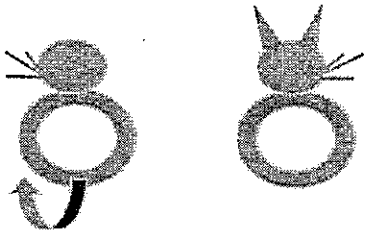


6cm
Standard card distance

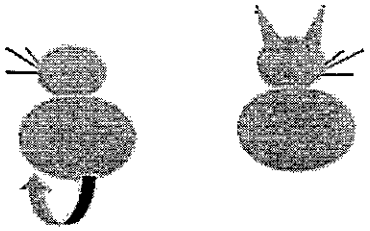
Distance was increased by
0.5cm (up to 8cm)

Distance was decreased by
0.5cm (up to 4cm)

Figure 2. Modifications of the cat-stereograms card involving distance adjustment by an increase of 0.5 cm (up to 8cm) and a reduction by 0.5 cm (up to 4 cm)



Open Cat-stereograms



Closed Cat-stereograms

Figure 3. Modifications of the cat-stereograms card entailing the elimination of the middle part of cat pictures (open cat-stereograms)

Control group

The control group was not given any treatment during the two weeks training period. The participants in that group were only measured in the pre and post visits (i.e. day 1 & day 15).

Statistical Analysis

A planned contrast analysis of variance (ANOVA) was used to analyse the data. Several planned contrasts were made with an alpha level of 0.05: On day1, the 'distance' measurements (base-in range & the heterophoria size) in all the four groups were compared with all the 'distance' measurements on day15. In all four groups the 'near' measurements on day1 were compared with the 'near' measurement on day15. Furthermore, all the 'distance and near' measurements in all the four groups on day1 were compared to all the 'distance and near' measurements on day15, and all the distance measurements (both the day1 & day15 in combination) were compared with all the near measurements (both the day1 & day15 in combination).

A between group analysis was also performed, where the diploscope group, the cat-stereograms with modifications group and the standard cat-stereograms card group were individually compared with the control group. Moreover, the cat-stereograms with modifications group was compared to the standard cat-

stereograms card group, and the diploscope group was compared to both the cat-stereograms with modifications and standard cat-stereograms card groups. Finally all treatment groups in combination were compared to the control group.

Results

The data was screened for normality and two statistical outliers were removed. Consequently, the planned contrast ANOVA was performed using only 38 subjects.

Divergence range (base-in)

A close to significant interaction between the cat-stereograms with modifications group and the standard cat-stereograms group, on the distance base-in range variable was found (F (1,37)=3.857, p=0.058). The cat-stereograms with modifications group showed a training mean distance base-in range measure of 5.4^ (SD=1.28^) on day1 and a training mean distance base-in range measure of 5.6^ (SD=1.497^) on day15, giving a total mean increase of -0.2^ (SD=-0.216^; Figure 4). The standard cat-stereograms group showed a training mean distance base-in range measure of 5.9^ (SD=1.921^) on day1 and a training distance mean base-in range measure of 5.2^ (SD=1.327^) on day15, giving a total mean decrease of 0.7^ (SD=0.594^) post-training (Figure 4).

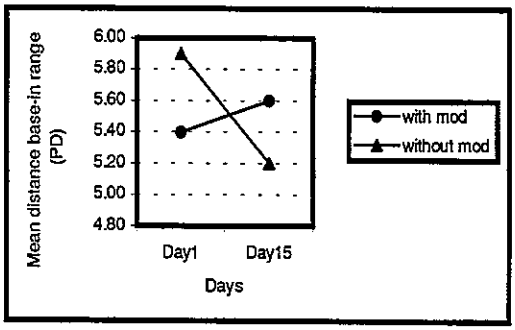


Figure 4. Significant interaction was found between the cat-stereograms with modifications group (with mod) and the standard cat-stereograms without modifications group (without mod).

Heterophoria size

A significant difference was found in the mean near heterophoria size pre and post training (F (1,37)=6.628, p=0.015). This significant change was found regardless of whether treatment was or was not given. That is, when compared to the mean distance heterophoria size post-training period, all three-treatment groups and the control group demonstrated an average increase in the mean near heterophoria (Figure 5). The groups showed a training mean near heterophoria measure of -1.42^ (SD=3.126^) on day1 and a training mean near heterophoria measure of -2.42^ (SD=3.023^) on day15, giving a total mean increase of 1^ (SD=0.103^) post-training (Figure 5).

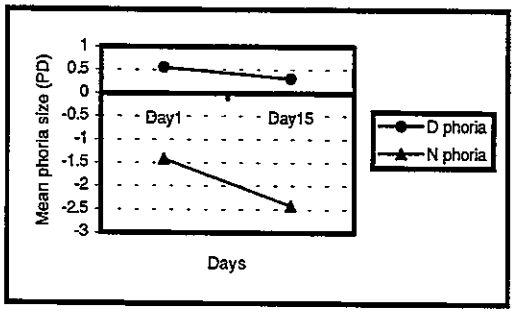


Figure 5. Change in the mean near heterophoria post-training period (D phoria=distance heterophoria; N phoria=near heterophoria)

A summary of the near heterophoria distribution across all experimental groups was attained to aid in finding a rationale to having had no overall treatment effect at the conclusion of the 2 weeks training period. The success of treatment is highly dependent on the types of the near heterophoria trained. Given that the treatments train divergence, esophorias would be the most successful treated heterophoria type. Orthophoric and exophoric types of heterophoria would be comparatively limited due to the smaller range available to diverge further. Figure 6 illustrates that the majority of participants clustered around the 0 line (i.e. orthophoric) or the -5^ line (i.e. exophoric) whereas only 4 participants showed an esophoric heterophoria type (Figure 6).

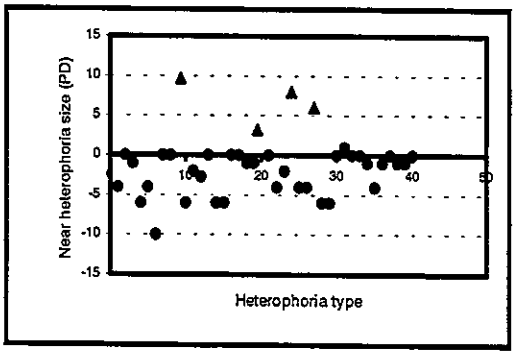


Figure 6. Summary of the near heterophoria distribution in all experimental groups

Single Case study

Three esophoric participants shown in figure 6 to measure more than 5^ of esophoria were considered closely as single case studies. The purpose of this was to observe any impact of the treatments those three participants trained during the 2-weeks period, on their near base-in range and heterophoria size.

Case study 1

Case study 1 participated in the diploscope group and was one of the outliers removed from the analysis. On day1, this participant presented with a near esophoria measurement of 10^ and on day15 following treatment presented with a near exophoria measurement of -2^ (Figure 7). Hence, there was a

total 12^ reduction in the participant's near esophoria size post training. Comparatively, the diploscope group, which presented with a near heterophoria mean of -2.63^ on day1 and a post near heterophoria mean of -2.88^ on day15, showed a mean increase of only 0.25^ (Figure 7).

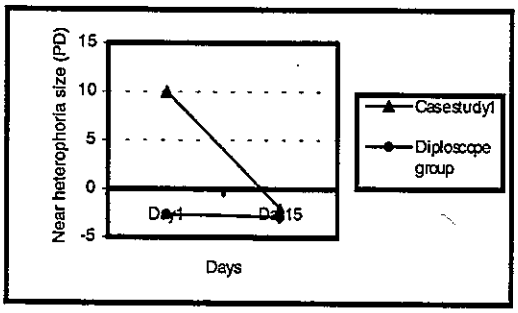


Figure 7. Change in the near heterophoria size in both case study1 and the diploscope group following training the diploscope treatment

Furthermore, case study 1 showed a change in the base-in range following the diploscope training. On day1 a base-in range measure of 12^ and on day15 base-in measure of 16^ were obtained. Hence, a total base-in range increase of 4^ was demonstrated following training (Figure 8). The total diploscope group, exhibited no mean change following training with the diploscope, given that it presented with the same mean base-in measurement of 13.5^ on both day1 and day15 (Figure 8).

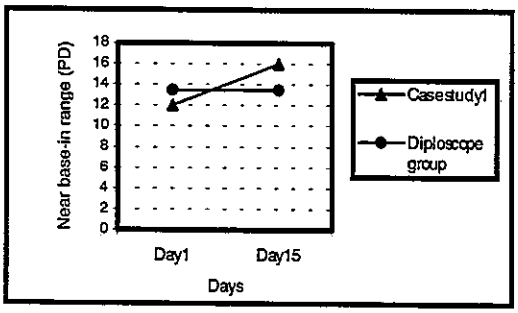


Figure 8. Change in the near base-in range of case study 1 and the diploscope group following training the diploscope treatment

Case study 2 & 3

Case study 2 and 3 represent the other two esophoric participants studied closely as single case studies. Both of these participants trained with the standard cat-stereograms without modifications card.

Case study 2 presented with near esophoria measurement of 8^ on day1 and a near esophoria measurement of 2^ on day15, demonstrating a total esophoria size reduction of 6^ following training (Figure 9). There was no change in the participant's base-in measurement, which was 6^, post training.

Case study 3 exhibited a near esophoria measurement of 6^ on day1 and a near esophoria measurement of 4^ on day15, signifying a total esophoria size reduction of 2^ (Figure 9). Equally, case study 3 did not show any change in the near base-in range, which measured as 10^, post training.

Comparatively, the standard cat-stereograms group, which presented initially with a mean near heterophoria measure of -1.2^ on day1 and a mean near heterophoria measure of -1.7^on day15, showed a total mean increase of 0.5^ post training period (Figure 9).

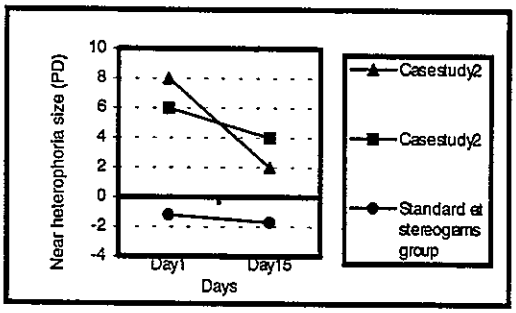


Figure 9. Change in the near heterophoria in case studies 2 and 3 and the standard cat-stereograms card following training the cat-stereograms without modifications card

Discussion

Overall, the current study did not find any significant difference in the base-in range or the associated heterophoria size following training with the diploscope or the standard cat-stereograms without modifications and the cat-stereograms with modifications card. The significant difference found in the near heterophoria in all experimental groups following treatments or no treatment given, could not be attributed to a specific reason in the literature. However, several authors6, 16, 19, 20, 21 have suggested that variability in the heterophoria measurement can occur due to different factors.

Schor6 suggested that, providing that the accommodative level is held fairly constant, heterophoria measurements can vary between 2^-3^ depending on the heterophoria measuring method used by the examiner6. Tracy16 observed that heterophoria measuring methods using similar methods of dissociation, for example flashing or prism dissociation, are more likely to report higher correlations than if different dissociation methods are used16. The method used in the current study (the von Graefe technique) would yield an overall good test-retest reliability with a coefficient greater than 0.9016 since it used prism dissociation which accordance to Tracy16 and accordingly, this method did not cause the variability in the near heterophoria observed in all groups.

Tracy16 also suggested that sources of error in measurement due to examiner and patient bias may cause variability in the near heterophoria. For example, errors in measurements caused by improper prism placement. Also variability could occur if the examiner overlooks small amounts of movements when assessing the near heterophoria when using a hand held prism.

In the present study the near heterophoria measurements procedure were kept as consistent as possible all through out the assessment of the four groups. This consistency was ensured as each measurement was taken three times in both day1 and day15 sessions. Nevertheless, it is possible that an uncontrolled for variation in the examiner technique could have occurred.

Variability in the near heterophoria size was also reported in the literature to occur following near vision stress. Few authors 19, 20 have shown that a near visual task (e.g. reading) that was either employed for 20 min18, or 90min20 lead to a near esophoric shift post task. According to Ehrlich20 this esophoric shift is in accordance with a current vergence theory that states "the vergence resting position moves closer following stress on the vergence system" (i.e. becomes more esophoric) 20.

The change in the near heterophoria in the current study was not in the esophoric direction. It instead showed an increase towards the exophoric direction, where orthophoric participants became exophoric, exophoric participants became more exophoric and esophoric participants became less esophoric post-training period. Therefore although the effect of near visual tasks on the near phoria was not controlled for in the study, it can be said that it had no direct effect on the participants near heterophoria due to having no esophoric shift evident post-training.

Therefore, it can be said that the significant change in the mean near heterophoria observed statistically in all four groups, is highly unlikely to be directly due to any of the factors discussed previously. The total mean difference of only 1^ (SD=0.103^) may not yield any clinical relevance. This total mean difference post training is most likely due to a chance occurrence.

A close to significant interaction between the cat-stereograms card with modifications group and the standard cat-stereograms card group was also found in the current study. The cat-stereograms card with modifications group, showed a total mean distance base-in range increase by -0.2^ (SD=-0.216^; Figure 4) post training. Conversely, the standard cat-stereograms card group demonstrated a 0.7^ (SD=0.594^; Figure 4) decrease in the mean distance base-in rang post training. These results signify that the cat-stereograms card with modifications group, showed better improvement due to the aid of the additional modifications applied to the card. The standard cat-stereograms card group, demonstrated a decrease in the distance mean base-in range following training, suggesting that the use of the cat-stereograms card without modifications might have created difficulties for the participants in achieving the third cat picture. This difficulty possibly may have lead the participants to achieve the third picture of the cat by way of convergence rather than divergence. That is, they exercised their eyes in the opposite direction to divergence and as a result their distance base-in range decreased.

The modifications applied in the cat-stereograms card group, has considered the participant's interpupillary distance (IPD). This factor, provided the participants in the cat-stereograms card with modifications group, an advantage over participants in the standard cat-stereograms card group, as the participants in the former group were able to begin training, using a cat-stereograms card with a distance between the two cats pictures, that is equivalent to their IPD. The latter group faced the dilemma of using the one card with the 6cm set distance between the two cat pictures, which in some cases exceeded the participant's IPD and created for them an obstacle in achieving the third cat.

Furthermore, the cat-stereograms card with modifications group had the middle part of the cat pictures removed (open cat-stereograms; Figure 3), which assisted the participants to achieve the third cat picture in an effortless fashion17. The standard cat-stereograms card group used the closed cat stereogram cards (Figure3), which contributed to making the task of achieving the third cat picture more difficult.

Principally the increasing in the distance between the two cats pictures in the cat-stereograms card with modifications group, facilitates the extension of the participant's divergence range through the extension of their negative relative fusion with the increasing of the card's IPD distances. The standard cat-stereograms card group trained using the set 6cm card IPD distance, which meant that achieving the third cat at that distance will not encourage any extension of the divergence range, it only improved the negative relative fusion of the participant at the that set distance.

Overall, the improvement shown in the cat-stereograms card with modifications group was only by -0.2^, and similarly the decrease in the standard cat-stereograms card group, was only by 0.7^. These results might not denote much clinical significance in either case, however, it does point towards a possible higher rate of success if additional modifications are applied to the card when training divergence.

The lack of change in the negative vergence and the associated heterophoria following training in the present study can be related to several factors. It is possible that the effect size of the two treatments was minor and possibly a larger sample size (n=>10/gp) might be needed to show greater treatment effect. A future study could allocate participants >10/gp and observe effect of divergence treatments on them.

The time spent in training the negative vergence (15 min/day) could have been insufficient. Similar studies have designated more time1, 3, 8, 13 and managed to achieve an improvement in the negative vergence range and the associated heterophoria size. Daum13 conducted a study using two participants for 45 min/day for 7 consecutive weeks, and suggested that at least 10-15 hours of divergence training is needed to achieve maximum effect. A future study may possibly increase both the duration (min/hrs) and training period (days/wks) for further treatment effect.

The time, at which the negative vergence and the associated heterophoria were assessed in relation to when the training was ceased, could have influenced the results obtained. Green11 and Daum3, 8 have observed an increase in the divergence range after a

certain period have passed since the termination of training. A follow up study may possibly be conducted after a certain period of time on the forty participants of the current study, to observe any increase in the base-in range or/and the associated heterophoria.

Green11 had recommended maximal training of the convergence amplitude, prior to training divergence for enhanced divergence treatment effect11. A future study could allocate two groups to train divergence in isolation in one group, and maximal convergence followed by divergence training in the other group.

Lack of participant's compliance with carrying out the treatments for the entire 2-week training period, may possibly have affected the results acquired. A future study may conduct all training sessions in clinic rather than to give treatments to participants take home to ensure total participant's cooperation.

Daum12 investigated two types of horizontal vergence training: smooth, slow and tonic activities and quick, stepwise, more phasic task, for 10 min/day for 3 consecutive weeks. The slow activities encompassed two training methods: a 'push up' method and variable vectograms12. The quick, phasic tasks included base-in or base-out prisms placed in trial holders and an aperture-ruler trainer. It was concluded that the quick, stepwise type of training demonstrated a larger improvement in both the positive and negative vergence training than the slow, smooth training12. Despite this conclusion Daum12 pointed out that the difference between the two methods is less than 5^ and may not be clinically significant and thus should not exclude smooth, slow and tonic training methods. The two training treatments used in the present study would be considered to be a slow, smooth and tonic type of treatments. It is a possibility that the application of quick and more phasic type of training such as base-in prism training may have produced a larger effect than the slow tonic methods used in the current study. However, Daum12's study did point out that insignificant difference exists between the two methods and clinically should not make a difference.

It may be of importance to point out, that although both the diploscope and the cat-stereograms card are considered to be slow and tonic type of training, they are fundamentally training two different aspects of the negative vergence system. The 'diploscope' trains the negative vergence via increasing the subject's voluntary ability to diverge (section 5.1). Concurrently, the 'cat-stereograms' encourages the participant to achieve greater divergence range through exercising their negative relative fusion with increasing the cat-stereograms card IPD distances. Therefore the difference in the mechanisms behind the two treatments may have a reason to not achieving treatment effect, however a further study is needed to investigate these aspects more thoroughly.

Belasco21 have suggested a selection and a matching approach when considering successful 'training' "changes associated with training may be improved dramatically through advanced selection of those individuals most likely to benefit from the given kind of training" 21. The most likely candidates to benefit from negative vergence training would be esophoric individuals than orthophoric or exophoric individuals14, 15, 17. Esophoric individuals have larger room for improvement particularly at near, as their visual axis is anatomically converged and should respond more readily to divergence treatment. Orthophoric and exophoric individuals face the 'ceiling effect' problem where they may not be able to exert further divergence beyond a certain point, due to their visual axis being limited anatomically.

In the current study, the three single case studies illustrated the possible success of negative vergence training in asymptomatic esophoric individuals. Following training using the diploscope treatment case study 1 showed an improvement in both the near heterophoria size and the near base-in range with the near heterophoria showing the most positive result. Case study 1 demonstrated a 12^ of total near esophoria reduction following diploscope training. In comparison, the entire diploscope group demonstrated a mean near heterophoria change of only 0.25^ (Figure 7). The change in case study's 1 near base-in range which showed a total difference of 4^ post training, is also notable, particularly when compared with the entire diploscope's group total mean change of 0^ (Figure 8). Therefore, the demonstrated change in both the near heterophoria and near base-in range of case study 1 signifies the extent to which the diploscope training could influence the negative vergence system of an esophoric individual.

Case studies 2 and 3 also showed some improvements their near heterophoria size following divergence training using the standard cat-stereograms card (Figure 9). Although the change in their near heterophoria following treatment was not as notable as case study 1, the change can still be considered noteworthy when compared with the entire standard cat-stereograms group's mean change of 0.5^. The difference is particular in case study 2 as they demonstrated a total near esophoria size reduction of 6^ post training (Figure 9).

Therefore the improvements in the near heterophoria size shown to be possible through the three single case closely studies, point towards a further training once the negative vergence is trained primarily in a group of esophoric participants. Moreover, these results advocate treatment success in reducing the amount of esophoria present, following the diploscope training, than when training the standard cat-stereograms card. Therefore it is essential for a future study to train divergence solely in asymptomatic esophoric participants using both the diploscope and the standard cat-stereograms to observe any changes in their negative vergences and their associated heterophoria. The training of the cat-stereograms with additional modifications may also be applied in this future study, to compare its effect to the other two treatments on both the measuring outcomes.

The lack of change in both the base-in range and the heterophoria size following training could also be attributed to the fundamental difference between divergence and convergence. Past research 1, 3, 5, 8, 9,

10, 11, 12, 13, 14, 17 have pointed towards fundamental differences between the negative and positive vergences, in that two different control systems or neural centres may exists for both of these horizontal vergences. Following training the negative vergence for 7 consecutive weeks, Daum10 observed that change in the negative vergence is still smaller in magnitude when compared to what is achieved following positive vergence training10. Daum10 concluded that this fact suggests fundamental differences between both positive and negative vergences. Therefore, it is a possibility that no matter how much negative vergence training is applied; the divergence magnitude may not be able to reach the same magnitude achieved by positive vergence training. However, continued research in the area is needed to satisfactorily reach a conclusion to that effect.

Lastly, it is also possible that the diploscope and cat-stereograms treatments do not have any effect whatsoever and may not be a wise choice in the clinical setting to aid in training the divergence range or the associated heterophoria size. However, a conclusion cannot be reached to their clinical irrelevance until a future study investigating esophoric participants using the same treatments is conducted and no training effect is achieved such as in the current study.

Conclusion

Although the current study did not demonstrate any treatment effect following divergence training, previous work in the area 1, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 16 have shown an increase in the divergence range and the associated heterophoria following negative vergence training. However, the magnitude of change achieved has always been much less than what can be achieved training the positive vergence. Therefore, the training in the current study does not necessarily represent the maximum to which the negative vergence can be changed, particularly when several possibilities have been put forward which may suggest room for improvement.

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Effect of whiplash injury on contrast sensitivity

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Abstract

The aims of this study were to compare the results of the measurement of distance visual acuity and contrast sensitivity for whiplash injured subjects and control subjects. A total of 35 whiplash subjects (mean age: 38 yrs, range 19-79 yrs; 71% female) and 72 control subjects (mean age: 35 yrs, range 18-62 yrs; 79% female) were examined. Measurements of uniocular distance visual acuity and uniocular contrast sensitivity were taken. There was no difference in visual acuity between the whiplash and control group subjects. There was a statistically significant reduction in contrast sensitivity in the mid to high spatial frequency range for the right eyes and in the mid spatial frequency range of left eyes of the whiplash subjects compared to the control subjects. These results indicate that an aspect of visual function (contrast sensitivity) was effected by whiplash injury.

Key words

Vistech Contrast Sensitivity Test System

Introduction

A variant of whiplash injury, the 'railway spine' was observed in railway passengers involved in train accidents in the 19th century.[1] The actual term 'whiplash' was apparently coined by Crowe[2] in 1928. Over the years various other terms such as 'acceleration injury', 'deceleration injury', and hyper-extension injury' have been used to describe this phenomenon, but whiplash has remained the most widely accepted descriptor.[3] There have also been a variety of bio-mechanical explanations of whiplash. However, the current view of the sequence of events leading to a whiplash injury is following a collision to the rear end of a car, the lower part of the victim's back is thrust forward and the head is thrown back causing hyperextension of the neck. The head is then thrown forward causing flexion of the neck. In addition to damage to neck structures,[3] whiplash has been shown to cause brain damage[4] and retinal changes.[5]

Visual and ocular disturbances following a whiplash injury have been numerous, but difficult to explain because by their very nature they manifest as subjective symptoms which cannot be demonstrated with objective testing. These symptoms have been attributed to: vascular disturbances;[2,6,7] stimulation of the cervical sympathetic pathway;[8,9] and impaction of the midbrain.[10,11]

Retinal damage, such as that caused in the 'shaken baby' syndrome, where it was hypothesized that the force of the whiplash caused macular changes has been reported.[5,12] Vitreous and retinal disturbances following a whiplash injury have also been published.[12,13,14,15,16]

In spite of common reports of visual disturbances, distance visual acuity has not been considered to be affected by whiplash.[10,15,17,18,19] With the exceptions of Daily[13] and Kelley et al.,[16] no evidence of defective visual acuity following a whiplash injury could be found in the literature. As with other ocular functions described by early investigators,[10,15,17,18,19] few details of the tests of visual acuity performed have been reported, and no comparison was made with a control group of normal subjects.

Research has demonstrated that standard visual acuity measurement does not test the majority of cells in the human visual system.[20] Following work by Arden,[20] contrast sensitivity testing has been used to examine loss of visual function not previously detected by measurement using standard vision test types. When a test requires the recognition of varying contrasts and spatial frequencies, a plot of visual performance (contrast sensitivity curve) can be determined. This involves the measurement of the subject's visual sensitivity to large, medium and small objects (spatial frequencies) under circumstances of varying contrast. The shape of the contrast sensitivity curve is dependent on the optical, retinal and neural properties of the visual system.[21]

Arden and Jacobson[22] found a reduction in contrast sensitivity in subjects with early glaucoma. Similarly in subjects with multiple sclerosis, Regan et al.[23] found a reduction of contrast sensitivity function was associated with normal or near normal visual acuity. Findings such as these have led to the conclusion that losses in differing ranges of the contrast sensitivity curve may be indicative of a particular type of loss, be it of a neurological, retinal pathological or optical origin. For example, a loss in the low spatial range has been shown in some cases of Alzheimer's disease.[24] A mid to high range loss has been found in some

pathological conditions such as macular and retinal disease[25] and a visual loss due to a simple uncorrected refractive error will be more marked in the high frequency range.[26]

The literature reports[16] that in the cases of retinal damage resulting from a whiplash injury there was almost total recovery suggesting that tests to detect such defects will need to be sensitive to minimal dysfunction. Consequently only specialized procedures are capable of detecting such a retinal lesion. Contrast sensitivity testing has been found to be effective in detecting visual dysfunction caused by ocular pathology before any retinal lesion is visible using ophthalmoscopy.[24] There has been no study which has investigated visual acuity and contrast sensitivity in subjects with whiplash injury. Therefore the aims of this study were to test distance visual acuity and contrast sensitivity of a group of whiplash subjects and compare the results with those of a control group of subjects.

Method

Whiplash Subjects

The criteria for subject inclusion in the study were: diagnosed whiplash injury by a physiotherapist or orthopaedic surgeon and no other head injury that would result in neurological damage.

A total of 35 subjects with a whiplash injury were tested in this study. All subjects had sustained a whiplash injury as a result of a motor vehicle accident. All subjects complained of neck pain and 24 of them complained of ocular or visual symptoms (Table 1). Some subjects had more than one symptom. The subjects' ages ranged from 19 years to 79 years. The mean age was 38 years. There were 25 females and 10 males.

Table 1 Symptoms of ocular disturbances reported by subjects in the whiplash group.
N = number of subjects with each disturbance.

Symptoms of visual and ocular disturbances	N
Intermittent blurred vision	15
Photophobia	7
Pain in & around eyes	4
Intermittent double vision	2
Stinging/burning sensation	2
Vision "comes and goes"	2
Print "jumping"	1
Flashes of white light at time of impact	1
"Blind spots" when reading	1
Worried by "things coming close"	1

Control Subjects

Seventy-two subjects participated as the control group for this study. None of the subjects had a history of a neck or whiplash injury. Their ages ranged from 18 years to 62 years. The mean age was 35 years. There were 57 females and 15 males.

Assessment of distance visual acuity

Each subject's distance visual acuity was measured using the Mentor B-Vat Monitor as the stimulus. A uniocular test of visual acuity was performed on each subject. The criterion for correctly reading a particular line of letters was that the subject should make no more than two errors. Normal distance visual acuity was considered to be 6/6 or better.

It was not within the scope of this study to determine whether subjects were tested with their optimal optic correction. Therefore, subjects were tested in their normal viewing situation ie without corrective lenses or with the corrective lenses normally worn for distance viewing. Where subjects presented without corrective lenses, they were tested without them.

Assessment of contrast sensitivity

A uniocular test of contrast sensitivity was performed using the Vistech Contrast Sensitivity Test System (VCTS) 6500 wall chart at three metres. The chart consists of five horizontal rows (A-E). On each row are nine circular sine wave grating patches. The gratings are displayed vertically, or tilted 15f in a clockwise or anti-clockwise direction. Each grating patch in a given row has the same spatial frequency: Row A is 1.5 cycles per degree (cpd); Row B is 3 cpd; Row C is 6 cpd; Row D is 12 cpd, and Row E is 18 cpd. While the spatial frequency per row remains constant, the contrast sensitivity decreases across the rows in 0.12 log unit steps from patch one to patch eight. Patch nine in each row is blank.

Care was taken to ensure that the chart was uniformly lit. The subjects were instructed to report the direction of the stripes on each of the eight patches in rows A to E. The contrast threshold level was recorded as the contrast prior to the first reported blank or incorrect response.

Statistical analysis

A descriptive analysis of the visual acuity results is given. The means and standard deviations were calculated for all contrast sensitivity scores for both the whiplash and control group subjects. T-tests were used to compare the means of the contrast sensitivity scores of the whiplash and control group subjects. The significance level was set at 0.05.

Results

Assessment of distance visual acuity

The right and left distance visual acuity was obtained from 35 whiplash subjects (note that one whiplash subject had vision in only one eye). Corrective lenses for distance viewing were prescribed for 14 (40%) of the whiplash subjects. The range of the optical correction, expressed as the spherical equivalent was from +2.375 D to -6.50 D for the right eye and from +2.75 D to -7.50 D for the left eye. Except for one subject (R. -7.00/+1.00x175; L. -8.00/+1.00x65), the optical correction of all subjects was within the range of the control group.

The right and left visual acuity of 72 control subjects was measured. Corrective lenses were prescribed for 30 (42%) of the subjects. Five subjects (7%) presented without their corrective lenses and were tested without them. Four subjects wore contact lenses. The strength of the lenses was not known.

Therefore, the range of the optical correction, expressed as the spherical equivalent was from +3.50 D to -5.00 D for the right eye and from +3.50 D to -5.75 D for the left eye.

The results of the right and left distance visual acuity testing are shown in Table 2. It can be seen from the table that the percentage of subjects with normal (6/6 or better) visual acuity was greater in the whiplash group than in the control group. Clearly there was no difference between the visual acuity of the right or left eyes of the whiplash group subjects compared with the control group subjects.

Assessment of contrast sensitivity

The contrast sensitivity of the right and left eyes of 35 whiplash and 72 control subjects was assessed (note that one whiplash subject had vision in only one eye).

As can be seen from Table 3 and Figure 1, the mean scores of the whiplash group subjects are consistently below those of the control group subjects. The reduction in contrast sensitivity is particularly evident in the mid to high spatial frequency range (Rows C, D and E) where there was a significant difference.

As with scores from the right eyes, the mean scores of the whiplash group subjects are consistently below those of the control group subjects (Table 4, Figure 2). This is particularly evident in the mid frequency range (Rows C and D) where there was a significant difference.

Discussion

The results of the present investigation showed no significant reduction in distance visual acuity of the whiplash subjects compared to the control group subjects. This finding is in agreement with those authors who considered distance visual acuity to be unaffected by a whiplash injury[10,15,17,18,19] and suggests that distance visual acuity is not significantly disturbed by a whiplash injury.

Contrast sensitivity testing has enabled detection of visual deficits in conditions where traditional visual acuity tests have failed.[27] When considering the results of contrast sensitivity testing, it is important to know that while a diagnosis of specific ocular disorders cannot be made on results of contrast sensitivity testing alone, they may show as an isolated loss of spatial frequency in a particular range.

In this study, there was an overall decrease in the contrast sensitivity curve of the whiplash subjects compared with the control subjects with the loss being most marked in the mid frequency range of the whiplash subjects which was statistically significant. These findings may be indicative of subtle retinal pathology.

Daily[13,14] and Kelley et al.[16] reported three cases who following whiplash injury had retinal/vitreous disturbance resulting in reduced distance visual acuity (ie less than 6/6). A vitreous abnormality was observed by Daily[13] in one case and Kelley et al.[16] described 2 cases with subtle retinal changes associated with reduced distance visual acuity. The

Table 2 Right and left distance visual acuity of whiplash and control subjects. N = the total number of subjects in a specific group.

Visual Acuity	whiplash subjects N=35 (100%)	control subjects N=72 (100%)	whiplash subjects N=34 (100%)	control subjects N=72 (100%)
6/4.5	13(37%)	31(43%)	11(32%)	27(37.5%)
6/6	14(40%)	27(37.5%)	16(47%)	30(42%)
6/75	4(11%)	5(7%)	4(12%)	5(7%)
6/9	2(6%)	3(43%)	1(3%)	6(83%)
6/10	2(6%)	0	0	1(13%)
6/12	0	1(13%)	1(3%)	0
6/15	0	1(13%)	0	1(13%)
6/20	0	1(13%)	1(3%)	0
6/24	0	0	0	1(13%)
6/30	0	1(13%)	0	1(13%)
6/60	0	2(3%)	0	0

Table 3. Means, standard deviations and p values of the contrast sensitivity scores of the right eyes of the whiplash and control subjects. * significant difference

Row	RE Mean (SD) cpd	RE Mean (SD) cpd	
A	5.40 (± 0.81)	5.75 (±0.8884)	0.051
B	6.00 (± 0.84)	6.29 (±0.99)	0.140
C	5.00 (± 1.11)	5.56 (±1.43)	0.046*
D	4.27 (± 1.60)	5.13 (±1.68)	0.012*
E	3.11 (± 1.75)	4.04 (±1.92)	0.018*

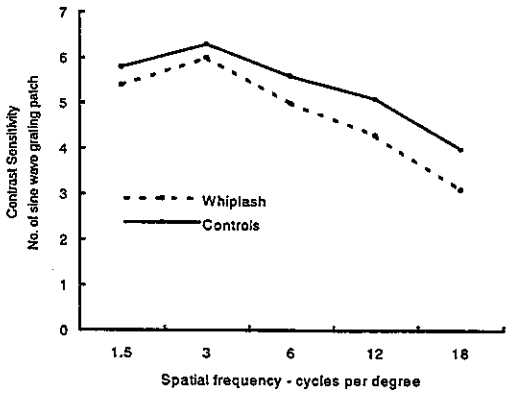

Fig. 1 Mean values of contrast sensitivity for each spatial frequency of the right eye of each subject in the whiplash and the control groups.

Table 4. Means, standard deviations and p values of the contrast sensitivity of the left eyes of the whiplash and control subjects. * significant difference

	Whiplash	Control	
Row	Mean (SD)	Mean (SD)	P values
A	5.53 (± 0.75)	5.67 (± 0.81)	0.4041
B	6.03 (± 0.63)	6.29 (± 0.88)	0.1217
C	5.00 (± 1.02)	5.71 (± 1.23)	0.0042*
D	4.27 (± 1.56)	5.00 (± 1.67)	0.0325*
E	3.24 (± 1.62)	3.82 (± 1.75)	

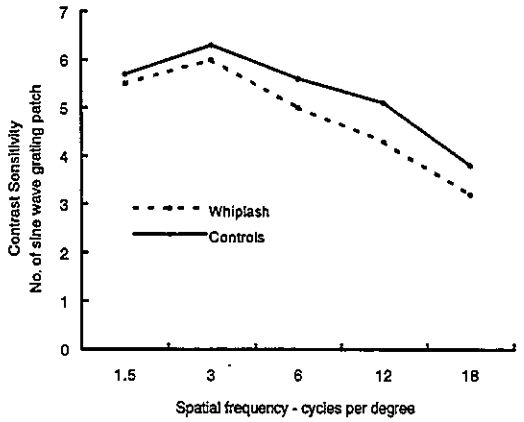

Figure. 2 Mean values of contrast sensitivity for each spatial frequency of the left eye of each subject in the whiplash and the control groups.

visual acuity improved in all cases to normal (6/6) within two weeks, while the retinal abnormalities remained observable. These authors hypothesized that the force of the whiplash caused traction on the macula by the vitreous creating a foveal pit[16] or that the lesion was the result of ocular and cranial concussion.[13]

If the retinal damage caused the reduced contrast sensitivity in this series, it might be expected that the damage might be uniocular or that there might be and inter-ocular difference as was the case in the majority subjects in this small series. In seven cases there was no reduction of contrast sensitivity. Of the 28 subjects with reduced contrast sensitivity, there was a difference between the eyes in 22 subjects (72%). Of these 22 subjects nine subjects had contrast sensitivity which was normal in one eye but reduced in the other eye, and in 19 subjects there was a reduction in both eyes with one eye being more effected than the other in 13 subjects.

This series differs from those of Daily[13] and Kelley et al[16] as all subjects in this study were tested months after the accident, and only 16 subjects had had a fundal examination. It is therefore not known if any of these subjects resembled those described by Daily[13] and Kelley and co-workers.[16]

However, it could be hypothesised that the force of the whiplash caused either vitreous or retinal damage that resolved sufficiently for the fundus to be judged as normal, in those examined, leaving a sub-clinical deficit which can only be detected by a sensitive test such as contrast sensitivity. As all subjects had normal visual acuity, it could be argued that the deficit was not of an optical nature. However without more detailed testing eg electro-retinogram (ERG) it is not possible to make a definitive diagnosis.

While it is not possible to specifically identify the reduction in the contrast sensitivity without more detailed testing, these results do indicate that an aspect of visual function (contrast sensitivity) was effected by whiplash injury. This finding may help to explain some of the visual disturbances reported by some whiplash suffers which until now have not be detected by a test of visual acuity.

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Vision Impairment in Australian Children

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Abstract

The Child and Family Services (CAF) Section of the Royal Blind Society (RBS) provides services for children and adolescents with a vision impairment throughout NSW and the ACT. Between January 1990 and December 1998, 1768 new referrals were received for clients aged between 9 days and 19.2 years.

This study was designed to determine the major causes of vision impairment, and subsequent referral to CAF, during this 9 year period. Results show that there is often more than one cause for impaired vision, with 120 primary and 35 secondary conditions being identified. The primary diagnoses have also been grouped according to the World Health Organisation (WHO) classifications for children with blindness and low vision.

Other areas addressed in this study, with relationship to the primary ocular diagnosis, include gender, age at referral, length of required RBS intervention, last recorded level of vision, and the most common secondary ocular associations. Additionally, the orthoptist's role with children who have a vision impairment is discussed.

Keywords: Vision impairment, children, Royal Blind Society, primary condition, secondary association, length of service, referral age, visual acuity, orthoptist, orthoptic assessment.

Introduction

'Visual impairment is the consequence of a functional loss of vision, rather than the eye disorder itself' (1). In 1995, the World Health Organisation (WHO) estimated that, globally, 1.5 million children were blind, a total of 5 million children were visually disabled and that 3.8% of blind people were aged between 0 and 14 years (2). In 1993, the Australian Bureau of Statistics (ABS) estimated that 0.4% of all Australian children aged less than 15 years were blind or vision impaired (3). In the USA, visual impairment occurs in 1% of individuals under the age of 18 years (4).

The causes of vision impairment vary from place to place, between more developed and less developed countries, urban versus remote areas. World-wide, 90% of children who are blind live in developing countries (5), with 80% of blindness reported to be avoidable, preventable or curable (2) (6). Mortality rates are often high in conditions that have secondary blindness (7). In third world countries, preventable causes of blindness predominate (for example cataract, Vitamin A deficiency and trachoma) whereas in developed countries, non-preventable causes, such as retinopathy of prematurity (ROP), cortical vision impairment (CVI) and optic nerve hypoplasia prevail (7).

In Australia, there is no centralised national or state register for blindness or partial sight (8). Data can only be compared to previous findings within agencies recognised for the rehabilitation of people who are blind or vision impaired, such as the Royal Blind Society (RBS) in New South Wales. The Child and Family Services (CAF) section of RBS provides assistance to children, from birth to approximately 18 years of age and their families, throughout NSW and the ACT. Early childhood intervention and school-aged services are offered via a team of orthoptists, physiotherapists, occupational therapists, psychologists, social workers and early childhood special education teachers. From computer database statistics, the average number of new referrals in the1980s to CAF each year was 137, with this figure increasing to 196 per year in the 1990s.

In order to determine current causes of vision impairment amongst a paediatric Australian population, data was collected from RBS. The current study identifies the ocular reasons for referral to CAF between January 1990 and December 1998, for children and adolescents aged between 9 days and 19.2 years. Additionally, the role of the orthoptist with children who are vision impaired is discussed.

Method

Details of 1768 new CAF referrals over the specified 9-year period were obtained from the computer database. It should be acknowledged that RBS service provision for each child was not continuous over the entire 9 years, but rather was received at intermittent periods. The length of service provision was noted as well as the primary ocular diagnosis and level of visual acuity at the time of discharge. Associated, or secondary, ocular conditions were also recorded. The difference between the child's age and the time of initial referral was evaluated in order to determine whether certain conditions were referred at an earlier age than others. If the gender of the child was not on the database, it was inferred, where possible, by the child's first name. At the time of discharge from RBS services, confirmation was given as to whether the original ocular condition at referral was the true cause of the child's vision impairment. Not all clients could be included in each area of data analysis due to missing information, for example, no date of birth or primary ocular diagnosis.

For inclusion in this study, the minimum age of nine days was selected as this was considered to be the youngest feasible age for referral of a child.

Additionally, it was felt that any ages listed as younger may have been computer database errors. The uppermost age relevant for adolescent services was 19.2 years as, at RBS, young people are transferred to the adult service area upon leaving school. Beyond these age limits, there was a decline in the number of cases.

When more than one ocular condition had been cited as a cause of vision impairment, they were ordered into 'primary' and 'secondary', for example, in one case of optic atrophy and cortical vision impairment, optic atrophy was considered to be the primary cause of the vision impairment. Some children had non-specific causes of vision loss recorded, such as eye muscle problem or tracking problems - in these cases, no primary diagnosis was recorded. Additionally, some conditions entered on the database were quite specific, for example, corneal dystrophy, corneal disease, corneal transplant. If listed in this way, each was counted as a separate diagnosis, rather than under the heading 'cornea', leading to a large number of overall diagnoses being cited. The recorded frequency of other conditions, such as myopia, may be a misrepresentation of their true frequency, as they are often part of a general syndrome, such as myopia with Marfan's Syndrome.

In total, 120 primary and 35 secondary singular conditions were identified. Each of these was coded, with the primary conditions also grouped under headings employed by WHO in its Programme for the Prevention of Blindness (PBL) (9) (Table 1). Only the ten most frequently occurring causes of visual impairment (referred to as 'Ungrouped') were analysed in this current study, due to the large number of primary conditions. The ten most common areas identified using the WHO/PBL classifications will be referred to as 'WHO Groups'.

Visual acuity results were graded according to those limits used by WHO/PBL (9) (Table 2). This study used the best recorded level of vision as its measurement, for example, if one eye was 6/6 and the other eye blind, 6/6 was recorded. In cases such as these, the child still has functional vision, despite the apparent 'vision impairment'.

Table 1: WHO (PBL) Classifications.

Classifications Employed by World Health Organisation (WHO) in its Programme for the Prevention of Blindness (PBL).

Whole Globe (phthisis, anophthalmos, microphthalmos, buphthalmos, glaucoma, removed, disorganised, other);
Cornea; Lens; Uvea; Retina; Optic Nerve;
Globe appears normal (refractive error, cortical blindness, nystagmus, amblyopia);
Other (trauma, ocular muscle involvement, field loss, squint, syndrome and tumour).

Table 2: WHO Visual Acuity Categories.

WHO Visual Acuity Categories

1 = 6/6 - 6/18 2 = <6/18 - 6/60 3 = <6/60 - 3/60
4 = <3/60 - PL 5 = no light perception

Results and Discussion

Primary Conditions and Number of Cases

Results show that the most common 'Ungrouped' conditions accounted for over half (966 children) of the referrals received during the 9-year period (Table 3). The most commonly referred cause of vision impairment was CVI (9.4%), followed by cataract.

Table 3: Ten Most Common Primary Conditions Identified.

UNGROUPED

PRIMARY OCULAR CONDITION	NO. OF CASES	% OF ALL CASES
Cortical Vision Impairment (CVI)	159	9.4
Cataract	155	9.2
Nystagmus	129	7.6
Optic Atrophy	120	7.1
Myopia	98	5.8
Ocular Albinism	71	4.2
Retinopathy of Prematurity (ROP)	70	4.1
Hypermetropia	61	3.6
Oculocutaneous Albinism	54	3.2
Retinitis Pigmentosa	49	2.9
TOTAL	966	57.1

Under WHO classification (Table 4), retinal problems were the main reason for referral,

accounting for almost two and a half times more children than that of CVI in the non-grouped categories (Table 3). This contrast in figures is due to 29 conditions coming under the heading of 'retina'.

Globally, trachoma is still the main global cause of preventable blindness amongst all ages. It is estimated that 146 million people have this active disease, with 10 million having trichiasis and 6 million being blind (2). Vitamin A deficiency is considered to be the leading cause of childhood blindness (1995) (4). Neither trachoma nor Vitamin A deficiency were identified causes for referral from the database.

Table 4: Primary Conditions as per WHO Grouping.

WHO GROUPS

PRIMARY OCULAR CONDITION	NO. OF CASES	% OF ALL CASES
Retina	365	21.6
Optic Nerve	176	10.4
Refractive Error	156	9.2
Lens	150	8.9
Cortical Blindness	133	7.9
Nystagmus	119	7.0
Uvea	59	3.5
Whole Globe	39	2.3
Syndrome	38	2.2
Cornea	32	1.9
TOTAL	1267	74.9

It has been observed, world-wide, that CVI is becoming more prevalent (1994) (4). By comparing this current study to another performed at RBS for the period 1980-1989 (10) (Table 5), it can be seen that there has been a slight decrease in the number of

children referred with CVI. In the developed world, congenital cataract, when appropriately managed, is the only cause of visual defect to have recently (1994) shown a decrease in prevalence (4), which is also reflected in Table 5. A USA study in 1980 estimated that prenatal cataract was the leading cause of legal blindness among children under 5 years of age (4). A further study in 1996 found the most common cause of vision impairment in children aged 0-5 years to be ROP (4).

Table 5: Comparison of Referral Conditions Between 1980-1989 RBS Study and 1990-1998 RBS Study.

1980 - 1989	1990 - 1998
CVI 12.3%	CVI 9.4%
Cataract (not Rubella) 12.0%	Cataract 9.2%
Optic Atrophy 10.3%	Nystagmus 7.6%
Albinism 7.0%	Optic Atrophy 7.1%
ROP 6.0%	Myopia 5.8%
Congenital Nystagmus 3.6%	Ocular Albinism 4.2%
Glaucoma 3.0%	ROP 4.1%
Coloboma 3.0%	Hypermetropia 3.6%
Microphthalmia 3.0%	Oculocutaneous Albinism 3.2%
Optic Nerve Hypoplasia 2.7%	Retinitis Pigmentosa 2.9%

Verification of Primary Diagnosis

Of the 1692 cases in this study with a primary cause identified, 72.8% had had the ocular condition verified by the time of discharge. The most readily confirmed condition was Ocular Albinism (87.1%), followed by Oculocutaneous Albinism (85.2%) and ROP (80%). 'Hypermetropia', as a primary diagnosis, was the least verified condition. Although it is one of the main reasons for referral, CVI appears to be one of the more difficult conditions to confirm (68.6%).

Primary Conditions and Gender

Results showed that 58.6% of clients were male and 41.4% were female. These proportions are also reflected in the number of Australian people with a primary vision impairment who receive disability support from the government, whereby 58% are male and 42% female (1997) (11).

With regard to the Ungrouped conditions, the number of males outweighed that of females in each condition, except for ROP (Table 6).

Table 6: Distribution of Gender in the Ungrouped Primary Conditions.

PRIMARY CONDITION	MALE (%)	FEMALE (%)
CVI	64.8	35.2
Cataract	51.6	48.4
Nystagmus	66.4	33.6
Optic Atrophy	60.2	39.8
Myopia	64.3	35.7
Ocular Albinism	60.6	39.4
ROP	48.6	51.4
Hypermetropia	57.4	42.6
Oculocutaneous Albinism	70.4	29.6
Retinitis Pigmentosa	53.1	46.9

Length of Service

Those clients still receiving the services of RBS at the conclusion of this study were not included in the summary. As shown in Table 7, those children with ROP as their primary diagnosis required the longest average period of service, that is, 2 years per child. This condition also demonstrated the broadest variation in the amount of RBS service provision for each individual, ranging from 0.7 months to 95.7 months duration. When the length of service was considered using the grouped WHO headings (Table 8) conditions affecting the whole globe required the greatest average length of service per child (1.8 years). Retinal problems displayed the greatest range of required intervention, with one child needing only two weeks through to another who was a client of RBS for 8.3 years. The short duration of RBS intervention for some of these conditions may be due to the child receiving services from other sources or agencies.

Table 7: Length of Service for Ungrouped Primary Conditions.

	UNGROUPED	
PRIMARY CONDITION	RANGE OF LENGTH OF SERVICE (MONTHS)	AVERAGE LENGTH OF SERVICE (MONTHS)
ROP	0.7 - 95.7 (7.9 years)	23.6 (2.0 years)
Oculocutaneous Albinism	0.9 - 87.2 (7.2 years)	21.8 (1.8 years)
Ocular Albinism	0.5 - 66.4 (5.5 years)	17.3 (1.4 years)
Optic Atrophy	1.0 - 68.0 (5.6 years)	14.6 (1.2 years)
CVI	1.0 - 45.4 (3.7 years)	14.2 (1.2 years)
Cataract	0.1 - 89.2 (7.4 years)	11.9 (1.0 years)
Retinitis Pigmentosa	1.3 - 37.4 (3.0 years)	11.2 (0.9 years)
Nystagmus	0.7 - 65.1 (5.4 years)	9.4 (0.8 years)
Myopia	0.4 - 37.8 (3.1 years)	6.1 (0.5 years)
Hypermetropia	0.2 - 27.8 (2.3 years)	4.7 (0.4 years)

Table 8: Length of Service for WHO Grouped Conditions.

	WHO GROUPS	
PRIMARY CONDITION	RANGE OF LENGTH OF SERVICE (MONTHS)	AVERAGE LENGTH OF SERVICE (MONTHS)
Whole Globe	0.2 - 80.6 (6.7 years)	21.1 (1.8 years)
Uvea	0.5 - 70.2 (5.8 years)	20.9 (1.7 years)
Retina	0.5 - 100.1 (8.3 years)	17.9 (1.5 years)
Optic Nerve	0.1 - 68.0 (5.7 years)	14.8 (1.2 years)
Cortical Blindness	1.0 - 45.4 (3.7 years)	14.2 (1.2 years)
Syndrome	1.5 - 90.0 (7.4 years)	12.9 (1.1 years)
Lens	0.7 - 89.2 (7.4 years)	12.1 (1.0 years)
Nystagmus	0.7 - 65.1 (5.4 years)	9.4 (0.8 years)
Cornea	1.1 - 18.2 (1.4 years)	6.1 (0.5 years)
Refractive Error	0.2 - 37.8 (3.1 years)	5.4 (0.5 years)

Age at Referral

CVI and ROP were both referred within a comparable age span (2 months to 200 months), with the same average age at referral (3 years). Retinitis Pigmentosa showed to be referred at a much later age, which reflects the nature of this particular condition (Table 9).

Table 9: Range of Age and Average Age at Referral for Ungrouped Primary Conditions.

PRIMARY CONDITION	RANGE OF AGE AT REFERRAL (MONTHS)	AVERAGE AGE AT REFERRAL (MONTHS)
CVI	2 - 202	35.7 (3.0 years)
ROP	2 - 197	36.8 (3.1 years)
Oculocutaneous Albinism	9 days - 177	49.9 (4.2 years)
Cataract	16 days - 208	58.7 (4.9 years)
Ocular Albinism	2 - 213	62.3 (5.2 years)
Nystagmus	3 - 190	79.7 (6.6 years)
Hypermetropia	10 - 188	79.9 (6.7 years)
Optic Atrophy	3 - 214	83.6 (7.0 years)
Myopia	4 - 216	103.1 (8.6 years)
Retinitis Pigmentosa	25 - 216	118.6 (9.9 years)

Secondary Conditions and Their Association with Primary Conditions

Squint was the most common secondary association identified, followed by nystagmus (Table 10). When analysing these results further, there appears to be co-morbidity of some primary and secondary disorders. Myopia and cataract had the greatest number of secondary associations and oculocutaneous albinism the least number. Myopia was often noted with astigmatism and nystagmus, whilst cataract was most linked with glaucoma. In other studies, it has been reported that CVI often exists with ROP (12). It has also been documented that CVI, ROP and optic nerve hypoplasia have high rates of associated systemic multiple impairments (7). In the present study, CVI was most often associated with optic atrophy.

Table 10: Most Common Secondary Ocular Conditions.

SECONDARY CONDITION	NUMBER OF REPORTED CASES
Squint	61
Nystagmus	59
Astigmatism	48
Myopia	37
CVI	29
Microphthalmos/Microcornea	21
Hypermetropia	20
Glaucoma	19
Cataract	19
Amblyopia	15
Field Loss	14
Blind Other Eye	11

Levels of visual acuity

Visual acuity was analysed in two ways. First, by a recorded result, however, it can be difficult to gain a measurement in some conditions, such as CVI, and often only a subjective summation can be gained from clinical observation. Second, the range of vision for each condition was obtained.

i) Recorded Visual Acuity

At the time of discharge, 66.6% of cases had a recorded level of vision. Of those Ungrouped conditions, CVI was the only one in which the majority of children were not able to have a recorded measurement. Myopia was the condition for which most children had a recorded visual acuity, followed by nystagmus. Under WHO classifications, nystagmus was more likely to have a visual acuity obtained. A high percentage of those children with a problem of the 'Whole Globe' also showed a measurable level of vision. This high proportion may be explained if the ocular problem only pertained to one eye, allowing the best level of vision from the 'sound eye' to be noted.

ii) Range of Vision

CVI was the condition with the most evenly widespread levels of vision. The majority of Ungrouped conditions had levels of vision ranging between the bands of '6/6-6/18' to 'Light Perception'

(Table 11). Over half (57%) of those children with a cataract had vision ranging from '<6/18-6/60', however, 94% had a visual acuity that was 6/60 or better. Only 49.2% of children with CVI had 6/60 or better, with the majority (36.9%) having vision of '<3/60- Light Perception'. All cases with retinitis pigmentosa had vision of 6/60 or better (Table 11). Within the WHO Groups, visual acuity, in the majority of conditions, extended to No Light Perception.

The visual acuities found in children with CVI cover a broad spectrum of levels. This is supported by Crossman (13) who categorised vision in CVI as "sees beyond 1 metre with visual-perception problems remaining" to "no apparent vision". Crossman also stated that "vision tends to fluctuate, being influenced by such factors as fatigue, a noisy or unfamiliar environment, medication, illness and seizures. Fluctuations can be from hour to hour or day to day". Additionally, "peripheral vision appears to be more functional than central". Taylor and Hoyt (14) suggest that a form of 'blindsight', "a preservation of visual functioning in a defective visual field", may be responsible for the relatively good navigational skills of a child with severe cerebral blindness.

Table 11: Range of Visual Acuity in Ungrouped Conditions.

UNGROUPED		
PRIMARY CONDITION	**VISION OF MAJORITY**	**RANGE OF VISION**
Cataract	94%: 6/60 or better Maj.:57%: <6/18-6/60	6/6-6/18 - No LP
CVI	49.2%: 6/60 or better Maj.:36.9%: <3/60-LP	6/6-6/18 - No LP
Nystagmus	94.5%: 6/60 or better Maj.:59.6%: <6/18-6/60	6/6-6/18 - <3/60-LP
Optic Atrophy	73.5%: 6/60 or better Maj.:51.8%: <6/18-6/60	6/6-6/18 - No LP
Myopia	92.9%: 6/60 or better Maj.:60%: <6/18-6/60	6/6-6/18 - <3/60-LP
Hypermetropia	97.6%: 6/60 or better Maj.:73.8%: 6/6-6/18	6/6-6/18 - <6/60-3/60
ROP	68%: 6/60 or better Maj.:54%: <6/18-6/60	6/6-6/18 - No LP
Ocular Albinism	89.5%: 6/60 or better Maj.:62.5%: <6/18-6/60	6/6-6/18 - <6/60-3/60
Oculocutaneous Albinism	75%: 6/60 or better Maj.:71.9%: <6/18-6/60	6/6-6/18 - <3/60-LP
Retinitis Pigmentosa	100%: 6/60 or better Maj.:66.7%: 6/6-6/18	6/6-6/18 - <6/18-6/60

The effect of a cataract on visual acuity is dependant on the extent of maturity and location of the opacity, whilst the level of vision when the optic nerve is involved is related to the number of neurones or nerve fibres affected. Residual vision in ROP parallels the grade of ROP reached - vision may be 6/6 or No Light Perception if total retinal detachment has occurred. Albinism is accompanied by reduced vision due to defective fundus pigmentation, foveal hypoplasia, nystagmus and possible refractive error. In the study, all children with retinitis pigmentosa had vision of at least 6/60, reflecting the age of the subjects and the general preservation of central vision until late in the progress of the disease.

The Role of the Orthoptist

An orthoptist is skilled in the visual assessment of a paediatric population. For an orthoptist to gain maximum results, it is essential that he/she has a vast knowledge of causes of vision impairment. Understanding the details of ocular conditions such as albinism or retinitis pigmentosa, will give the orthoptist an idea of visual expectations for the child, and the conditions under which each test should be performed. The orthoptist needs to acknowledge the child as a whole and their overall functioning abilities, not just their ocular diagnosis. Often, the children seen in CAF have multiple disabilities, particularly if they have CVI. It has been documented that children with intellectual and multiple disabilities exhibit an incidence rate of vision anomalies at least twice as high as normally developing children (15). With additional disabilities, many of the children do not respond appropriately to standard vision screening procedures, and modifications need to be made.

Armed with the background information about the existing medical condition, the orthoptic assessment of a child who is vision impaired should include the basic tests of measurement of near and distance vision, evaluation of binocularity and ocular alignment, as well as visual fields and colour vision. Additionally, there should be an objective assessment of how the child functions in unfamiliar indoor and outdoor environments and in differing levels of room illumination. Most importantly, the child's actions need to be observed, as this often brings with it a wealth of knowledge. All orthoptic tests should be performed in a calm and quiet environment without undue time constraints, allowing both the child and their family to feel relaxed. This also allows the family to readily absorb what their child can and cannot do visually, with time for discussion.

Following the assessment, the orthoptist needs to give feedback of his/her findings and consider ways of assisting the child. A vision impairment may have been found, but the child has a lifetime ahead of them - consideration should be given as to what changes need to be done to make it visually easier for them. A young child with visual impairments has little reason to explore the environment. Visual impairments can create obstacles to a growing child's independence (1). There needs to be a focus on the positive - the child may only be able to see N24 size print, but their school work can be enlarged to accommodate this situation.

Explanations should be given for any head posture that may be used, positioning of objects in a seeing area must be emphasised, room illumination adjusted and expectations of the child need to be acknowledged. Additionally, seating positions within the classroom and the use of clarity and contrast have to be discussed. Often, these issues need a 'common sense' approach.

The orthoptist must think of the visual expectations for the child at their age and suggest how to enhance the environment to a level suitable for the visual acuity. Often, simple changes such a fluorescent strip on a top step, a bright toy on a simple plain background, or an angled desk is all that is necessary to assist the child. The child with a vision impairment should be assessed at a young age to benefit from early intervention programmes and adaptive technology. These children should be considered by a wholistic approach, and liaising with other health and education professionals is of prime importance.

CONCLUSION

In developed countries, the incidence of CVI, and its resultant vision impairment, is increasing. In agencies such as RBS, children with an array of ocular conditions are assessed, with appropriate intervention instigated. The length of required RBS service provision will vary depending on the cause of vision loss. It is important that the primary reason for the vision impairment is acknowledged so that the expected visual outcomes are realistic, for both the child and their family. As some conditions can be progressive, the family need to be aware of any implications this may have for the future. Orthoptic input is essential in the assessment of the child who is vision impaired. By evaluating the vision standard of a child, through the use of conventional clinical tests, and the functional behaviour of the child, the orthoptist can provide information for, and interact with, other disciplines. In this way, the orthoptist is contributing to the development and well-being of the child so that they may achieve their maximum potential.

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Humphrey and Tomey Biometry for Cataract Surgery: Is there a difference in visual outcome?

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Abstract

This retrospective study compares the refractive outcomes of cataract surgery when two different biometric techniques are used to calculate axial length. One, the slit lamp mounted Humphrey A- Scan and the other the hand held Tomey A- Scan. The medical histories of 344 patients who underwent cataract surgery during 1998-1999 at the Royal Victorian Eye & Ear Hospital were studied. In 179 cases the A-Scan measurement was done using the Tomey, while in 165 cases the Humphrey was used. Results show the refractive outcomes were within +/-1.00D of the expected refractive outcome in 87% of cases with the Tomey and 84% with the Humphrey ($p = 0.36$), indicating no difference between these groups. Mean error, as defined as expected refraction minus achieved refraction, was less with the Humphrey (-0.08D) than with the Tomey (0.11D), ($T=2.4$, $p=0.017$). Despite this small statistically significant difference in mean error, a difference of 0.19D is not clinically significant. Refractive outcomes were similar between the groups showing both instruments give similar results.

Introduction

Cataract surgery with intraocular lens implantation (IOL) has led to dramatic improvement in the rehabilitation of the patient with cataract. Advances in the techniques used to calculate the power of intraocular lenses, have led to the capacity to tailor post-operative refraction to individual needs. This can result in good post-operative visual acuity without the need for distance glasses, to balance the refraction of the fellow eye or to give some reading ability. To achieve this desired outcome the lens power must be both calculated and selected carefully. However the actual final refractive outcome may differ from the selected outcome. Errors may occur from many sources.

One potential source of error is the position of the intraocular lens within the eye. If the lens moves closer to the retina the eye becomes increasingly hypermetropic and as the lens moves further away from the retina the eye becomes myopic. Erickson (1990)[1] calculated that 1mm of longitudinal change was equal to 1D of refractive error. Autopsy studies demonstrate that the lens does move within the eye and haptics can move into the sulcus.[2,3] Modern techniques for cataract surgery are more likely to result in both haptics being 'in the bag', however even within the capsular bag IOL position can vary.[4]

Another potential source of error is the formula used to calculate the IOL power. A study by Olsen (1992)[5] showed 38% of the post-operative refractive error was caused by an error of the formula in estimating anterior chamber depth when a fixed anterior chamber depth was used, and 22% when a predicted anterior chamber depth was used. Both theoretical and regression formulas have been found to be inaccurate for long eyes giving a higher error of refractive outcome in this group.[6,7,8]

Yet another source of error could be found in the lens itself. Error in lens labelling can occur and would only be suspected if the post-operative refraction differed markedly from the expected refraction. However smaller errors in lens mislabelling or manufacture can lead to apparently unaccounted for disappointing results.[9,10]

Keratometry could also be another source of error and in 1992 Olsen[5] attributed 8% of post-operative refractive error to error in keratometry measurements.

However, the largest source of potential error is the measurement of axial length. A 0.33mm error in measuring axial length will result in a 1.00D refractive error variation post-operatively.[11] In 1992, Olsen[5] calculated that errors in measuring axial length would account for 54% of the post-operative refractive error. Olsen compared pre and post-operative axial lengths in 584 patients and found the post-operative axial length to be more myopic. Likewise Kalogeropoulos (1994)[12] found the measured post-operative axial lengths to be longer than the pre-operative axial length. The difference arises from the uncertainty of the exact velocity of ultrasound through a cataractous lens, especially given the varying degrees of cataract density. Errors in the A-Scan biometry can also be the result of different operators and differences in individual models of instruments. The manufacturers of both the Humphrey and Tomey instruments claim an error of 0.1mm between repeated measures with the same operator, which already equates to a 0.3D refractive variation post-operatively. Ultrasound biometry can utilise either the immersion or contact techniques. The contact technique is less time consuming and has the obvious benefit of greater patient comfort. However, the immersion method gives a longer axial length due to the lack of indentation of the cornea.[13,14,15] Indenting the cornea with an A-Scan

probe shortens the measured axial length resulting in a too strong IOL being used and therefore resulting myopia post-operatively. Another variable of biometry techniques is the hand held probe compared with a slit lamp mounted probe. Although both methods indent the cornea, hand held probes might result in further indentation of the cornea, difficulties with correct alignment and unsteady fixation. However, a study by Whelehan et al (1996)[16] comparing the Humphrey biometer in both the hand held and slit lamp mounted techniques, showed no significant difference between the two methods in measuring axial length, although the sample size in this study was small with only 32 patients.

The aim of this study is to compare the actual final post-operative refractive state of the eye with the predicted result in two groups of patients using two different A-Scan machines, the hand held Tomey, Bio & Pach Meter AL1000 and the slit lamp mounted Allergan Humphrey Model 820.

Method

Subjects

The medical records department produced a list of 344 patients who underwent cataract surgery by phacoemulsification and intra-ocular lens implantation at the Royal Victorian Eye & Ear Hospital between 1998 and 1999. Of these patients, 165 had their A-Scan done using the Humphrey A-Scan and 179 patients had their A-Scan done using the Tomey A-Scan.

Apparatus

A Tomey, Bio & Pach Meter AL 1000 and an Allergan Humphrey biometer, model 820, both utilising the SRK/T formula and a Topcon keratometer.

Procedure

Patients' notes were examined. The data collected from each history was as follows:

Patient identification number; Operative eye; Pre-operative visual acuity; Axial length; Surgical date; Procedure performed; Complications; Intraocular lens power, model and A constant; Post-operative refraction and vision including date; Post-operative spherical equivalent; Desired refraction.

The desired refraction was determined by examining the IOL calculation printout and the power of the IOL used (ensuring adjustment for A constant). Spherical equivalents were used as the measure of refractive outcome and error was calculated by subtracting the real final refractive outcome from the expected outcome. For example, patient No. 13 had a 25D IOL inserted. By looking at the IOL calculation printout and adjusting for A constant it was seen that the aimed for refractive outcome was -0.39D. The actual post-operative refraction was -0.63D. Therefore the resultant error from expected to actual was -0.24D.

Data Analysis

SPSS for Windows was used for statistical analysis. Statistics employed included chi square test for proportions and T-test for comparing continuous data.

Results

Pre-operative data can be seen in Table 1. Statistical analysis shows no difference between the groups for visual acuity (Chi-sq = 7.93, p = 0.16) or axial length (T = 0.407, p = 0.685). It can be seen that most surgeons aimed for a slightly myopic, rather than emmetropic, final refractive state, although the range of refractive outcomes indicates that some cases were aimed at balancing the refraction of the fellow eye.

Table 1. Pre-operative data by biometer group

	Humphrey A-Scan N=165	Tomey A-Scan N=179	Test Statistic	P Value
Visual Acuity Range 6/12 or better (%)	6/480 - 6/6 58	6/480 - 6/6 48	Chi-sq = 7.93	0.16
Axial Length (mm) Range Mean (SD)	20.97 - 29.86 23.34 (1.33)	21.11 - 26.67 23.28 (0.92)	T = 0.407	0.685
IOL Power Inserted (D) Range	1.0 - 28.0	13.0 - 29.0		
Desired Refraction (D) Range Mean (SD)	-2.19 - +2.91 -0.29 (0.49)	-4.9 - +0.47 -0.33 (0.42)	T = -0.95	0.34

Post-operative data are shown in Table 2 & 3. There was no statistical difference in error between the groups (Chi-sq = 1.43, p = 0.697) in the percentage of cases between +/-0.5, +/-0.5 to 1.0, +/-1.0 to 2.0 or +/-2.0 or more (Table 3). However, a statistically significant difference was found between the mean error in each group (T = 2.4, p = 0.02) (Table 2). Although a statistically significant difference was found between these two means (Humphrey = -0.08D, Tomey = 0.11D), a difference of 0.19D is not of clinical significance. Figures 1 and 2 show the deviation from the expected outcome in both the Humphrey and Tomey groups. The two outliers seen in the Humphrey group(Figure 1) were both the results of difficult surgical procedures with complication.

Table 2. Post-operative data by biometer groups.

Visual Outcome	Humphrey A-Scan N=165	Tomey A-Scan N =179	Test Statistic	P Value
Visual Acuity Range 6/12 or better (%)	6/60 - 6/6 99	6/60 - 6/6 95	Fishers Exact Test	0.11
Final Refraction (D) Range Mean (SD)	-3.75 - +2.25 -0.38 (0.90)	-7.0 - +1.75 -0.22 (0.89)	Chi-sq 4.19	0.24
Error (D) Range Mean (SD)	-3.49 - +1.54 -0.08 (0.77)	-2.1 - +2.33 +0.11 (0.70)	T = 2.4	0.02

Table 3. Refractive Results

(% of cases) within	Humphrey A-Scan N=165	Tomey A-Scan N=179	Test Statistic	P Value
+/- 0.50 D	57 (n=94)	58 (n=103)		
+/- 0.50-1.00 D	27 (n=44)	30 (n=53)	Chi-sq 1.43	0.697
+/- 1.00-2.00 D	15 (n=25)	11 (n=20)		
Over +/- 2.00 D	1.2 (n=2)	1.7 (n=3)		
+/- 1.00 D	84 (n=138)	87 (n=156)	Chi-sq 0.85	0.36

Discussion

As the outcomes of cataract surgery continue to improve with improving technology, patients' expectations of their surgical procedure continue to increase. Many patients now expect good vision without the use of distance glasses. To achieve good vision without the need for glasses, the appropriately powered intraocular lens must be selected. The final refractive state is important for the patients' comfort and satisfaction. If the axial length is measured incorrectly the patient will have an unexpected post-operative refractive error. A too short axial length will result in too strong an IOL being used that will in turn induce a more myopic error, and a too long axial length will result in too weak an IOL being used, inducing a hypermetropic error. In 1990, Sanders et al[17] found 81% of eyes were within 1.00D of the expected refraction. In 1995, the authors of the SRK/T formulae, Sanders, Retzlaff and Kraff stated that 'even under ideal circumstances, actual post-operative refraction will differ by more than 1.00D from the calculated expected refraction in about 15% of cases'.[11] . This is consistent with our study, which showed 13% of cases with a difference of more than 1.00D using the Tomey A-Scan and 16% using the Humphrey A-Scan.

This study shows mean error from the expected outcome was -0.08D in the Humphrey group and 0.11D in the Tomey group. Looking at the Scattergrams, Figures 1 and 2, show an almost even distribution of over and under corrections with the Humphrey A-Scan, and a more hypermetropic distribution of error with the Tomey A-Scan. The mean errors we found were less than others have reported, with mean errors ranging from 0.45 to 0.64 in other studies.[17,18,19]

Our study showed a statistical difference in mean errors between the Humphrey and Tomey groups. However, visual outcomes were similar between the groups suggesting that the statistical difference in mean error may not be clinically significant.

This study is in agreement with Whelehan et al[16] in showing no difference between hand held and slit lamp mounted biometry. Hand held biometry probes have obvious advantages with difficult patients who are unable to co-operate with fixation, or due to physical difficulties are unable to be positioned on the slit lamp, or even simply when a slit lamp is unavailable. Although a true comparison between biometry instruments would involve a randomised clinical trial using both A-Scanners on each patient, this was not possible in this retrospective study design. In addition, an ideal study design would use one biometry operator and one surgeon. The Royal Victorian Eye & Ear Hospital has over 80 visiting Ophthalmologists and Ophthalmic registrars performing cataract surgery and 20 Orthoptists performing biometry. Adjusting A-constants for individual surgical techniques is therefore not possible and there will be variation within individual practitioners. These methodological limitations should be kept in mind when interpreting these results.

Both the Humphrey and Tomey A-Scanners use ultrasound to measure axial length. Carl Zeiss has recently introduced a laser biometer to measure axial length. This new technology is fully automated eliminating operator error, comfortable for the patient, and being a non-contact instrument reportedly gives axial length results comparable to immersion A-Scan. However light does not travel easily through cataracts and the usefulness of this technology needs to be determined.

With continually improving surgical techniques, developing biometric technology and increasing patient expectations, cataract surgery is increasingly becoming refractive surgery. Routine monitoring of the refractive outcomes of cataract surgery is a highly recommended quality measure that can detect any systematic introduction of error.

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A journey of innovation or rediscovery?

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Abstract

Good research should be an integral part of the continued development of the discipline of orthoptics and yet many practitioners do not consider research fundamental to their practice. Research is often seen as the domain of the universities and whilst it is a major part of the university role research is increasing in importance in clinical practice with the current shift to evidence based practice. The subject of this paper is to discuss the concept of research in an attempt to encourage all practitioners to consider research a part of their daily practice. An overview of the development of the scientific method is presented including the contribution of observation and trial and error. The more formal elements of literature search, research design and statistics are considered in the clinical context.

I wish to thank Council for the honour of asking me to present the 1999 P M Lance Lecture. Patricia (Pat) Lance MBE is a great pioneer of orthoptics. I am grateful I joined the Orthoptic profession at a time when pioneers such as Pat Lance; Bev Balfour and Diana Craig were still active in the profession, my regret is not joining early enough to actively work with such people. Each of these early pioneers was in the true sense a researcher. These pioneers established the discipline of orthoptics as a science based on research. We must continue with these principles today if we want our discipline to grow and have standing with other professional areas.

As defined in the Oxford Dictionary research is a "careful search or inquiry; endeavour to discover new facts etc. by scientific study of a subject; course of critical investigation". It is in the broadest sense that I wish to define research, that is, an exploration of new ideas leading to the development of theory and practice. However, research is often seen as a complicated scientific process that takes place in universities and requires specific training. Whilst to some extent this is true, research is also an activity in which we can all be involved in. This lecture will be used to present the concept of research as a journey of discovery, an activity to be enjoyed not feared. Aspects of my own research will be referred to as illustration of certain points on the journey.

Research: the concept.

The early scientists were very much philosophers who created theories to explain the phenomena around them. An interesting example of the changes in approach to research can be seen in the development of the periodic table of elements, which is fundamental to our understanding of chemistry and the world around us.

Key concept: A large step forward in knowledge is often based on many small steps and therefore scientific theory can be slow to develop.

- Empedocles (c490 to 430 BC) theorised that everything on Earth was made not from one substance as was the view of his predecessor's but was instead derived from 4 elements - fire, wind, water and earth.
- Aristotle (c384 - 322BC) took Empedocles theory further by seeking to classify Empedocles four elements into subgroups thus introducing a greater level of organization into our view of the world. This theory of organization remained the cornerstone of chemical science for 2000 years.
- John Dalton (1766 - 1844) introduced the concept of all matter being composed of atoms, that atoms had a specific weight and that when elements combined to form compounds they did so in specific proportions.
- Dmitry Mendeleyev (1834 - 1907) took this information a step further determining that there was an inter-relationship amongst chemical elements based on their atomic weights this classification formed the periodic table as we know it.

Development of the scientific method.

Key concept: The use of research to support theory remains basic to science to this day.

Aristotle's lasting contribution to science was his insistence on observation and classification and initiating research to facilitate this process.

Key concept: It is as important in scientific research to record failure as well as success, we can learn much from analysing failure.

Hippocrates (c460 - 377 BC) the "father" of modern medicine established experience and observation as the basis of medical diagnosis. Whilst Hippocrates is perhaps better remembered for The Hippocratic Oath he left another great legacy to science and that was his insistence on recording failures as well as successes.

Galileo (1564 - 1642) Wrote the first paper describing scientific method in the 1620's. Today the scientific method has been claimed by many disciplines from Psychology to Geography. In recent times the traditional scientific method as the basis of

research has given way to two areas of methodology: quantitative and qualitative research. Quantitative research results in outcomes, which can be measured in numeric terms and analysed by statistical calculation. Qualitative methodology enables us to explore phenomena that do not lend themselves to quantitative measurement such as human feelings or the impact of disability on quality of life. Research in the health sciences requires both methodologies and often both may be employed to answer the one research question.

Research: the process

In my opinion a good glass of red wine and a decent bowl of pasta are an integral part of the research process! As enjoyable as the pasta and wine may be they are really only an allegory for time to think. If one becomes totally involved in research it becomes a lifestyle not just an occupation! The research process requires a flow of ideas which is not achieved by waking up one morning and saying "today I will do research!" Ideas will have been generated by your observations and experiences, they may not be immediately useful, but remain stored in memory until the right sequence of events occurs.

Key concept: Simple observation can be a powerful tool.

Hans Lippershey (c 1570 - 1619) a German born spectacle maker who lived and worked in the Netherlands is credited with discovering the telescope. Allegedly a child playing in his shop put two lenses together and noticed that distance objects came closer, from this observation Lippershey developed the telescope (Not verified).

Key concept: Good research should be based on careful observation and thorough evaluation.

Observation alone does not result in good research. Observations are often matched against existing theory to develop new concepts, which must then be tested. Some examples based on my own experience where observation has lead to the development of new clinical tools can be seen in the development of both the EccVue and the VizTest computer programs.

- The idea to develop EccVue grew from a number of sources from my personal experiences with clients learning the process of eccentric viewing. I was frustrated by my inability to create good quality training materials, by the limited range of materials available and the lack of a simple and repeatable training method. Combining these frustration's with some basic educational theory and the versatility of the desk top computer resulted in the development of EccVue1.
- VizTest germinated from my clinical work assessing multiple-handicapped children. I found that existing tests were not suited to the abilities of the children being tested. However, the alternative to substitute conventional test procedures with batteries of toys and pictures was cumbersome and ineffective as a means of measurement. In this case my observation of the problems encounted by the children in trying to respond to conventional clinical tests and the use of procedures which could not provide meaningful assessment lead to a complete change in my approach to thinking about the problem. The new approach was to establish images that would be meaningful and of interest but still provide a degree of clinical measure combined with a method of response suited to the children. These ideas were then evaluated with the target children and validated against conventional tests 2 3 4.

The result has been two new successful and novel clinical procedures.

Key concept: Not all research is based on an "original" idea sometimes it is the development or novel application of an existing concept.

Some aspects of research are also serendipidous. In my case the move into using computer technology came from a combination of my own interest, sporadic exploration of computing and the chance meeting with a colleague who was skilled in computer programming. The idea of using computers as a means of providing vision rehabilitation programs and a means of assessing functional vision was an extension of my desire to create better materials and a basic knowledge which indicated the computer would be the appropriate vehicle to achieve this. By chance finding a colleague who had appropriate computer skills and a desire to further explore the application of computer technology enabled us to convert my ideas into working programs.

Research is not only the creation of new ideas and concepts but is often the result of old ideas being placed into a new context. The development of computer technology is a good example of looking at old ideas in a new light and in this case ideas which were probably much older than most people realise! The development of computer technology is a good example of concept development in research.

The first computer was actually designed by Charles Babbage (1792 - 1871) who also invented an early ophthalmoscope. Babbage's computer was an extension of the calculators of the day, which in turn had their roots in the abacus. Babbage observed the pattern cards which had been developed by Joseph Jacquard to control the complex patterns created by weaving looms and believed the same technology could be used to feed instructions into a calculator to enable it to perform more complex calculations. Babbage reasoned he could use these "batch cards" to control an "analytical machine". The machine would be controlled by programmed instructions and have a memory to allow comparison with previous data, thus the digital computer was born, although not activated until much later.

It was not until the 1930's that Babbage's design was put into practice when differential analysers powered by electricity were developed and the analogue computer was born. As with many forms of technology computers were further advanced during wartime as decoders. The following is a brief chronology of computer development in more recent times that illustrates the evolution of an existing concept.

- Britain developed the Colossus which filled a room and could read coded tape at tremendous speed.
- The Americans had independently developed the Electronic Numeric Integrator and Computer (ENIAC) to calculate gun trajectories. This machine also occupied a whole room it weighed in excess of 30 ton and generated so much heat it could not run for more than an hour at a time. It used so much power that all the lights in the surrounding district dimmed when it was turned on If a valve broke down it could take up to 8 hours to locate the problem! This was the first digital computer, which operated on a binary system.
- Australia was also a part of this computer revolution. Council for Scientific and Industrial Research Automatic Computer (CSIRAC) was developed by the Council for Scientific and Industrial Research. Development began in Sydney in the late 1940's moving to Melbourne in the 1950's. This large machine looked like a series of gym lockers it had 2 kilobytes of memory and an output of 4 characters a second. For those who think their Personal Computer's are pretty clever when they play Compact Disc's, CSIRAC also played music through rather primitive speakers. CSIRAC was used to run calculations on building design and the State's electricity distribution system.
- 1951 saw the first commercially available computer the Ferranti mark 1, which was developed in Manchester England.
- 1960 the development of integrated circuits revolutionised computer development so that by 1977 Robert Noyce wrote in Scientific American: "Today's micro computer at $300 has more capacity than ENIAC, it is 20 times faster, has a larger memory, is a thousand times more reliable, consumes the power of a light globe not a locomotive, occupies 1/30,000 the volume, costs 1/10,000 of the cost and is available by mail order from your local hobby shop!"

Computers were mainly used for their ability to perform complex calculations and their phenomenal memory storage capacity. Even in the mid 1980's when my colleague and I were formulating our ideas computers were rarely being used in therapy. Yet the computer offered the ability to store many images and manipulate those images with ease and speed. In addition computers were interesting; - an observation I had made in the Special Development Schools where I was working.

Research: where do you find it?

Key concept: Search widely, if you have had a good idea someone may have had it before you.

Another intrinsic component of research is the literature review - so, you have an idea, has some one else had the same idea? Perhaps some one else done work that might add to or help define your idea. My literature searching on eccentric viewing took me back to the 1970's when the idea of vision rehabilitation was sweeping America.

This searching demonstrated early attempts at eccentric viewing and demonstrated a number of paradigms based on bright lights5. As an orthoptist this literature should have suggested an obvious training method, pleoptics. My clients with centre field loss are extremely photophobic, the use of an afterimage would be extremely distressing to them and I initially dismissed this suggestion. However further thought about the basic concepts of pleoptics (without the bright lights) did lead to the development of the eccentric stimulation component of the EccVue package (Figure 1). This component has proven to be a useful feature of the package. It enables the clinician to check if the eccentric viewing position selected on the basis of vision field testing is appropriate; and it gives the client a good idea of the quality of vision to be expected from the eccentric viewing point. The ideas I found in the earlier literature proved to be quite successful when applied in a modified form

Literature searching for VizTest took me even further back to the 1870's and the first attempts to develop accurate tests of vision. Key factors in the early development of vision charts related to optotype legibility. A point of interest in this literature relates to the initial choice of optotypes, which was based on convention not science. Snellen's first optotypes were in a font known as Egyptian Paragon a print type with serif. Green suggested that a print type without serif would form a better optotype his idea was dismissed on the basis that it would not be pleasing to the eye!6 So much for scientific method. My literature searching enabled me to better understand the process of vision chart development as well as detecting the lack of tests devised specifically for the population in which I was interested.

Key concept: Many good developments are the result of taking a "different" approach to an existing idea.

After my literature searching in relation to development of tests of visual acuity I was left with the question: what did all of these conventional and modified conventional tests have in common and why were they not suited to my population of interest?

- The tests were developed in high contrast so always black on white;
- Where pictures were employed they were stylised pictograms, which require a high degree of cognition and familiarity for recognition.
- The only tests suggested for less cognitively developed subjects consisted of black and white gratings. Such targets are boring for the target population.
- Finally there was a big jump in testing procedures from the strictly controlled clinical tests to the inventory style questionnaires being developed by allied health professionals working in the field who had no training in vision assessment.

Not all research fits comfortably within conventional thinking sometimes the researcher has to be prepared to go out on a limb; this was the case with VizTest. Having studied the work of my colleagues and considered the short comings of existing designs I decided the basis of the problem was taking a validated test and trying to modify this to suit the

population. Why not start from the known abilities of the population and then find a way of gaining meaningful information Figure 2 demonstrates the basis of optotype design for VizTest, a very unconventional optotype!

Research: doing it!

Key concept: Clinical research may not always be as exacting as controlled laboratory research but it does not have to be without rigour or validity.

Having made your observations, formulated your theories and considered the current thinking comes to the fun part of designing the "experiment" and collecting the data. I am not going to speak at length on the theory of experimental design but rather raise a few points for consideration.

Knowing in our heart of hearts that a particular intervention works because we have observed our patients improve in the clinic and had that warm fuzzy feeling when the client/patient walks away delighted does not prove the validity of your method. To convince the hardened critics a good random controlled study with plenty of statistical power is best practice. This it is not always practical or achievable in the work place but that is not an excuse to ignore good research principles, some methodologies are simple but effective.

If you are unable to establish a full random controlled study some degree of validity can be gained from a pre / post test design to demonstrate a change in behaviour or performance. This design enables measurement of change and provides the basis for statistical analysis. When I designed EccVue I was not able to gain access to a sufficiently large number of clients to make a random controlled experimental design viable. There was also the ethical dilemma that confronts all clinical researchers - should I withhold treatment? To overcome these problems I used a pre/post test design to evaluate EccVue7. Objective pre training measures combined with a subjective functional evaluation were used to test my hypothesis that EccVue was an effective method of training eccentric viewing. Post training I re-tested the objective measures (Figure 3) and asked clients to complete an evaluation questionnaire relating to perceived functional changes. In this design the traditional subject and control groups are replaced by developing base-line data and then providing comparative measures. This is valid research but the researcher must be aware of the limitations of the conclusions. For example improved performance may be due to the attention received and not the intervention the "Hawthorne effect".

The research design involved in assessing VizTest was undertaken in the university environment and was more rigorous. This was not just a new test but it incorporated new designs in optotypes. The new optotypes had to be validated by comparison with an existing "gold standard" test. This testing was undertaken with 96 cognitively normal children with varying levels of visual acuity, testing was undertaken with two examiners each blind to the results of the other - to minimise bias. The new test then had to be evaluated with a sample population similar to our target population. Subjects were chosen on the basis of their (or parents) agreement to participate - this does not eliminate all bias but when working with clinical populations this is often the closest one comes to random sampling. Secondly we needed to have a good-sized sample we achieved this by sampling from a number of centres. This added to the statistical power and the confidence with which we could extrapolate our results to the target population as a whole.

Validation testing allowed the calculation of sensitivity and specificity data for the test as a whole and for individual optotypes (Table 1). The optotypes were also evaluated for legibility so that the final selection of picture optotypes would be of comparable legibility. Evaluation trials indicated the applicability of the test to the target population and tested the concepts of coloured optotypes and movement as components of a vision test4.

I have presented two examples of methodology, one limited by the clinical practice environment the other set in an academic context. There are times when a project seems never ending - a long uphill climb, it is still worth doing well.

Key concept: A researcher must find time to reflect on the data and methodology.

Time to reflect - back to the wine and pasta! An important part of the research process is time to think and reflect on your work. A good scientific study does not spring up overnight (even though it may appear to). The time spent in formulating the ideas for EccVue and trying to gain grant money to support development probably appeared to my colleagues to have occurred with little obvious time input. The reality was much of this work was done through the night and on the weekends. This is not a satisfactory way to approach research particularly in the long term, appropriate time must be found. How do you find time? I learned this the hard way and not without a large amount of soul searching, this will require making sacrifices. So what should they be?

- Give up your partner? - probably not;
- Give up sleep? - not long term;
- Rationalise the workload? Yes!

If you are going to undertake a research project do it properly and factor this into your workload which means something else will have to come out. This is never an easy decision but if you are to be productive and not have a nervous breakdown it is essential.

I have talked about the research journey in terms of observation and awareness of other work in the field. The ability to adapt existing knowledge and be bold enough to break with convention and imagine new ideas. I have touched on the need for careful planning and good design to support and validate our work. I hope I have encouraged you to consider taking on this process because we all should contribute. There remains but one point to be made:

Most of all research should be FUN- thank you.

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ABSTRACT

Rehabilitation or assisting someone who is ill to lead a normal life has been the role of the Orthoptist for many decades. Reskilling fighter pilots was the first recorded involvement of orthoptists in active rehabilitation, during World War 11.

The real push for Orthoptists to assume a rehabilitation role began in 1973 with involvement at the Spastic Centre of NSW with children with cerebral palsy. Other developments at this time included rehabilitation therapy for cerebro-vascular accident patients and the National Trachoma and Eye Health Programme in rural Australia.Orthoptic involvement in the Low Vision area began in 1977 with Orthoptists being employed at the Royal Blind Society of NSW in the Child Development Unit, Sensory Development program and the Low Vision Clinic, with a specialised Vision Training program. The Low Vision area has expanded with reading efficiency programs for the vision impaired student.Sports rehabilitation and the involvement of orthoptists in driving rehabilitation commenced in 1990.

Key Words: Rehabilitation, Orthoptist, Low vision, Driving, Stroke, Sport Rehabilitation.

REHABILITATION

Introduction.

Rehabilitation is Latin for re skilling[i] and, in the case of Orthoptic assessment and Treatment, involves assisting someone who is ill to lead a more normal life. Orthoptists have been involved in Rehabilitation since the 2nd World War, where "Workers in factories using precision instruments often required the help of the orthoptist as well as those cases in the Head Injury Hospitals where the orthoptists assisted in perimetry and the diagnosis and treatment of ocular muscle palsies."[ii] Orthoptists then became involved in the assessment and treatment of children with cerebral palsy and developmental delay. To-day orthoptists are still employed in these areas and have expanded their role into driving, sport, stroke and low vision rehabilitation.

History of Rehabilitation in Australia.

Children with cerebral palsy have been assessed and rehabilitation programs developed by Orthoptists since 1973 at the Spastic Centre of NSW[iii]. Treatment programs that involve repetitive saccadic and smooth pursuit movements have been used to assist some cerebral palsy children to control their eye movements[iv].The specialised assessment of the Developmentally delayed patient has continued from this pioneering work, with interesting findings presented in 1998 that these patients presented with a significantly higher incidence of visual impairment than the normal population[v]. The multi-handicapped, visually impaired child provides additional challenges in assessment and particularly the team approach to rehabilitation where an accurate assessment of the visual status is essential to the other team members[vi]. Cortical blindness can be very difficult to assess and treat but some progress has been made in improving this to "panoramic vision"[vii]. Aboriginal health has been a very important part of the Orthoptist rehabilitation expertise since our involvement with the National Trachoma and Eye Health Program[viii] which commenced in 1976 and has extended to orthoptists participating with the Hollows Foundation in overseas countries[ix].

Driving Rehabilitation.

The Orthoptist's role in driving rehabilitation is as a consultant to confirm the presence or absence of eye defects that may affect driving[x] and advise on visual strategies to assist in overcoming any visual problem. Driving rehabilitation may benefit people who have suffered from a stroke, head injury, serious eye disease, or a general condition from birth with resulting eye condition (eg. cerebral palsy or spina bifida) that makes driving difficult[xi]. The Orthoptist will take a full medical history and Orthoptic Assessment will include visual acuity, visual fields, cover tests, ocular movements, binocular vision and colour vision tests. The Orthoptists may assess the driver's ability in the driving situation (on road) in order to observe their specific eye movements and visual deficiencies and needs. The most common vision problems found are visual field defects, neglect, monocular fixation, nystagmus, ocular movement defects and strabismus. The vision defect is assessed and techniques to enable safe driving are discussed which may include ensuring that the best glasses are prescribed for use when driving, discussing adaptations to the vehicle that will assist visual performance e.g. extra mirrors. Rehabilitation programs may be developed to ensure the best use of vision when driving e.g. for patients with visual field loss Orthoptists have also been involved in assessing the visual standards of adult drivers with a commercial

vision screening device thus proving this as a reliable test to measure visual function[xii].This was performed in collaboration with Vic Roads, with a later study which found that older drivers performed significantly worse on the vision screener showing a very marked increase in visual defects[xiii].

Research is continuing into the effect of diplopia[xiv] on driving ability and the impact of visual field defects on driving[xv]. The most recent work has been presented at the International Vision and Vehicles Conference in Boston (1999). The unique professional expertise the Orthoptist has in this field has involved the Orthoptist working closely with other professionals, not only in the allied health field, but also the licensing authorities.

Sport Rehabilitation.

The challenge for Orthoptist's to become involved in Sport Rehabilitation was presented to the Orthoptic Association by Air Vice-Marshall Daley in 1970, who after discussing the importance of the Orthoptist in the training of pilots in World War II stated: "As you can see, learning to fly is visually rather like playing a ball game, and this brings me as a member of the A.M.A. S.M.F to the suggestion that there should be greater awareness by this body of the importance of orthoptics in sport and therefore greater links in this field."[xvi] This challenge was not taken up until 1990 when the visual and ocular motility performance of one hundred cricketers was tested and compared to a normal population and no significant differences were found[xvii]. The effects of aerobic exercise on reducing intraocular pressure was investigated[xviii]. This was followed by a study of the latencies of horizontal saccades in table tennis players and non-table tennis players, with a group of the elite table tennis players exhibiting anticipatory saccades[xix].

The Orthoptic Sports Vision eye examination[xx] involves tests designed to detect visual problems and include standard orthoptic assessment, Humphrey's field test, contrast sensitivity, dynamic visual acuity (measured with a moving target), stereopsis in the distance (measured with Mentor) and Ober 2 eye movements. Visualmotor deficiencies[xxi] that could effect athletic performance are tested by assessing eye hand coordination (proaction and reaction, measured using the Acuvision 1000), peripheral awareness reaction time, total reaction time(i.e. the measurement of reaction time plus movement time based on responses from the visual, auditory and motor systems.), eye foot coordination(i.e. that ability of the feet to respond in a smooth and coordinated manner as a result of information provided by the visual system.) and coincidence anticipation (i.e. the ability to make a motor response coincident with the arrival of an object at a designated point.).

Sports Rehabilitation programs[xxii] may involve treating visual deficiencies orthoptic and ophthalmic, sports specific programs may be developed for coaches and trainers both Off field (Visualmotor drill, quantifying and training skills) and On field (reinforcing the off field training with simulation techniques e.g. peripheral vision on the netball court). The International level at which this rehabilitation is being presented is indicated by the involvement of the OAA in the International Congress on Sport Science, Sport Medicine and Physical Education held in Brisbane in 2000, prior to the Sydney Olympic Games.

Stroke Rehabilitation.

Orthoptists have been involved in the rehabilitation of the patient suffering from a Cerebro-Vascular Accident (CVA) from 1977. The multi-disciplinary team relies on the orthoptic assessment to prepare the most appropriate rehabilitation program for the patient[xxiii,xxiv]. Assessment of visual function usually involves visual acuity, visual fields, ocular muscle balance, abnormal head posture, stereoscopic vision, colour vision, and investigation of an abnormal head posture used for adaptation to diplopia or to obtain the null point of nystagmus. Due to the varied and sometimes profound disabilities of these patients it is a challenge for the Orthoptist to adapt normal testing procedures to cope with patients who often suffer from hemiplegia, neglect , apraxia (inability to motor plan.), dysarthria (motor speech disorders), aphasia (communication disorder, impaired language comprehension) and frontal lobe induced behaviour problems (confusion).

Some of these adaptations include history taking reduced to simple "yes", "no" answers, checking correct glasses are being worn, or bi focals being used correctly, visual acuity testing with modified Sheridan Gardner or Catford Drum, using opto-kinetic nystagmus methods to test saccadic movements and using eye contact for gross eye motility.

Homonymous Hemianopia may occur following CVA, head injury or tumour removal, training with the SEETEC program or adaptation of this assists these patients to improve their tracking and scanning skills[xxv]. This is done by the Orthoptist in the Rehabilitation setting and followed by a home visit to advise staff or carer's on management. The initial work with CVA patients has lead onto the involvement of the Orthoptist in working with the Head Injury patient[xxvi] often presenting with the following clinical categories[xxvii] orbital or soft tissue injury, refractive errors from traumatic cataract,lens dislocation or traumatic myopia, traumatic maculopathy or cranial neuropathies which may include neurogenic paralytic strabismus or visual field defects.

Also cerebral lesions, intra axial brainstem damage or glaucoma secondary to trauma may occur. Current research is being done to use predictive factors to assist in formulating the rehabilitation program for individual patients[xxviii].

Low Vision Rehabilitation.

During 1977 an Orthoptist was offered the position of Honorary Consultant to the Royal Blind Society of NSW. Working in a voluntary capacity for some time with the Sensory Development program, which was a program designed to assist clients who had recently lost their vision to make the best use of their other

senses and thus regain some independence[xxix]. Then being appointed as a consultant in the Low Vision Clinic[xxx] instructing clients in the use of magnifiers and telescopes with advice as to adequate lighting. Home visits are also performed to ensure that the lighting is adequate and the low vision aid is being used appropriately. Eccentric viewing training programs[xxxi] were pioneered in Australia in 1978 in close collaboration with Professor Lederer, head of NSW School of Optometry. This program was first described by Professors Otto and Bangerter in St. Gall, Switzerland, in which they describe the retraining of patients with macular degeneration to use a paramacular point as their primary point of fixation. Most patients improve in visual acuity but also showed a marked improvement in mobility and confidence to perform everyday tasks, which leads to them regaining their independence. An orthoptist was seconded from Sydney Eye Hospital to work in the Children's Development unit[xxxii], with an Orthoptist on the Honorary Medical Advisory Panel. The Orthoptist's role was to determine the amount of useable vision the child had, develop a visual stimulation program for each child, to encourage them to utilise their residual vision[xxxiii]. This work has continued to expand with the Royal Blind Society being one of the major employers of Orthoptists.

The orthoptic position at the Royal Victorian Institute for the Blind was pioneered in 1982 where a pilot program was performed to determine if visual efficiency and reading efficiency training could improve a visually impaired student's reading efficiency[xxxiv]. This vision training consisted of eccentric vision training and null point training for patients with nystagmus. A review of these students twelve months later showed they were able to maintain an improved reading speed[xxxv]. Following these pilot studies techniques to further develop these training programs[xxxvi] were developed with subsequent development of vision training programs[xxxvii] on the computer (EccVue[xxxviii] and VizTest[xxxix]), and the development of a Home Eccentric Viewing Kit. Studies were also done on the effect of Spectral composition of lighting on visual performance of persons with retinal pathology[xl].

The other states soon became involved and now Orthoptists are employed in low vision centres in all states. Each state has its own specific low vision needs and resources.

Eccentric viewing techniques are now being taught in all states with the future of eccentric viewing training resting with the patience of the orthoptist and the motivation of both orthoptist and patient, some patients like the structured computer approach while others prefer a more day to day hands on approach. Orthoptists working in this field have to be able to assess each patients individual needs and abilities in order to assist with these specific problems. All Orthoptists are involved in some form of low vision rehabilitation even if it is as simple as suggesting an appropriate reading light to a patient with slightly reduced vision. Patients in this category are often the most affected by their visual loss as it makes everyday tasks difficult (even presbyopia) simple techniques can be used to make life easier.

Orthoptists has taken on a major role in the management and administration of many low vision centres as we have the expertise to assess the client's total needs and co-ordinate the low vision team. An example of this is the Vision rehabilitation training program described at the 1998 OAA Scientific Conference, where orthoptists and other staff from the Royal Blind Society trained health professionals, teachers and community workers in Papua New Guinea[xli]. Orthoptists are increasingly being consulted by government bodies and employment agencies as experts in this field such as the Queensland Department of Family Services and Aboriginal and Islander Affairs, Health Department Victoria, Victorian Department of Education, and the Department of Health Housing and Community Services. The role of the Orthoptist in the management of the low vision patient presents a challenge for the future as our training permits us to undertake so many varied roles with this patient group.

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Rehabilitation.

Keynote address to the 56 th Annual Scientific Conference Orthoptic Association of Australia.Melbourne 1999

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Named Lectures, Prizes and Awards of the Orthoptic Association of Australia Inc.

The Patricia Lance Lecture

1988	Elaine Cornell (Inaugural)
1989	Alison Pitt
1990	1990 Anne Fitzgerald
1992	Carolyn Calcutt
1993	Assoc Professor Judy Seaber
1995	Dr David Mackey
1997	Robin Wilkinson
1998	Kerry Fitzmaurice
1999	Pierre Elmurr

The Emmie Russell Prize

1957	Margaret Kirkland	Aspects of vertical deviation
1959	Marion Carroll	Monocular stimulation in the treatment of amblyopia exanopsia
1960	Ann Macfarlane	A study of patients at the Children's Hospital
1961	Ann Macfarlane	Case history "V" Syndrome
1962	Adrienne Rona	A survey of patients at the Far West Children's Health Scheme, Manly
1963	Madeleine McNess	Case history: right convergence strabismus
1965	Magaret Doyle	Diagnostic pleoptic methods and problems encountered.
1966	Gwen Wood	Miotics in practice
1967	Sandra Hudson Shaw	Orthoptics in Genoa
1968	Leslie Stock	Divergent squints with abnormal retinal correspondence
1969	Sandra Kelly	The prognosis in the treatment of eccentric fixation
1970	Barbara Denison	A summary of pleoptic treatment and results
1971	Elaine Cornell	Paradoxical innervation
1972	Neryal Jolly	Reading difficulties
1973	Shayne Brown	Uses of fresnel prisms
1974	Francis Merrick	The use of concave lenses in the management of intermittent divergent squint
1975	Vicki Elliott	Othoptics and cerebral palsy
1976	Shayne Brown	The challenge of the present
1977	Melinda Binovec	Orthoptic management of the cerebral palsied child
1978	Anne Pettigrew	
1979	Susan Cort	Nystagmus blocking syndrome
1980	Sandra Tait	Foveal abnormalities in ametropic amblyopia
1981	Anne Fitzgerald	Assessment of visual field anomalies using the visually evoked response
1982	Anne Fitzgerald	Evidence of abnormal optic nerve fibre projection in patients with Dissociated Vertical Deviation: A preliminary report
1983	Cathie Searle	Acquired Brown's syndrome: A case report
	Susan Horne	Acquired Brown's syndrome: a case report
1984	Helen Goodacre	Minus overcorrection: Conservative treatment of intermittent exotropia in the young child
1985	Cathie Searle	The newborn follow up clinic: A preliminary report of ocular anomalies
1988	Katrina Bourne	Current concepts in restrictive eye movements: Duane's retraction syndrome and Brown's syndrome
1989	Lee Adams	An update in genetics for the orthoptist, a brief review of gene mapping
1990	Michelle Galaher	Dynamic Visual Acuity versus Static Visual Acuity: compensatory effect of the VOR
1991	Robert Sparkes	Retinal photographic grading: the orthoptic picture
1992	Rosa Cingiloglu	Visual agnosia: An update on disorders of visual recognition
1993	Zoran Georgievski	The effects of central and peripheral binocular visual field masking on fusional disparity vergence
1994	Rebecca Duyshart	Visual acuity: Area of retinal stimulation
1995	Not Awarded	
1996	Not Awarded	
1997	Not Awarded	
1998	Nathan Clunas	Quantitive Analysis of the Inner Nuclear Layer in the Retina of the Common Marmoset Callithrix
1999	Anthony Sullivan	The Effects of Age on Saccadis Mode to Visual, Auditory and Tactile Stimuli

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1992 Kerry Fitzmaurice
1994 Margaret Doyle
1998 Not Awarded

Paediatric Orthoptic Award

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