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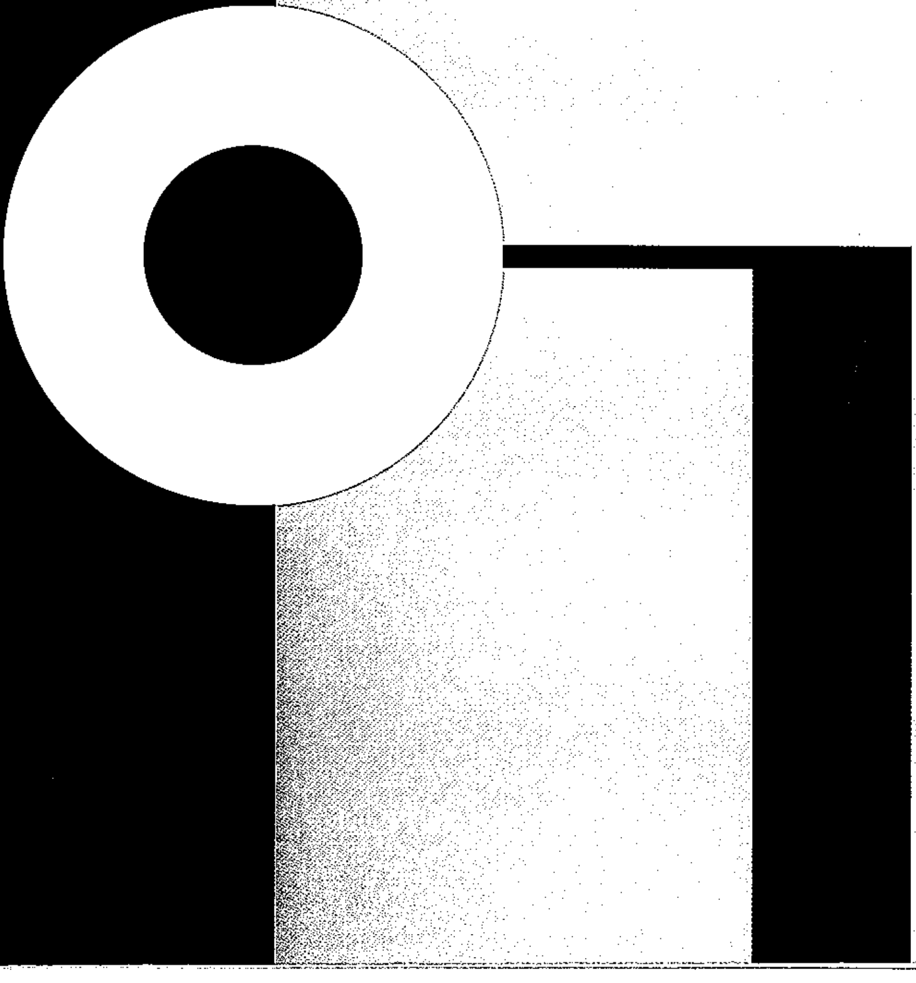

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Preface

Notes for Contributors

It is a condition of acceptance of any article for the Australian Orthoptic Journal that only original material is submitted unless suitable acknowledgement has been made in the references and that such articles have not been previously published nor are under consideration for publication elsewhere. This must be stated in a covering letter. Articles for submission may include original scientific papers, case histories, book reviews or letters. Manuscripts with one high quality copy and three photocopies should be typewritten in double spacing with wide margins on one side only, on A4 paper. Authors are requested to supply a disc with the hard copy. Place author(s)' name(s) in the top right hand corner of each page as well as on the floppy disc.

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Abstract

The abstract should be a succinct representation of the article. The components should relate directly to the format of the body of the article including aim, procedure, results, discussion and conclusion. The abstract should be limited to 150 words and be submitted on a separate sheet. Submit key words underneath the abstract. Do not duplicate words in the title and limit these indexing features to five words.

Text

Clearly prescribe the purpose of the study. Include methodological information on procedure and design. Outline statistical methods of analysis and demonstrate results using figures and tables. Avoid duplication of information between text and diagrams. Discuss the relevance and implications of the study and provide a brief conclusion.

Acknowledgments

Include professional, methodological, analytical, technical or financial support.

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All articles will be reviewed by two independent referees who have expertise in the article content. Referees may be from the Orthoptic profession or related areas, such as Ophthalmology or Psychology.

References

References should be indicated in the text by superior numbers in the order that they appear in the text and should correspond with a detailed list at the end of the article. Only references directly referring to the text should be listed. References should follow the format: author(s), title of article, journal name (as abbreviated in Index Medicus), year of publication, volume number and inclusive page numbers. References to books should include author(s), title, editor(s), edition, city of publication, publisher, year of publication and page numbers.

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Papers for publication in the Australian Orthoptic Journal may be submitted to the Editor. The journal is published annually. Papers, case histories and other communications should be sent to:

The Editor
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CONTENTS

ORTHOPTIC ASSOCIATION OF AUSTRALIA INC.

OCCUPATIONAL HEALTH AND SAFETY What can it teach us?

Occupational Health and Safety Legislation in all Australian States and Territories has been developed to ensure a safe working environment for employees, regardless of the place or form of employment. Not surprisingly most employment involves vision. Thus the assessment of vision is an integral skill to be tested for every work environment.

The assessment of vision can reveal if an employee meets a generally accepted normal standard such as an acuity level of 6/6 or detect the existence of an abnormality. Vision tests can extend into the assessment of the vision skills necessary for the employment task as identified by a laid down standard or in special cases through an on site visit. The tests can also provide a rich source for the collection of normal responses within an adult population.

Vision tests to determine the presence of normal function can be as simple as a test for acuity. Even in this simple form the tests can provide a base line of information so that change in standard can be detected at a later time. Some changes have been argued to be due to poor work place environments and have led to the generation of assessment strategies such as the Hazpak[1] which is one method that determines the risk associated with employment tasks and ensure strategies are set into place to avoid damage.

Alternatively, vision tests can extend to determine if an individual meets an occupational standard. The tests include colour vision, detection and measurement of ocular deviations for the armed forces[2] or commercial drivers licensing standards[3]. Such standards are sometimes challenged through OHS testing procedures and revoked by individual appeal based on the Anti Discrimination Act (1977) NSW. The Commonwealth also has the "Human Rights and Equal Opportunity Commission to which complaints may also be made, pertaining to various bases of discrimination such as race, sex and physical disability" P. Staunton (2003)[4]. At times Occupational Health and safety reports can cumulatively change existing policy as has been seen in the most recent medical standards for licensing[3] where colour vision was removed as a required standard for commercial drivers. The change was based on reports of no accidents in colour defective drivers.

The assessment of vision in a general format such as an acuity test alone, does not provide an adequate guide about the ability of an employee to undertake a task. If for instance an employee has as a major role working at night, or in a situation where light levels are decreased, then tests to determine the ability to cope in low light levels should be performed along with the general tests. The increased incidence of accidents in a work environment signals environmental problems and the need for specialised testing techniques. These may be best performed by observing the employee in the work environment and making recommendations to enhance performance and safety. These on site visits can then lead to a vision standard being established for future employees. During clinical consultations orthoptists are often in the situation where simple common sense recommendations can be made, for instance the value of regular short breaks from computer use and increasing blink rate during working hours, can be emphasised with a patient experiencing dry eyes.

Personal experience has shown that assessment of the vision of employees yields many people with a very high standard of vision. Data from these tests has provided valuable information about the "normal" response in an adult population. This has two outcomes. The first is it increases our knowledge of normal standards which may be at a higher level than previously thought. The second is by setting a new normal level the point for the existence of abnormality is reset.

OHS is therefore a rich source of information for the employee, the employer and the practitioner. It can bring change to policy, protect the employee and provide evidence to enhance the knowledge of health professionals.

Neryla Jolly
Kathryn Thompson

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The Complicated Diagnosis of Cortical Vision Impairment in Children with Multiple Disabilities

The Emmie Russell Prize 2001

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ABSTRACT

Cortical vision impairment is caused by a variety of neurological insults affecting the posterior visual pathways and/or visual cortex. Children with cortical vision impairment often have additional disabilities and ophthalmic findings, which can complicate the diagnosis of CVI. Children with multiple disabilities and a suspected vision impairment require a thorough investigation to determine the source of their reduced visual responses. Orthoptists may be involved in this process. The importance of distinguishing between reduced visual responses due to cortical vision impairment as opposed to attention difficulties or cognitive delay is discussed in this paper.

KEY WORDS: attention, arousal, cognitive delay, intellectual disability, intervention

INTRODUCTION

Cortical vision impairment (CVI) is a complex condition in which the vision impairment, rather than being of an ocular cause, is primarily due to damage to cortical areas that process vision. Many children with CVI also have additional impairments such as an intellectual disability or cerebral palsy[1]. However there is little emphasis in the literature on the diagnosis of cortical vision impairment in children who have multiple disabilities. Given the increasing incidence of CVI in children over time[2,3], it appears that there is a need for specific information about the diagnosis and prognoses of CVI in children with multiple disabilities.

The neuroanatomical structures related to the processing of vision are implicated in CVI. Significant processing of visual input occurs within the retina and brain before images reach the primary visual cortex. Initially, information from the retina is relayed to the lateral geniculate nucleas (LGN) of the thalamus via the optic nerves and optic tracts. This pathway is referred to as the anterior visual pathway. In addition to the anterior visual pathway it is hypothesized that there are two visual pathways present in the human brain; the geniculostriate pathway and the extragenciculate pathway. These have implications for the diagnosis of CVI. It is well established that the geniculostriate pathway is responsible for the conscious visual analysis of the environment[4]. Involved in this pathway are the LGN, optic radiations, primary visual cortex and visual association cortex (within the occipito-parietal regions)[5]. There is increasing evidence for an extrageniculate visual pathway, which is thought to be responsible for visual attending to a stimulus away from the point of fixation[6]. The extrageniculate pathway extends from the superior colliculus of the midbrain through the pulvinar nucleas of the thalamus, to the visual association cortex[2]. Damage to varying areas of this pathway appears to produce differing types of deficits in being able to shift attention covertly to a stimulus[6]. The extrageniculate pathway may also be responsible for pupillary and blink responses to light, optokinetic nystagmus, pattern discrimination and colour sense[7].

CVI occurs when there is damage to the geniculostriate pathway, extrageniculate pathway or visual cortex[2] and should be suspected in any child with decreased vision that cannot be explained by ocular findings[8]. Different types of neuroimaging techniques have been used with various levels of success to identify damage to the visual pathways and visual cortex in children suspected with having CVI[9]. Identification of regions of dysfunction within the visual pathways assists in confirming a diagnosis of CVI.

In pure CVI, pupillary functions are normal and there is an absence of nystagmus as these are controlled by the anterior portion of the visual pathway[2]. Any insult to the brain may cause CVI, with the main causes being hypoxia-ischemia, head injuries (over half due to 'shaken baby'), shunt failure in hydrocephalus, developmental brain defects, infections of the central nervous system and infantile spasms[10,11]. CVI can be present in children as an isolated finding[12]. However, given that many of the causes of CVI result in diffuse brain damage or are associated with syndromes, it is not surprising that many children who have a vision impairment due to cortical damage, also have ocular findings, additional disabilities and medical conditions[11,13]. The presence of additional problems in children with CVI complicates the process of diagnosing this condition according to the traditional diagnostic criteria.

Implications of additional findings

It is evident that children who have CVI may have ocular findings including nystagmus and abnormal pupillary responses. These may be due to ocular conditions related to the cause of CVI, conditions unrelated to this cause or additional damage to the anterior visual pathways. As many as 65.3% of patients with CVI have been found to have at least one ophthalmological deficit[13]. Optic atrophy is one of the main ophthalmic findings in children with CVI. Groenvald, et al.,[10] found that the prevalence of optic atrophy in children with CVI was 26%. Optic atrophy most commonly occurs due to transynaptic degeneration of the optic nerve following damage to the posterior visual pathways, but may occur at the time of insult as part of the widespread brain damage[14]. The presence of nystagmus in up to 11.2% of children with CVI[13] is further evidence of involvement of the anterior visual pathway in CVI. The nystagmus may occur subsequent to optic atrophy or be due to additional damage to the anterior pathways. This ocular finding is in conflict with the definition of 'pure CVI'. It is of interest though that nystagmus can be absent in the presence of ocular or anterior pathway defects when there is extensive damage to posterior visual pathways[2]. In addition to the above ocular findings, children with CVI have also been found to have strabismus, ocular motor apraxia, gaze palsy, significant refractive error and retinal conditions[13]. In light of the vast array of ophthalmic findings in children with CVI, it is apparent that a thorough ophthalmic investigation, functional vision assessment and sound clinical judgement is necessary to determine whether or not the level of vision impairment can be related to ocular causes, or is in fact attributed to cortical damage. The orthoptist may have a role in performing functional vision assessments and explaining their findings to parents, teachers and other allied health or medical professionals.

The high incidence of additional impairments and medical conditions in children who have CVI may further complicate the diagnosis of CVI. The most common of these are cerebral palsy, epilepsy, hydrocephalus, deafness and intellectual disability[1]. The characteristics of CVI as described by Crossman[4] include the following: poor visual communication skills, fluctuating vision and visual inattention or lack of curiosity. Additional behaviours include that spontaneous visual activity is of short duration, objects may be mouthed instead of explored visually and body position may influence use of vision. Good, et al.,[15] stated that the clinical examination is usually sufficient to establish the diagnosis of CVI. Hence the presence of characteristics, such as the above, in a child with evidence of brain damage but an absence of ocular findings may result in a diagnosis of CVI being made. This is supported by Utley, et al., (1998) who stated that CVI is frequently best diagnosed by considering characteristic behaviours. However, much care must be taken to establish that the visual behaviours are attributed to CVI rather than being directly attributed to a related condition. Difficulties in determining the primary cause of some visual behaviours have been identified[15]. An example of such difficulties includes children who have ocular motor disturbances, as in cerebral palsy. Their inability to shift their gaze towards objects may be mistaken for visual inattention, which is a characteristic behaviour of CVI. A further example of such difficulties is children who have subclinical seizures due to epilepsy. The disturbance of a seizure during certain activities may appear as the child having a short visual attention span[15].

Due to the high incidence of additional disabilities in children with CVI, a thorough medical investigation is necessary to determine whether or not a child has CVI or whether their behaviours are characteristic of their additional disabilities. There is also a need to actively deter professionals and teachers from labeling a child with the often confusing diagnosis of CVI on the basis of visual behaviours, until appropriate investigations have taken place. Orthoptists working with children who have CVI and multiple disabilities would benefit from knowledge of the implications that various impairments such as cerebral palsy and epilepsy have on the use of vision. This knowledge would assist them to make accurate judgements about the cause of a specific visual behaviour in a child with multiple disabilities.

Implications of attention problems and cognitive delay

In addition to difficulties with diagnosis arising from additional conditions, one concern raised in this article is that a child may meet the criteria for diagnosis of CVI and demonstrate the characteristic behaviours, but may experience difficulties in other areas of development at a similar level to their vision impairment. For example, a child may be equally as inattentive and lacking in curiosity to auditory stimuli as to visual stimuli. This raises the concern that CVI may not be an appropriate diagnosis for children who have general cognitive delay or general attention difficulties in several areas including vision. The definition of CVI by Whiting, et al.,[17], encompasses the issue addressed above. Their definition includes that "the diagnosis of CVI should be suspected when there is a greater delay in the visual development than in other areas" (p. 738). In addition Luna, et al.,[18] have commented that it is difficult to determine whether or not deficits in CVI are related to specific anatomical lesions or to more global deficits including attention problems. They stated that techniques for separating attention deficits from visual deficits would be advantageous.

As yet there does not appear to be a method of separating attention deficits from visual deficits in children with multiple disabilities. It is apparent that determining a child's comparative level of development across a variety of areas would be a detailed task and may require the involvement of several professionals in the area of childhood development.

It is likely that the cause of a child's visual behaviour will influence the likelihood of visual improvement over time. Differentiating between visual behaviours specifically due to CVI as opposed to visual behaviours due to cognitive delay or attention deficits raises the issue of whether there are differences in the expected visual prognoses for children in these two groups.

Prognostic outcomes

In general, little is known about specific prognostic outcomes in CVI[15]. Studies have shown that some degree of visual improvement in CVI is common but not to normal levels of vision, with many children remaining vision impaired[2]. Of interest are studies that investigate the visual outcome in children with CVI and multiple disabilities. On the whole it has been found that a poorer visual outcome is more likely in children with extensive neurological damage and a lower level of intellectual attainment in addition to

CVI[2,18,19,20]. More specifically a poorer visual outcome for children with CVI has been found in those with lower IQs[19] and those with neonatal seizures[20]. In children with hypoxic insults but no seizures, visual outcome has been related to general neurological outcome[20]. Additionally it has been well documented that treatment of underlying disorders, such as reduction in seizures in children with CVI and treatment of hydrocephalus is usually accompanied by an improvement in vision[2,21]. The above conclusions clearly identify a relationship between visual outcomes and overall developmental outcomes, with improvements in vision occurring as other areas of development also improve. This supports the author's premise that many children diagnosed with CVI and multiple disabilities may be experiencing visual difficulties which are more related to their general cognitive delay or attention problems rather than being specifically due to CVI. According to the additional definer of CVI put forward by Whiting et al.,[17] children in the above categories may not meet the proposed criteria for diagnosis of CVI.

The importance of an appropriate diagnoses

Children with CVI and multiple disabilities are often involved in programs where the aim is to maximise the use of functional vision[15] and to improve residual vision. Commonly suggested strategies for improving residual vision in children with CVI and for encouraging the use of vision in these children include providing a visually stimulating environment, using strong colours and patterns, using movement and performing tasks in a consistent and standardised fashion[4,15]. However, the notion presented in relevant professional literature, that the level of vision improvement in children with CVI and multiple disabilities is dependant on overall development, indicates that improvements in vision, for these children, may be closely related to attentional or cognitive development. Geniale[22] discussed the importance of arousal level for improvements in overall abilities for children with cerebral palsy. She stated that a prerequisite for optimising visual interest and visual motor control is to obtain an appropriate level of arousal and postural activity. It is apparent that a child's diagnoses may influence whether or not the intervention provided has a specific vision bases or is more related to general development.

Identifying the cause of visual difficulties in a child with multiple disabilities is an important consideration for the appropriate design and implementation of programs to encourage the use of vision. The diagnosis of CVI for some children with multiple disabilities may lead to confusion for parents and teachers, with the misleading belief that the vision impairment exists as a separate entity to the presence of diffuse neurological damage. As a result of this belief children with the diagnoses of CVI may receive a decreased amount of intervention in the area of general attention and arousal, in relation to specific vision intervention. Providing only minimal intervention in the area of attention and arousal would be unfortunate for children whose reduced visual responses are more related to their cognitive delay.

Conclusion

The diagnosis of cortical vision impairment in a child with multiple disabilities is complicated. One of the roles of professionals involved in making such a diagnosis is to carefully evaluate the child's visual behaviours to determine whether these can be attributed to a primary diagnosis of cortical vision impairment or are more related to their additional physical, cognitive or ophthalmic findings. The orthoptist may have the role of performing a functional vision assessment and determining whether the child's visual behaviours can be explained by their ophthalmic findings.

A primary diagnosis of cortical vision impairment as explanation for reduced visual responses should be made with caution, even in the presence of neuroimaging which indicates damage to the visual pathways. Children with extensive neurological damage causing severe intellectual disability may demonstrate reduced responses to stimuli from a variety of mediums. Reduced responses to visual stimuli as well as auditory and tactile stimuli may be indicative of reduced cognitive function rather than a specific vision impairment.

As yet there is no simple means of identifying whether or not poor visual response in a child with multiple disabilities is due to CVI or deficits of attention. Therefore the author recommends that a child with multiple disabilities and suspected cortical vision impairment should be carefully assessed by a multidsciplinary team who are experienced in this field. The overall aim of the team assessment would be to identify whether or not the child's primary impairment is their vision impairment or cognitive delay. The outcome of such assessments may have direct implications for the type of intervention that a child with multiple disabilities and a vision impairment receives.

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The effect of aging on horizontal saccades and smooth pursuit eye movements

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ABSTRACT

A review of the literature indicated that the decrease in ocular motor function with aging may only become apparent as saccadic amplitude and pursuit velocity increase. Tasks within the normal range of movement may show no decrement.

This study with 181 adult participants, from 17 to 78 years of age, measured the effects of aging by testing saccades and smooth pursuit movements, both those that were within the normal range of function and those that were greater. It was found that certain aspects of both saccadic and smooth pursuit eye movement function significantly declined with age - saccadic latency, duration and accuracy; pursuit gain, pursuit trace time and both frequency and amplitude of catch-up saccades. However, smooth pursuit movement showed a more marked decline with aging than saccades.

These results suggest that the age-related decline in eye movement function is due to degenerative changes in the central nervous system and raise the question as to whether these changes affect visual tasks or everyday activities.

INTRODUCTION

Eye movement characteristics are used as part of the diagnosis for a wide variety of neurological conditions, as disorders of either the central or the peripheral nervous system can result in eye movement problems. For example, studies have shown that saccades or pursuits may be affected in adults who have suffered a stroke or neurological trauma[1-3] or in individuals with schizophrenia.[4,5] It is very important that the diagnosis of eye movement abnormality is assessed in the context of age-related normals in order to discriminate between changes occurring as a result of pathology and those related to the normal aging process. Several authors have stated the necessity to establish the normal range of responses from a large range of healthy subjects prior to the diagnosis of eye movement pathology[6-10] with Versino and colleagues[11] stating that aging is one of the most important physiological variables in human function.

Saccades are rapid, conjugate eye movements used to gain foveation and to change fixation from one object to another, they may be voluntary or involuntary. Neurological control is complex, with contribution from various areas, including the frontal eye fields, supplementary eye fields, occipital cortex, posterior parietal cortex, posterior eye fields, dorsolateral prefrontal cortex, thalamus, pulvinar, basal ganglia, superior colliculi and cerebellum. Input from these areas is projected to the paramedian pontine reticular formation (PPRF), the horizontal gaze centre, to produce a temporally coded innervational response from the spatially coded stimulus.[12]

Smooth pursuit movements are present in foveate animals and enable continuous clear vision of moving objects. The stimulus for pursuit is movement of the image on the retina and it is thought to be a negative visual feedback, closed-loop control system where retinal slip results in eye movement to stabilise the image on the fovea. Various cortical areas play a role in smooth pursuit control, with several stages of afferent and efferent processing including the primary visual cortex, middle temporal visual area, medial superior temporal visual area, posterior parietal cortex, frontal eye fields and supplementary eye fields. Neurons from these areas project to the cerebellum and dorsolateral pontine nuclei.[12] There is a final common pathway from the ocular motor nuclei to provide the co-ordinated conjugate eye movements required for all horizontal gaze.

Saccades may be described according to various characteristics which include saccadic latency, duration, amplitude and peak velocity. Saccadic latency is a reflection of the total time required for the afferent and efferent processes required to see the stimulus, to make the decision to perform a saccade, to break fixation and to program and execute the eye movement. Regular saccades are those with a latency in the order of 200 milliseconds.[12] The literature is inconsistent as to the effect of amplitude on saccadic latency. It has been reported that latency increases with amplitude,[12-14] though Versino and colleagues[11] found that latency was not dependent on amplitude. It has also been reported that latency varies with predictability of the target.[12,13,15,16] Peak velocity is related to amplitude in a quasi-linear manner up to amplitudes of 15 - 20 degrees, where it reaches a soft saturation limit and then does not increase as rapidly.[17] This non-linear relationship has been confirmed by various authors, [12,14,18-22] with many authors commenting on the considerable intra-subject variability of peak velocity.[14,21,23-27] Saccadic gain (saccade amplitude/target amplitude) is a measure of the initial accuracy of a saccade. The normal range of saccadic dysmetria is considered to be 10% undershoot.[12,14]

Smooth pursuit latency, the time delay between movement of the stimulus and the eye movement response, is reported to be in the order of 130 milliseconds,[12] with latency not dependent upon target velocity.[28] Smooth pursuit is measured by pursuit velocity, which may then be converted to pursuit gain as the ratio of eye velocity to target velocity. The level of smooth pursuit velocity that can be achieved is considered to reach a maximum in the order of 30 - 40 degrees/second,[12,28,29] with pursuit gain decreasing as the target velocity increases.[28-35] When gain falls below one, the smooth pursuit movement is compensated by saccadic corrections or 'catch-up' saccades, which combine with the pursuit movement to form the eye movement response. The frequency of these saccades increases with target velocity.[29] It is stated that pursuit of predictable targets is better than unpredictable targets.[12,28,32,36,37]

Senescence, the act of growing old or aging, is associated with a decline in various functions, therefore it would be expected that changes may be noted in eye movement function across the adult age range. These ocular motor system changes have been given different levels of importance by various authors. Those studies that assessed ocular motor function in the total context of overall neurological function, stated that the eye movement changes were not commonly believed to cause any substantial disability in the elderly, that they did not interfere with reading or any other functional tasks,[38,39] nor did they result in any symptoms or outward signs of ocular motor disease.[40] In contrast, Hutton and Morris[41] commented that slowness in initiating saccades, inappropriate scanning and abnormal smooth pursuit, compounded by age-related limitations in upgaze, visual fields and contrast sensitivity, may all provide a 'faulty visual framework on which perceptual abnormalities and impaired judgement are superimposed'.

The effect of aging on saccadic function has been studied by several authors. All researchers have found that saccadic latency increases with age.[7-11,14,15,23,42-46] However the effect of age on saccadic peak velocity and duration have remained inconsistent. Several studies report no significant difference in peak saccadic velocity with age.[6,11,25,42] Others reported a difference as the saccadic amplitude increased.[7,9,10,14,46] In contrast, one reported a significant decrease in peak saccadic velocity.[8] The reported effect of age on saccade duration is also inconsistent.[11,14,23] Some studies have reported a decrease in accuracy with age,[9,10] while others found no difference.[7,11,14,42,44]

The effect of aging on pursuit function has also been studied by various authors, again with some conflicting results. Pursuit latency was found to be significantly prolonged with age,[28,34] particularly with higher velocities.[32] However, a later study by Morrow and Sharpe[47] found no difference in latency between a young and an elderly group. There have been many studies of the effect of aging on pursuit gain. All but one of the studies have found pursuit gain to decrease significantly with age, though there are inconsistent results concerning the effect at different target velocities.[5,7,28,31,32,35,38,39,47-53] The frequency of catch-up or corrective saccades provides an indication of the compensatory mechanisms for reduced pursuit gain that occurs with increased velocity or with aging. Several studies found an increase in the frequency of saccades with aging.[5,7,32,51,52]

The specific effects of aging on eye movement function are still uncertain, though it appears that the decrement in eye movement function is related to increased target amplitude in saccades and increased target velocity in smooth pursuit. The differences in results and conclusions are most likely to be due to methodological differences between the research studies. The studies all use different techniques for target stimulus, eye movement recording and analysis, which means that absolute values such as eye velocity cannot be compared. The variation in results may be due to the differing sample sizes, age ranges, and the use of experienced subjects in comparison to naive observers also makes the conclusions of some authors debatable. Aging changes may only become apparent in the stressed situation, when the task requires optimal neurological functioning, but tasks within the range of that performed in normal daily viewing may show no decrement. The aim of this study was to establish the normal range of both horizontal saccades and smooth pursuit movements across the full adult age range, using the Ober 2 infrared measurement system. Unlike most previous research, both saccades and pursuit eye movements were measured over a wide range of amplitudes and velocities to assess whether both systems are affected concurrently or selectively and whether age-related changes are dependent on saccadic amplitude or pursuit velocity.

METHOD

Participants

The participants were 181 healthy adults, 60 male and 121 female, aged between 17 and 78 years. All were naive to eye movement measuring techniques, with no known history of ocular pathology, neurological disorder, or psychoactive medication in the last week prior to testing. All of the older participants were healthy, independent and socially active. Visual acuity was 6/12 or better in each eye, with no manifest deviation detected at either 0.33 or 6 metres and full eye movement excursions as determined by orthoptic examination. The study was approved by the Faculty Human Ethics Committee, Faculty of Health Sciences, La Trobe University.

Instrumentation

This study used the Ober 2 infrared reflection binocular measurement system, with the stimulus being a white target subtending 0.29 degrees projected via a computer overhead projector system to a wall-mounted translucent, white screen at a testing distance of 1.5 metres. The subjects viewed the target binocularly and recordings were made of both eyes, with analysis of the data of one eye only. Eye movements were analysed using custom-designed interactive computer programs, which converted the graphical format of the Ober 2 files into eye movement measurements, via the ASCII file format.

Procedure

Prior to the eye movement measurement, the project was explained and the Informed Consent form was signed. Orthoptic assessment was then performed to determine eligibility.

The Ober 2 goggles were adjusted for the inter-pupillary distance, correctly centred and held comfortably with a velcro strap. The participants were

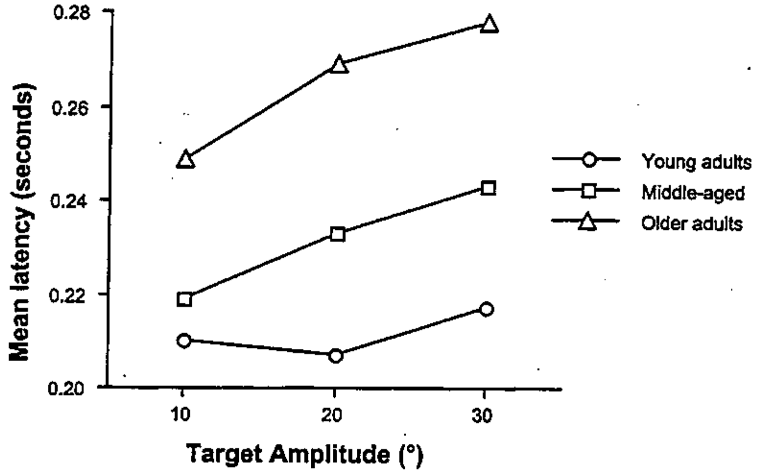

Figure 1. Mean latency values for the three groups for each target amplitude

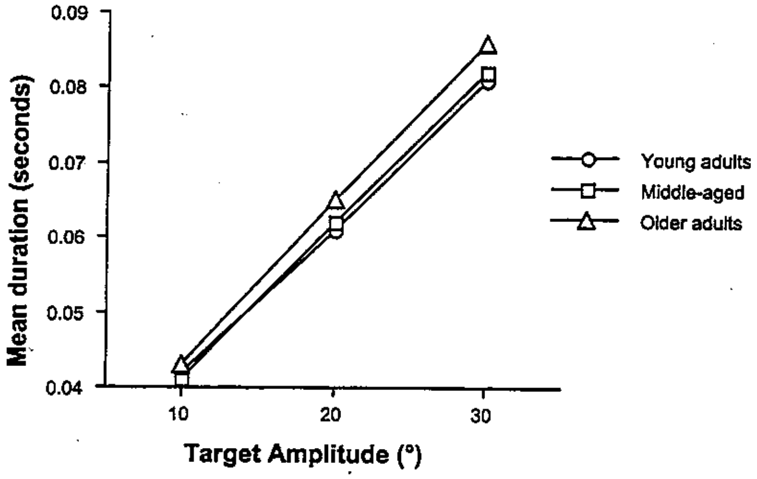

Figure 2. Mean duration values for the three groups for each target amplitude

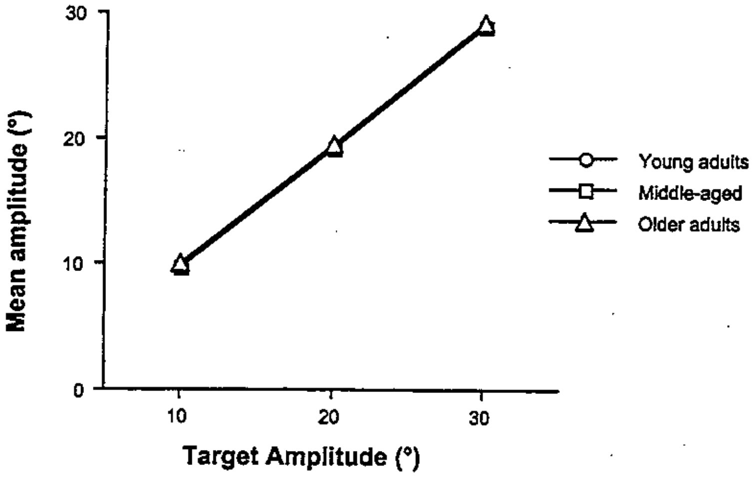

Figure 3. Mean saccadic amplitude values for the three groups for each target amplitude

seated in the darkened room, with the head stabilised by a chin rest and forehead restraint. The saccade protocol was then explained, aiming to gain the most rapid response whilst reducing the incidence of anticipatory saccades. A calibration sequence was run to assess the level of illumination required on the infrared emittors. This calibration sequence not only served the purpose of setting appropriate levels on the Ober 2, but also allowed the participants to practise the technique prior to the first recording.

Saccade stimuli were then presented in predictable sequences with a 1.5 second frequency. Predictable sequences were used with verbal instructions to wait for the target in order to avoid anticipatory saccades.[42] The cycles commenced with fixation to the left of centre, followed by a saccade to the right of centre and a return saccade to the left, so all saccades were across-centre. Five cycles were presented at each of three amplitudes; 10, 20 and 30 degrees. The sensitivity was reduced if necessary to prevent saturation. A sequence was accepted if at least 6 of the 10 saccades appeared to be without blinks or anticipation, or was repeated if this was not achieved. Following the saccade sequences, instructions were given regarding the pursuit movements, that participants were to follow the light as closely and accurately as they could. Smooth pursuit stimuli were then presented in predictable sequences with a constant velocity triangular waveform stimulus moving over an amplitude of 20 degrees, 10 degrees to each side of centre. Five cycles were presented at each velocity; 6.50, 12.99, 19.44, 25.87 and 38.56 degrees/second. These levels of target velocity were due to the constraints imposed by the quality of the computer monitor to allow an apparently smooth movement of the target. Verbal contact was maintained throughout the pursuit procedure in order to sustain attention.[31, 47] The recording was again displayed after each velocity sequence to view that it was an acceptable recording. The total recording sequence usually took between 8 and 18 minutes.

Analysis

The saccadic dependent variables were mean latency, mean duration, mean and standard deviation of saccadic amplitude, and mean peak velocity. The pursuit dependent variables were mean pursuit gain, mean pursuit time (the percentage of the recorded cycle defined as smooth pursuit), frequency of catch-up saccades and mean amplitude of catch-up saccades.

In each set of 10 recordings the program calculated the measurements for each individual saccade or pursuit. The amplitude of each saccade was calibrated by measurement of the mean eye position 0.8 to 0.3 seconds prior to each stimulus presentation, in a similar manner to Wilson et al.[46] To measure regular saccades, generally in the order of 200 milliseconds latency[12] and to avoid anticipatory saccades, acceptable saccades were defined as those with a latency of 90 milliseconds or greater and an amplitude within 10% of target amplitude. Pursuit samples were calibrated by 0.5 seconds of fixation at each extreme position prior to the pursuit movement to determine amplitude of the pursuit, with velocity then calculated for each time sample. Within the pursuit recordings, when the velocity of a single time sample was greater than 79 degrees/second, these time samples were defined as saccades and removed from the pursuit velocity calculations. This detected all saccades of amplitude 1 degree or greater in a similar manner to Bahill et al.[36] With saccade time samples removed, calculation was then made of the total proportion of the trace time that was actually smooth pursuit (pursuit time).[29, 48, 50] Saccades or pursuits that were not acceptable, or were incorrectly identified by the computer program, were deleted from the table and the means recalculated for each set. Only the data from participants where a mean and standard deviation was calculated from at least 6 of the 10 recordings were acceptable was included in the data analysis.

The participant data was grouped into three levels, a young adult group from 17 to 29 years (N = 55, mean age = 21.6, SD 4.16 years), a middle-aged group from 30 to 59 years (N = 81, mean age = 43.8, SD 8.25 years) and an older adult group including those of 60 years and older (N = 45, mean age = 67.6, SD 4.16 years). For saccadic function the final number from which the data for all variables was analysed was 44 participants in the young, 72 in the middle-aged and 43 in the older adult group. For smooth pursuit function the final number from which the data for all variables was analysed was 51 participants in the young, 74 in the middle-aged and 34 in the older adult group.

For the analysis of saccadic eye movement function, each of the dependent variables was analysed using a two-way Age by Target Amplitude ANOVA. For the analysis of smooth pursuit eye movement function, each of the dependent variables was analysed using a two-way Age by Target Velocity ANOVA. Rejection of statistical null hypotheses was set at $p \leq 0.05$.

RESULTS

Saccades

Latency

In Figure 1 it can be seen that mean saccadic latency increased both with age and with target amplitude, and that the latency was increased for all ages for all target amplitudes. The effects for Age [F (2, 156) = 22.17, p = 0.0001] and Target Amplitude [F (2, 312) = 26.90, p = 0.0001] were significant. The interaction effect, Age by Target Amplitude, was significant [F (4, 312) = 3.44, p = 0.009] but appears to be minimal.

Duration

In Figure 2 it can be seen that the largest effect was the increase in mean duration as target amplitude increased with a significant effect for Target Amplitude [F (2, 312) = 3,536.35, p = 0.0001]. There was also a significant effect for Age but this is not particularly large [F (2, 156) = 3.80, p = 0.0244]. The duration was similar for all ages for 10 degree saccades but as target amplitude increased to 20 and 30 degrees, those in the older age group showed longer durations than those in the other groups, with a significant interaction effect [F (4, 312) = 4.03, p = 0.0034].

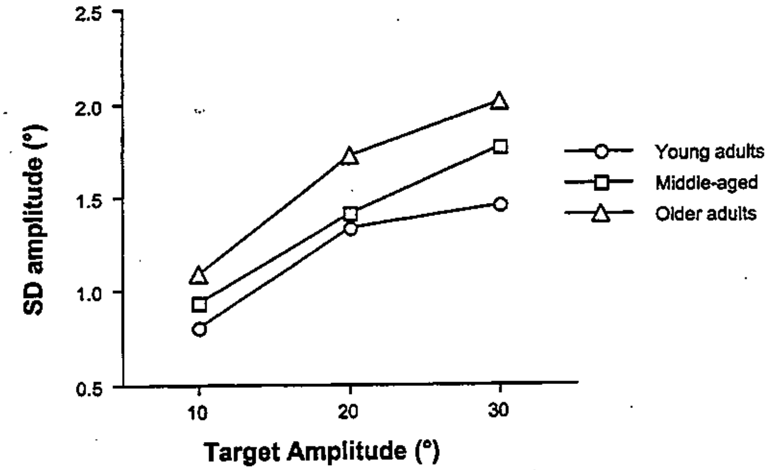

Figure 4. Mean standard deviation of saccadic amplitude values for the three groups for each target amplitude

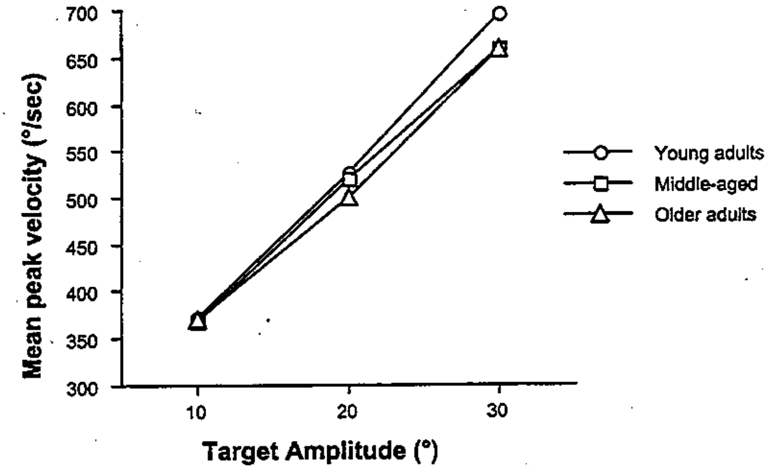

Figure 5. Mean peak velocity values for the three groups for each target amplitude

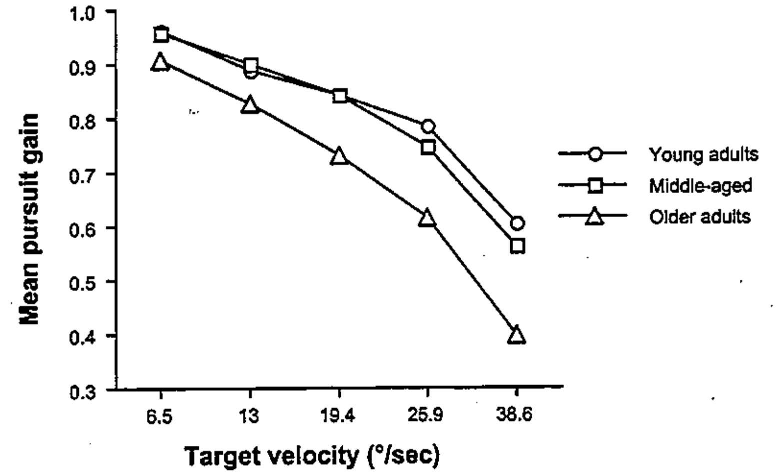

Figure 6. Mean gain values for the three groups for each target velocity

Amplitude

Because the measured variable was mean saccadic amplitude the main effect of Target Amplitude was expected to be large [F (2, 312) = 39,502.84, p = 0.0001] and therefore was of no interest. While the Age effect was significant, it can be seen in Figure 3 that it was only small [F (2, 156) = 4.02, p = 0.0198] and there was no interaction effect [F (4, 312) = 0.20, p = 0.9363]. The individual standard deviations of saccadic amplitude showed significant effects for both Age [F (2, 156) = 5.05, p =0.0075] and Target Amplitude [F (2, 312) = 85.69, p = 0.0001], with no significant interaction effect [F (4, 312) = 1.04, p = 0.3881], displayed in Figure 4. This measure of saccadic accuracy demonstrated that even though the mean saccadic amplitude showed minimal variation with increasing age, the variance around this mean increased with age.

Peak saccadic velocity

Figure 5 shows that mean peak velocity [F (2, 156) = 774.10, p = 0.0001] significantly increased with increasing target amplitude. There was no significant Age effect [F (2, 156) = 1.16, p = 0.3159], nor any interaction effects [F (4, 312) = 1.60, p = 0.1754].

Smooth pursuit

Pursuit gain

In Figure 6 it can be seen that mean pursuit gain steadily decreased as the target velocity increased, with a significant effect for Target Velocity [F (4, 624) = 583.36, p = 0.0001]. The older group had a pursuit gain value less than the other groups at all target velocities, with the middle-aged group showing a decrease only at the faster velocities of 25.9 and 38.6 degrees/second. Pursuit gain in the older group was only minimally less than the other groups at the slowest velocity of 6.5 degrees/second but this difference increased as velocity increased, demonstrated by a significant Age effect [F (2,156) = 13.63, p = 0.0001] and interaction effect [F (8, 624) = 6.83, p = 0.0001].

Pursuit time

In Figure 7 a decrease in mean pursuit time was demonstrated as target velocity increased, with a significant effect for Target Velocity [F (4, 624) = 1,203.24, p = 0.0001]. Pursuit time was minimally decreased from the young to the middle-aged group with a larger effect observed for the older group, particularly for the target velocities of 19.4 degrees/second and faster, with significant Age [F (2, 156) = 17.48, p = 0.0001] and interaction [F (8, 624) = 8.71, p = 0.0001] effects.

Saccadic frequency

In Figure 8 it can be seen that generally there was a decrease in the number of saccades recorded in the five cycles of the pursuit trace from target velocites of 6.5 to 13.0 degrees/second with an increase towards the faster velocities, then a decrease again at the fastest target movement of 38.6 degrees/second. This was demonstrated by a significant Target Velocity effect [F (4, 624) = 4.04, p = 0.0001]. The frequency of saccades within the pursuit trace increased with age, with the more marked difference being at the slowest velocity, with only a minimal difference at the fastest velocity, demonstrated by a significant Age effect [F (2, 156) = 10.98, p = 0.0001] and interaction effect [F (8, 624) = 4.04, p = 0.0001].

Saccadic amplitude

Figure 9 presents the results of mean saccadic amplitude and demonstrated that saccadic amplitude increased as target velocity increased, with a significant Target Velocity effect [F (4, 624) = 408.51, p = 0.0001]. It can be seen that there was only a minimal increase from the young to the middle-aged group but a more marked increase for the older group. There was no difference between the groups at the slowest velocity but the older group demonstrated increasingly larger saccades as the target velocity increased, with a significant effect for Age [F (2, 156) = 9.56, p = 0.0001] and a significant interaction effect [F (8, 624) = 8.18, p = 0.0001].

DISCUSSION

Saccades

Latency

Mean latency of 20 degree saccades increased from 207 milliseconds in the young to 233 milliseconds in the middle-aged and 269 milliseconds in the older adult group (see Figure 1), so giving an apparently steady increase with age, consistent with that reported in the literature.[8,10,15] The latency was longer in the older group than the younger group by 39, 62 and 61 milliseconds for 10, 20 and 30 degree saccades respectively, showing a differential effect in that the variation with amplitude was more apparent in the middle-aged and older than the younger adult groups. Though this study used predictable targets, these latencies were within the range of previous studies,[7-9,11,14,23,27,45,54] most of which used random sequences.

It has been suggested that this increase in latency is not unexpected with age due to the involvement of the entire visual and ocular motor systems, a long and complex pathway, and therefore an increased neural conduction time associated with aging[8,10] and that this is consistent with the increased reaction time for other motor tasks in the elderly.[23] Abel and colleagues[23] suggested it was a result of deterioration of the higher centres involved in programming saccades and Sharpe and Zackon[9] further hypothesised that increased latency may be associated with frontal lobe changes, with parietal lobe deficits resulting in a delayed shifting of attention, or with a general cognitive decline.

Duration

The small but statistically significant increase in duration with age and the more marked increase with saccade amplitude, with duration in the young adult group increasing from 42 to 81 milliseconds and in the older adult group from 43 to 86 milliseconds for 10 and 30 degree saccades respectively (see Figure 2), were consistent with most other studies.[12,17,20] The results of this study also demonstrated a differential aging effect with increasing amplitude, with a similar duration for all ages for 10 degree saccades and a

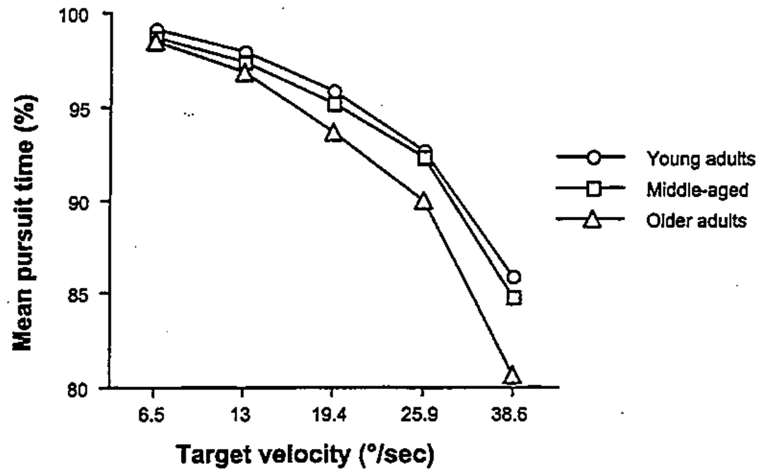

Figure 7. Mean pursuit time values for the three groups for each target velocity

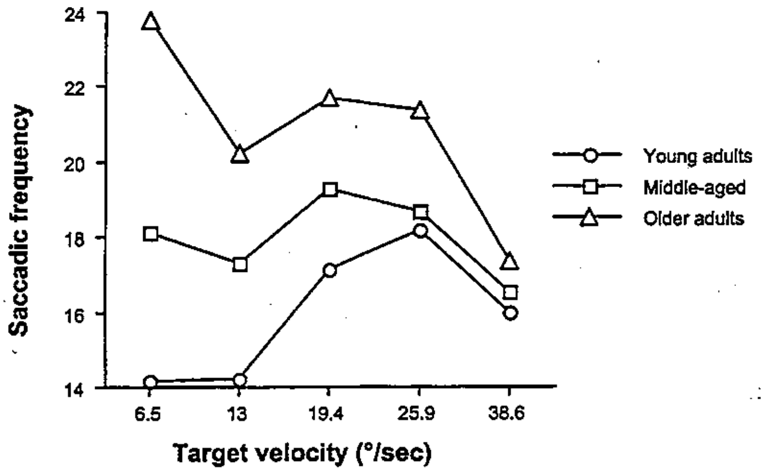

Figure 8. Mean saccadic frequency values for the three groups for each target velocity

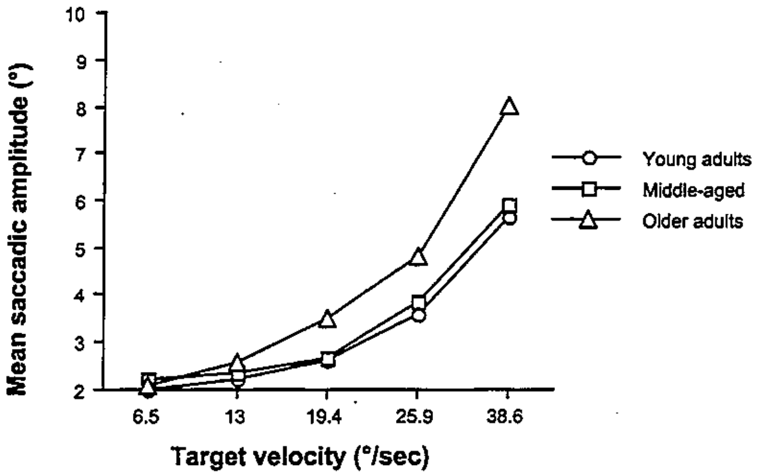

Figure 9. Mean saccadic amplitude values for the three groups for each target velocity

larger increase for the 20 and 30 degree saccades for the older adult group than the other two groups.[11,14]

It might be suggested that the increased saccadic duration is linked with the increased neural conduction time associated with aging in the same way that latency is increased, with an increase in reaction time reflecting the increased processing time required to build up a more accurate premotor command.[11] This would suggest that the increased latency is linked to the increased duration as a compensatory mechanism.

Amplitude

The results of the present study showed no real difference in mean saccadic amplitude with age, but individual variance as measured by the mean of individual standard deviations, significantly increased with increasing age (see Figures 3 & 4). This measurement demonstrated that saccadic accuracy decreased with increasing age even though the mean saccadic amplitude was not markedly affected. A reduction in accuracy has been reported by some studies,[9,10,23] but contradicted by others.[7,11,14,42] Interestingly, Moschner and Baloh[7] reported no decline in accuracy with age, stating that the mean accuracy did not decrease with age but that there was a significant aging effect for intrasubject variability based on individual variances, which finding is replicated by the present study. It has been suggested that deterioration in the higher centres of eye movement control such as the frontal lobes or cerebellum may be responsible for the decrease in accuracy.[9,10]

Peak velocity

The results of the present study (see Figure 5) found, as all others, that peak velocity increased with increasing saccadic amplitude.[12,14,17-22] An aging effect was not found for peak velocity, similar to previous studies.[11,23,25,42] It appears that the aging effect for peak velocity is not strongly demonstrated by other studies except for larger amplitude saccades in the order of 25 degrees or greater,[10,14] and in subjects aged 70 years or older.[7,9,14] On observation of the raw data it was noticed that the peak velocities of those subjects aged 70 years and older did show an apparent decrease compared to those subjects aged in their 60s for saccades of 20 and 30 degree amplitudes, however the number of subjects in the older group was too small for separate analysis.

It has been suggested that the strong effect on latency and the small effect on velocity with age indicate that the higher centres involved in programming saccades deteriorate with age, but that the brainstem saccadic generator is relatively unaffected.[7,9,10,23,43,44] Due to the resistance to aging of the PPRF, significant changes in peak velocity may be an indicator of pathological change rather than aging in anyone under 70 years.

Smooth pursuit

Pursuit gain

The findings of a decrease in mean pursuit gain with increasing velocity (see Figure 6) agree with previous studies.[28-33,35] Pursuit gain also decreased with increasing age. At the target velocity of 6.5 degrees/second there was only a minimal difference in gain between the younger and older adult groups, with mean gain of 0.96 and 0.91 respectively which agrees with previous studies, most of which demonstrated an aging effect when target velocity is in the order of 10 degrees/second or greater but not at slower velocities.[27,32,34,35,47-51] At increasing velocities there was minimal difference between the younger and the middle-aged adults, whereas the older adults demonstrated an increasing difference as target velocity increased, with mean gain being 0.61 and 0.40 for the younger and older groups respectively at the target velocity of 38.6 degrees/second.

Pursuit time

The decrease in the proportion of time of the pursuit cycle that was actually defined as smooth pursuit movement is concomitant with the decrease in mean pursuit gain (see Figure 7). The most marked decrease in pursuit time occurred only at the highest velocity in the younger adult group, from 92.6% to 86.0%, with the middle-aged adults demonstrating similar results, whereas the older adults showed a steady decrease at the slower velocities and dropped to 80.7% at the highest velocity.

Saccadic frequency

In Figure 8 it can be seen that the findings agree with previous reports regarding the increased frequency of catch-up saccades as pursuit velocity increased.[28,29] In the present study the relationship between the frequency of saccades and aging in pursuit movements demonstrated an interesting pattern, where the older adult group demonstrated a much greater saccadic frequency at 6.5 degrees/second target velocity than at 13.0 degrees/second. Kaufman and Abel[49] reported that the elderly showed more distraction than the young at the slower pursuit velocity of 5 degrees/second, compared to a faster velocity of 20 degrees/second. At 38.6 degrees/second target velocity there was minimal difference between the three groups, as was also reported by Sharpe and Sylvester[28] who found no difference between age groups at velocities greater than 40 degrees/second.

Saccadic amplitude

This study demonstrated a significant increase in saccadic amplitude as pursuit velocity increased, from a mean of 2.0 degrees to 5.7 degrees at target velocities of 6.5 and 38.6 degrees/second respectively (see Figure 9), agreeing with the study by Schalen.[29] Saccadic amplitude also increased with aging as reported previously.[28,32] There was only a minimal difference between the saccadic amplitudes of the young and middle-aged group, with the older adults showing a marked increase in amplitude at velocities of 19.4 degrees/second and greater, concomitant with the decrease in pursuit gain.

These four measurements of smooth pursuit combine to give a complete description of the smooth pursuit eye movement, demonstrating a decrease in pursuit gain in the older adult group which was adequately compensated by larger and more frequent saccades than those performed by the younger group.

Similar to the hypotheses concerning the decline of saccadic function with aging, it has been suggested that the decline in pursuit function with age may be due to incipient degenerative processes, such as cerebral cortical atrophy, degeneration of the nigrostriatal pathway and loss of cerebellar Purkinje cells.[7,28,32,35,40,47,51] It has been proposed that there is an age-dependent deterioration in attention to visual targets and visuo-motor tasks and that this may be a reason for the decline in pursuit gain.[7,34,48,49,55,56] Morrow and Sharpe[47] suggested that the sensory limitations of target motion signals were a contributing factor.

CONCLUSION

The results of this study have shown age-related decrements in both horizontal saccadic and smooth pursuit eye movements, with the changes in smooth pursuit more marked than those in saccades. This finding agrees with other studies which reported that the changes in pursuit function were more marked than those in saccadic function.[7,39,53] The decrease in pursuit function occurred predominantly in the older group with minimal differences between the young and the middle-aged groups. In contrast, the changes in saccadic function showed a gradual aging effect across the middle-aged range. It was also demonstrated that the age-related decrement in pursuit function was certainly velocity dependent, with more marked differences as pursuit velocity increased, whereas saccade changes were less amplitude dependent.

The greater effects on pursuit function may be due to the greater reliance of the smooth pursuit eye movement system on the afferent visual system, the closed-loop system which is dependent upon the recognition of retinal slip and target motion and the conversion of afferent information to efferent signals. The many aging changes that occur in the afferent pathway such as senile miosis, cataract development, reduced visual acuity, reduced contrast sensitivity, along with the cerebral cortical changes may all contribute to this greater effect on smooth pursuit than on saccadic function. The prolonged neural conduction time resulting in increased saccadic latency was not amplitude dependent but was apparent as an aging effect even at the smallest target amplitude and across all age groups. The lesser effect on peak saccadic velocity appears to be related to the fact that the brainstem integration centres, such as the PPRF, which are responsible for the pulse of saccade innervation and so primarily peak saccadic velocity, are more resistant to aging changes than other structures involved in saccade function.

A further explanation of the different aging effects of saccade and smooth pursuit function may be the fact that pursuit eye movements are not regularly exercised in the same way as saccades, particularly in the way in which they are clinically examined. In the normal viewing situation the smooth pursuit system is more involved in retinal image stabilisation in combination with the vestibulo-ocular reflex to maintain fixation in the presence of either head, body or target movement, rather than in the following of a moving target with the head and body completely stabilised.

This study raises two other areas for further research. First, the question of differentiating senescence, or normal aging, from pathological changes as raised by Versino and colleagues.[50] As these authors suggested, a study with a large number of older adults is required to measure eye movement function, assess neurophysical and neuropsychological function and document morphological changes to differentiate normal aging from pathological aging. This may be particularly evident in the age group of 70 years and older, where some studies have found a subgroup of subjects who appeared to be different from the rest of the subjects in this age group and suggested that this may be a sign of pathological change rather than normal aging.[38,39] A study of this nature may connect decrement of eye movement function more clearly with degenerative aging changes.

The second question to be resolved is that of the functional implications of the decline in ocular motor function found with aging. This study has found changes in some of the measured variables of saccadic and smooth pursuit function with increasing age, but it is not known to what extent this decrease in ocular motor function can be translated into changes in actual visual activities or even everyday activities. Some of the previous studies have suggested that this decline, along with the reduction in visual sensory systems that occurs, may be quite disabling in the everyday function of elderly people.[15,41] However others, particularly those who assessed a wide range of neurological functions, suggested that the eye movement changes did not cause any substantial difficulty and did not interfere with everyday tasks.[38-40] Again, a large study which measured eye movement function and assessed certain aspects of neuropsychological function may determine the effects of reduced ocular motor function on some aspects of everyday living such as reading and mobility.

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The effects of reading from different mediums (computer screen and paper) on blink rates and lacrimation.

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Abstract

Aim: To evaluate the difference, in lacrimation levels and blink rates, when reading from a Visual Display Unit (VDU) compared with reading from paper.

Procedure: 27 ocularly healthy volunteers were measured for lacrimation (phenol red thread test) and non-invasive tear film break up time (NIBUT) pre and post- reading. Duration of reading was 50 minutes from both mediums (VDU and paper). Blink rates were recorded during reading and averaged at 10-minute intervals.

Results: The blink rates showed a statistical significant increase when subjects read from the VDU. The results showed no significant difference in lacrimation levels before and after reading from either medium.

Conclusion: People who use computers should be advised that computer use increases their blink rates. It has been proven in previous research that regular computer users have decreased lacrimal counts. Therefore, it is recommended that computers should be placed at a lower height to the eyes with the screen tilted upwards, and people who experience dry eye symptoms should use lubricating eye drops.

Key Words: Visual Display Unit (VDU), dry eye, lacrimation, blink rates, reading, paper, computer terminal.

Introduction

Since their introduction into the community, computers have played an increasing role in daily activities and office work, replacing conventional bookwork and reading activities for many people.[1] Computers, as a relatively new technology, are frequently blamed for ocular problems and for this reason should be managed appropriately and in a different way to other near activities.[2] Computer work and conventional bookwork both require reading for extended periods at a position close to the eyes. Therefore, the usage of the two mediums will be considered as near activities. However computer work is generally performed in primary position, at a medium distance (50–70cm), whereas bookwork is usually performed in depression and at a closer distance (30– 40cm).[3] Computers are also light emitting, while paper is light reflective. If these two activities require reading in the close position then similar symptomology should occur and general advice for management of near activities can thus be given. However, if symptomology is different then people should be advised to adjust when reading from either computer or print.

Participants in an OHS (Occupational Health and Safety) vision screening program[4] reported working with computer screens for a high percentage of their work day (5-8 hours). In response to the increased use of computers in the workplace and reports of ocular discomfort with use, a number of anecdotally based documents advising people how to use a VDU have been generated throughout the World Wide Web. These educative documents describe many symptoms that can be associated with computer use such as sore, tired, red and dry eyes, burning sensations, fatigue and blurry vision.[3,5-8] Twombly[5] assumes that computer use causes decreased blink rates. Evidence based articles have shown that symptoms associated with computer use usually occur after 50 minutes of activity.[6,9] Tsubota, Nakamori, Miyake, Matsumoto and Shintani[10,11] states that VDU work is one of the main causes of decreased blink rates.

Dry eye, according to Lemp and Marquardt[12] can be caused by a dysfunction in any of the three differing functional layers of the tear film. The outer lipid layer of the tear film prevents evaporation of the underlying aqueous layer, while the middle aqueous layer contains lysozymes, which nourishes and protects the cornea from invading organisms. The layer closest to the cornea is the inner mucous layer. This layer stabilises the tear film by coating the hydrophobic corneal surface with a hydrophilic layer, over which tears can spread and adhere to the cornea. The tear film covers the outermost surface of the cornea and eye.[13] Constant lubrication of the cornea is essential to maintain its optical surface. If the cornea is not kept wet, it rapidly dries and symptoms of dry, gritty, heavy eyes and occasional blurring can occur. If dry eye becomes a serious condition and no treatment is sought, the cornea can scar and result in blindness.[13] Another natural response is for the tear film to decrease with age.[14]

Asthenopic symptoms are reported to occur when reading print presented on paper[15,16] but there is no reference to the existence of dry eye associated with this activity. This would suggest VDU use specifically causes dry eye problems. In a study by Nakaishi and Yamanda,[17] VDU users with and without asthenopic symptoms were compared. The occurrence of dry eye was more apparent in VDU workers with symptoms.

Yaginuma, Yamada, and Nagai[18] conducted a comparable experiment involving VDU users and non-VDU users (controls). Both groups carried out VDU work for 120 minutes while the experimenters measured blink rate and lacrimation. Lacrimation refers to the production of the aqueous layer of the tear film produced by the lacrimal gland. From the results, they reported that lacrimal secretion rates in the control group, were normal (20.5mm of wetting on the phenol red thread test [PRTT]) before VDU work and decreased after VDU work (18mm).

It is important to note that VDU users in general tend to have drier eyes at base line (10-11mm average). The amount of dryness changes for users hence non-VDU users developed drier eyes when using the computer, while VDU users continue to have the same level of dry eyes.[18] The authors suggest that accumulated VDU operation for consecutive days may create an abnormality in the oily layer of the tear film resulting in increased evaporation of the tear film and dry eye.[18] This raises one aspect of the normal function of lubrication of the eye; another aspect is blink rates.

The blink rate is an adaptive response to dry eyes. Blinking is essential to wipe the cornea free from debris and to keep the tear film evenly spread.[13] Blink rates can vary due to many different reasons including increased tear evaporation, ocular surface drying, and psychiatric conditions. As a person gazes (stares) they blink less and as a result, tears evaporate causing dry eye.[18] Additionally, blink rates can increase as a result of dry eye. Thus, as eyes become dry, a person will blink more frequently to attempt to increase lubrication. Increased blink frequency has been shown to be correlated with reduced tear film break up time (BUT).[12] Therefore, during the course of reading or concentrating on a task (gaze), a person may have decreased blink rates, and as their eyes become relatively dryer, they will increase their blinking to lubricate the eye more, and enhance ocular comfort.

Several researchers have investigated the effects of near activities including VDU and hard copy reading on subjects' blink rates.[9,10,18,19] The research investigated a range of variables including distance (accommodation), height, mediums, time on task, lacrimation, and physiological fatigue. In two separate studies[18,20] the relationship between blink rates and lacrimation associated with VDU work was investigated. Overall, it was found that blink rates are increased when reading from a VDU. Nakamori, Odawara, Nakajima, Mizutani, and Tsubota[20] account for the increased blink interval (decreased blink rate) in terms of being a response to the ocular surface drying.

Mourant, Lakshmanan, and Chantadisai[19] compared VDU search tasks to hard copy and measured physiological fatigue through accommodation and blink rates. They found that two hours of VDU use produced measurable fatigue in the accommodation mechanism of the eyes and higher blink rates (4.94 mean). Such visual fatigue was also present in the hard copy task (3.76 mean) but to a lesser extent. Mourant et al.[19] account the increased blink rates to be suggestive of the ocular muscles being more highly stressed when viewing VDU characters.

Tsubota and Nakamori[10] compared paper reading and VDU reading and its effects on tear film. They found that blink rates decreased when viewing text on the computer screen (7 per minute) and increased when reading a book (10 per minute) at table height, and were higher still when subjects were under relaxed conditions (22 per minute). Tear evaporation was also evaluated and it was found that there was an increase in tear evaporation when VDU viewing was performed. It is important to note that the subjects' blink rates could have been affected by the position of gaze for the three situations as investigated by Cho, Sheng, Chan, Lee, and Tam.[21] Tsubota et al.10 mention that tear evaporation increases with increased ocular surface area. Since the subjects performed the activities at different heights, i.e. VDU work at primary position and reading in depression, then the evaporation of the tear film could be due to the difference in height of the two mediums. This identifies a need for research which investigates tear film and blink rates when reading from the two mediums at the same height and distance from the subjects.

Whilst the symptoms of dry eyes and reduced blink rates have been investigated in relation to VDU use,[5,7,17,18,22,23] limited research has been undertaken in relation to the parallel near activity of reading. Therefore, these two symptoms form the basis of this study which aims to investigate whether there is a difference in blink rates and tear production as elicited in two situations: (1) when reading from a computer specifically, and (2) when engaging in general near activities as represented by reading from paper. The following research questions were explored.

Are the measurements of lacrimation, as tested with the phenol red thread test (PRTT) and the non invasive tear film break up time (NIBUT), the same when reading from paper as compared to when reading from a computer?

Does blink rates differ when reading from paper in comparison to reading from a computer?

Blink rates may increase or decrease while reading from both mediums, but computer work may show a higher increase.[18,19] Even though research has been conducted in this area, the variables of accommodation and distance have not previously been controlled. Therefore, blink rate was also examined when reading from the two different mediums.

METHOD

Sample

A total of 27 volunteers were recruited via convenience sampling. Each subject was provided with an information sheet detailing the procedures and signed the informed consent form. Ethical issues were resolved by using the least invasive measurement methods of lacrimation as possible, for example the phenol red thread test was used for the comfort of the patient instead of the more invasive Schirmer's tear test. To ensure there was no age related impact which could interfere with near performance (e.g. presbyopia and an increase in dry eye) the age range of the subjects was limited to between 18 and 31 years with a mean of 22 years (SD, 3.07) (19 females and 8 males). A history was taken to ensure good general and ocular health. Normal ocular function was ensured by subjects having an unaided Snellens visual acuity of 6/6 and N5 near vision, bifoveal BSV, a deviation which measured less than +/- 8 prism dioptres in the near position, full convergence (=< 5cm, with the royal air force [RAF] rule), and no anomalies of accommodation (RAF rule with N5 print). Red reflex and Slit lamp examinations demonstrated an absence of any obvious eye abnormalities.

Materials and apparatus

In order to provide an accurate measure of blink response a video camera was used. The frequency of each subject's blink was recorded on video.

The dryness of the eyes was measured with two tests: the non-invasive tear film break up time (NIBUT) and the phenol red thread test (PRTT). The NIBUT was chosen because it is a rapid way of assessing the quality of the tear film and it is non invasive. NIBUT was chosen because it does not use fluorescein and there is less chance of a reduction of tear film stablility.[24]

The PRTT was used for the measurement of lacrimation. The PRTT was selected because it is fast to use (15 seconds instead of 5 minutes) and less irritating for the eye particularly compared to the Schirmer's tear test.[17,25]

The NIBUT was measured first and then the PRTT. After testing the first 18 subjects it was found that excessive lacrimation was occurring in some subjects after performing the NIBUT which possibly compounded the PRTT results. A further nine subjects were tested in the opposite order (PRTT then NIBUT) to investigate the order effect of the two tests.

Procedure

A preliminary assessment was conducted to ensure that the criteria for inclusion in the study were met. The subjects were randomly assigned into two groups. Group one read from a computer for 50 minutes on the first visit and on the second visit they read from paper for 50 minutes; group two read from the different mediums in the reverse order. The subjects were exposed to each of these media for 50 minutes to comply with the reported onset of discomfort occurring with VDU use after 50 minutes.[6,9]

In order to undertake the reading tasks the subjects were set up in front of a cathode ray tube screen with 60cm between the subject and the screen. The distance was 60cm because this is the average distance at which a subject will prefer to read from a computer.[23] The same distance (60cm) and height was placed between the subject and the paper so that variations in distance and gaze height would not affect blink rates.[21] A head-rest was used to maintain head height and distance. Room environment was controlled (curtain and illumination constant). Across test sessions, tests were conducted in the same air conditioned room to control for humidity and temperature and its impact on tear film evaporation.[12] Ambient temperature was recorded as being between 22.1–24.6°C, and humidity between 33–49% (using a digital thermometer and humidity analyser). Subjects were asked to scroll through the material on the computer in a way that mimicked reading from paper (reading from the top of the screen down to the bottom then scrolling the material to the top). The reading material included National Geographic articles which were at a maximum of an 11th grade Flesch-Kincaid Grade Level score. After reading the material, the subjects were asked what they learnt from the material read. This was to ensure attention was kept at a high level whilst reading.

Whilst reading from both mediums, the frequency of blink of all subjects was recorded on video. A blink is defined as the complete covering of the cornea by the eyelid. Blink rate is the number of blinks that occur in a minute. The blinks were recorded and averaged at six, three-minute intervals: 0-3min, 9-12min, 19-22min, 29-32min, 39-42min and 47-50min. These blinks were then converted into a blink rate for the six different times.

Lacrimation and NIBUT was measured in each subject pre and post-reading from both mediums. Non-invasive tear film break up time is a measure of tear stability. The NIBUT was performed by using the Slit lamp on the widest aperture and dimmest light source at a 15-degree angle temporally focussing on the tear film. Each subject was asked to blink three times before keeping their eyes open for measurement of the NIBUT. The NIBUT was recorded as the interval between the last complete blink and the development of the first dry spot over the central part of the cornea,[12] or at the point at which the patient blinked or produced reflex tearing. The test was repeated three times for each eye and the average score was calculated. Normal values are above 25 seconds and a NIBUT of less than 10 seconds is considered abnormal.[26]

Lacrimation was measured using the PRTT. The PRTT was performed by placing the 3mm bent end of the thread into the inferior conjunctival sac on the temporal side of the eye. The patients were instructed to look straight ahead and blink normally whilst the thread was left in place for 15 seconds.[17,25] The length of colour change was measured in millimetres. The average wet length for normal eyes is approximately 17mm, and dry eye is defined as less than or equal to 10mm wet length.[17]

Design analysis

To investigate a possibility of dry eye occurring when reading from the two mediums (computer and paper), descriptive statistics were initially calculated on the PRTT and NIBUT results, and the distributions were examined for normality. Because the NIBUT data was skewed and not normally distributed, the non-parametric Wilcoxon Signed ranks test was used to test the hypothesis. To examine the PRTT results a two-factor repeated measures analysis of variance was performed on the data. The two factors were medium (VDU or Paper) and time (before and after).

To investigate the pattern of difference of the blink rates over time when reading from the two mediums an ANOVA with planned orthogonal contrasts was employed. The factors were medium (VDU or paper) and time (1, 10, 20, 30, 40, 48 minutes).

RESULTS

Preliminary Analysis; Order Effects

No significant order effect was found from the difference of scores when either BUT or PRTT was performed first. The test order scores are recorded in Table 1 for right and left eye (Table 1). Accordingly, order was not considered in further analyses.

Table 1 Mean rank NIBUT differences for order of testing

ORDER EFFECT	Test order	N	Mean Rank	Z=	P=
NIBUT RE VDU Difference	BUT 1st	18	12.28	-1.595	0.111
	PRTT 1st	9	17.44		
NIBUT LE VDU Difference	NIBUT 1st	18	12.94	-0.977	0.328
	PRTT 1st	9	16.11		
NIBUT RE Paper Difference	NIBUT 1st	18	13.56	-0.412	0.681
	PRTT 1st	9	14.89		
NIBUT LE Paper Difference	NIBUT 1st	18	12.22	-1.646	0.100
	PRTT 1st	9	17.56		

Phenol Red Thread Test (PRTT)

This section tests HA 1:

Phenol red thread test (PRTT) mean in paper reading is not equal to the mean in VDU reading.

To test HA 1 a two-factor repeated measures analysis of variance was performed. No significant difference was found between the two mediums (VDU and Paper) (right eye F1,26 = 0.29, p = 0.595, left eye F1,26 = 0.25, p = 0.62). No significant difference was found between the results from before reading to after reading (right eye F1,26 = 0.0, p = 1.00, left eye F1,26 = 0.937, p = 0.342). No significant interaction was found between the two mediums and time (right eye F1,26 = 1.883, p = 0.182, left eye F1,26 = 0.703, p = 0.409). Therefore, for PRTT results the null hypothesis is accepted.

Overall, when looking at Figures 1 and 2 it appears that there is an increase in lacrimation after reading from the VDU and a decrease in lacrimation when reading from paper. This difference is very small (2mm) and is not significant. Table 2 shows the descriptive statistics for PRTT results.

Figure 1 Right eye PRTT before and after reading (VDU vs Paper)

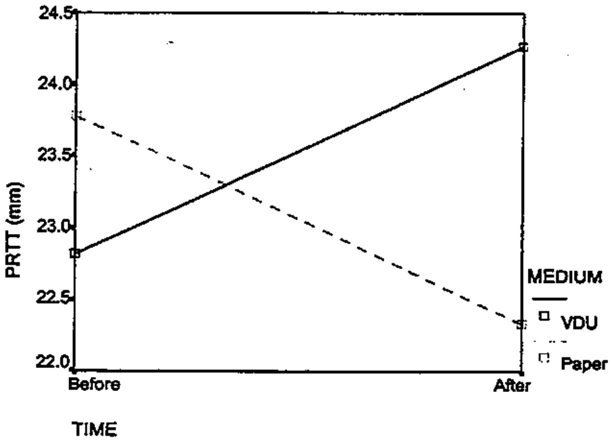


Figure 2 Left eye PRTT before and after reading (VDU vs Paper)

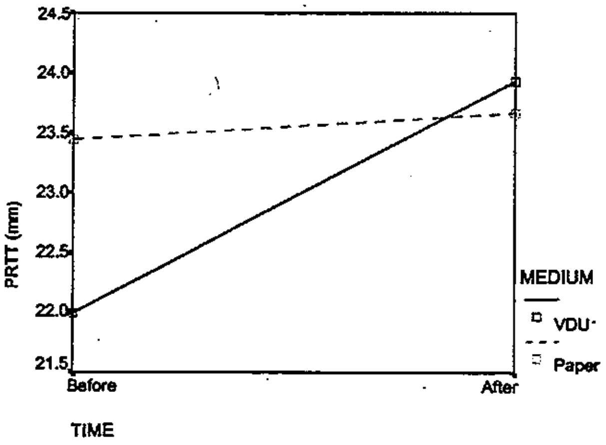


Table 2
Mean PRTT scores and standard deviations for right eye and left eye for VDU and Paper, before and after reading.

PRTT (mm)		Right		Left	
		Before	After	Before	After
VDU	M	22.81	24.26	22.00	23.93
	sd	7.2	6.91	8.64	7.88
Paper	M	23.78	22.33	23.44	23.67
	sd	6.10	7.97	7.27	8.29

M= Mean

Non invasive tear film break up time (NIBUT)

This section tests HA 2:

Non invasive tear film break up time (NIBUT) median in paper reading is not equal to the median in computer reading.

Table 3 displays results of NIBUT for paper and VDU. As the entire NIBUT results were highly skewed a Wilcoxon Signed Ranks Test was applied to analyse the results. The NIBUT results after reading appeared to be slightly larger than the NIBUT scores before reading but this difference was not significant. As can be seen from Table 3 no significant difference was found in the NIBUT results between reading from the computer or from paper. Therefore the null hypothesis is accepted, there is no significant difference between reading from computer or from paper in regard to NIBUT results.

Table 3
Median NIBUT scores and ranges for right eye and left eye for VDU and paper, before and after reading

NIBUT (sec)		Right Eye			Left Eye		
		Before	After	Difference Sig.	Before	After	Difference Sig.
VDU	Median	15	15.3	Z= -0.312	25	12.9	Z= -1.345
	Range	4.9 - 122.9	3.7 - 116.1	P= 0.755	4.6 - 100.9	5.2 - 98.8	P= 0.178
Paper	Median	13	13.9		14.7	14.8	
	Range	6.3 - 156.9	5.4 - 93.1		6.7 - 138.7	5.8 - 209	

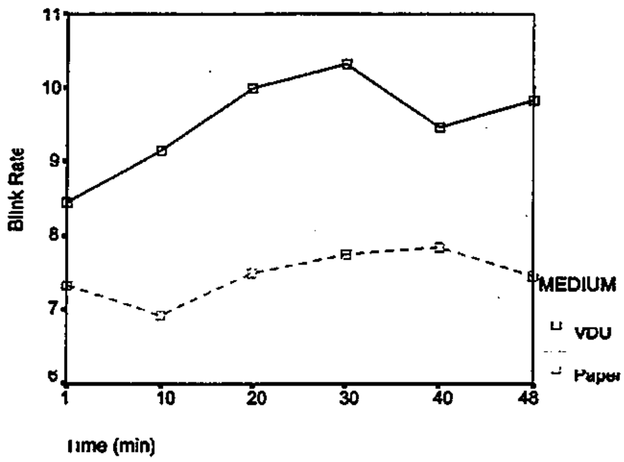
Blink Rates

The blink rates for VDU and paper were averaged at approximately 10-minute intervals (1, 10, 20, 30, 40, 48 min). The results were examined for normality. A portion of the averaged data was slightly skewed but the within-subjects contrasts are not affected by slight skewness.

After performing the within-subjects contrasts the test showed that there is a significant difference (F1,26 = 6.689, p = 0.016) between reading from a computer in comparison to reading from paper with regard to blink rates. The subjects' blink rates were higher when reading from a computer (Figure 3). There were no interactions between medium and time, indicating that the difference between the mediums was the same at all times.

The subjects in this sample had a peak in blink rate at 30 minutes after commencement of reading from a VDU. However, because the change in blink rates over time was not significant for a quadratic effect (F1,26 = 2.647, p = 0.116) only the subjects in the sample have a peak at 30 minutes and this peak cannot be applied to the total population.

Figure 3 Averages of blinks vs time via mediums



DISCUSSION

The current study demonstrates an important association between blink rates and the use of different mediums when reading. There was a statistical significant increase in blink rates when subjects were reading from the VDU. On the contrary, there was no significant difference found for both of the dry eye tests results (PRTT and NIBUT) pre and post-reading when subjects read from either medium. Although due to the low number of subjects in this study, it is possible that these non-significant results could be a type II error.

The significant increase in blink rates when subjects read from a VDU has been both supported[18-20] and condradicted[10] by previous research. Mourant et al.19 and Yaginuma et al.[18] found similar findings of increased blink rates with VDU work, when they compared hard copy search tasks to VDU search tasks. Nakamori et al.[20] found that VDU use was associated with decreased maximum blink intervals (increased blink rate).

The research of Tsubota et al.[10] presented a conflicting result. They found VDU users blink less when reading from a VDU. However, their study did not control for reading distance and therefore accommodation when subjects read from both mediums. They did not control for the effect of position of gaze on blink rates as found by Cho et al.[21]. Although Tsubota et al.[10] found decreased blinking when the subjects read from the computer in the primary position and increased blinking when subjects read from paper in depression, the research of Cho et al.[21] found that in the primary position people should blink more than when their eye position is in depression. The results of the current study were that blinks increased when reading from the VDU and decreased when reading from the hardcopy form. However, as seen in the current study, accommodation and height were controlled by the subjects using a head rest. The results from the current research may be more reliable because more variables were controlled.

There may be many reasons as to why the blink rates increased when subjects read from the VDU. Such reasons include the light source of the two mediums, increased concentration levels when reading from paper, time on task, and age of subjects.

Variability in blink rates across the two mediums may have differed due to the light source of the two mediums. Computer screens are light emitting whereas paper is a light reflective medium. Increased blink rates, when the subjects read from the computer, may have been due to this light-emitting factor. The computer screen was brighter and had light flicker which could have produced a more irritative effect on the eyes causing the subjects to blink more. Conversely, the subjects in this study may have blinked less when reading from the paper version because there was decreased light reflecting from the paper, a possibility supported by the research of Tsubota et al.[27] who found that blink rates decrease with decreased illumination.

Many researchers have associated decreased blink rates with increased concentration and difficulty of activity.[10,18,27] In this study the decreased blink rates found when subjects read from paper may have been due to increased concentration levels. The subjects were exposed to an unnatural situation. The paper-reading situation was set up to mimic reading from a computer. Usually people read from paper at a much closer distance and at a lower height than what was the case in the reading situation. The subjects may have found that reading from the paper form was more difficult; they may have stared for longer periods, and therefore produced a lower blink rate. Further research should investigate if a closer distance would change the blink rates when reading from the two mediums.

Mourant et al.[19] found a statistically significant increase with time on task when performing visual search tasks on VDU and paper. Mourant et al.[19] account for the increase in blink rates with time on task causing fatigue in the human visual mechanism. However this research did not find any statistical significant difference between the 2 mediums for time on task.

Decreased blink rates can cause the eye to be susceptible to drying, and increased blink rates can be a reaction to the eyes becoming dry. However, if the tear film is stable low blink rates can be sufficient to prevent desiccation of the normal ocular surface.[28] It has been found previously that there is an increased incidence of decreased lacrimation, and decreased blink rates among more mature people.[14,19] As the subjects of this study were of a relatively young age (mean 22 years), their lacrimal production would have been sufficient to counteract the drying effect that the computer had on the eyes by increasing their blink rates. Inversely, the blink rates were reduced when subjects read from paper because there was a less drying effect on the eyes; subjects then blinked the required amount to lubricate the eye sufficiently. Further research on older subjects would be required to examine how their blink rates and lacrimation levels change when reading from different mediums. It is likely that older subjects wouldn't be able to overcome the drying affect that computer reading would have on the eyes because their lacrimal systems are insufficient.

Although the current study did not demonstrate any decrease in lacrimation (PRTT and NIBUT), previous work in the area[18] has shown a decrease in lacrimal counts, after reading from a computer, in those people who are non-computer users. Yaginuma et al.[18] found that computer users have decreased lacrimation levels at baseline. A computer user is defined as a person who uses a computer for a minimum of four hours per day for six months.[18] The subjects in the current study had varying amounts of computer use per day. The average amount of computer use by subjects of the current study was three hours per day but this range varied such that some subjects hardly ever used a computer and others regularly used a computer for up to eight hours per day. Therefore, because this extraneous variable (average hours of computer use) was not controlled for in the current study, it may have influenced the lacrimation test results. It would also be beneficial to replicate this research using increased illumination on the paper, so that luminance levels from the two mediums are roughly equal. Further research into the area of computer usage would be beneficial. The period of time required at the computer to produce decreased lacrimal counts could be investigated, for example. Also it would be valuable to find out how long a computer user needs to stop using a computer in order to regain baseline normal lubrication. This further research may have implications for occupational health and safety standards.

CONCLUSION

Contrary to advice given by Twombly[5] that people using computers should blink more often, the current study found that people are already increasing their blink rates when using computers. Rather than suggesting that people should change their behaviour when using computers, they should be supported in their present and typical action (blinking more). It is therefore needful to encourage people to continue to blink normally because it is a natural response to increase blink rates when reading from a computer.

Previous research has found that computer users have drier eyes than non-users.[18] Therefore it is suggested that people who use computers should place the screen at a lower height to the eyes, with the screen tilted upwards.[10,28] This decreases the surface area exposed and thus decreases tear film evaporation. If a patient is complaining of dry eye symptoms when using a computer they should be managed appropriately by using ocular lubricants.

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CLINICAL JUDGMENT OF GDX vcc VERSUS GDX gss

in the detection of nerve fibre layer thinning for glaucoma patients

A PRELIMINARY STUDY

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ABSTRACT

The aim of this preliminary study was to compare retinal nerve fibre layer (RNFL) thinning in patients with either established or suspected glaucoma using the two nerve fibre analysers (GDx gss and GDx vcc) manufactured by Laser Diagnostics Technologies Inc (San Diego). The results obtained were compared with conventional clinical data of 33 patients attending glaucoma clinic. The results demonstrated that both analysers were useful for detecting RNFL loss in established glaucoma and have a positive correspondence with conventional clinical data. The GDx vcc was superior in detecting RNFL loss, which corresponded with the clinical data in 23% of glaucoma suspects compared with a lesser outcome from the original GDx gss. However, from the results there is a significant possibility that 41% of glaucoma suspects may go undetected irrespective of which GDx analyser is used.

Key words: Retinal nerve fibre layer, GDx, glaucoma.

INTRODUCTION

In recent decades ophthalmology has seen many advances in the early detection of glaucoma, primarily assisted by new and improved methods for detection of retinal nerve fibre layer (RNFL) damage. It is now recognised that RNFL damage is visible up to 6 years prior to visual field damage[1]. Nerve fibre analysis using polarimetry is believed to "show damage that leads to glaucoma" as opposed to optic disc and visual field findings that show the damage resulting from glaucoma.[2]

The GDx analyser technology, which is based on scanning laser polarimetry, measures the thickness of the RNFL rather than the surface topography of the retina. The birefringent properties of the nerve fibres cause the polarized laser light to split into two parallel rays that travel at different velocities. The light undergoes a wavelength shift proportional to the thickness of the RNFL. The retardation of the parallel rays as they emerge from the RNFL, directly correlates to the nerve fibre layer thickness.

As the cornea and lens also have birefringent properties, the original GDx Glaucoma scanning system (GDx gss) incorporated a " corneal compensator" to correct for the effect this may have on the retardation measurements. The compensator is set for the average cornea, and is considered to be satisfactory for 80% of patients; however, some patients significantly deviate from the average. When the corneal compensation falls outside 80%, the RNFL may appear thinner or thicker than normal, which leads to unreliable results[3].

To overcome the variability in results associated with the corneal birefringent property, the manufacturers have released the GDx Variable Corneal Compensation (vcc) or GDx Access. The new technology determines and corrects for anterior segment birefringence, from both the cornea and lens, based on individual eye determinations rather than an 'average' corneal birefringent database.

AIM

To determine if individual corneal birefringent compensation in the updated analyser made a difference to the RNFL measurements, staff from the Orthoptic Department undertook a one-month trial, where patients were scanned with both analysers. The results from the two analysers were compared with each other using the Temporal-Superior-Nasal-Inferior-Temporal (TSNIT) graph as the main benchmark. This method was selected because the range of the global indices used in the updated GDx vcc are not the same as those used in the GDx gss and hence not comparable.[2] The TSNIT graph compares 13 parameters with a normative database and highlights deviations from the average parameters. The TSNIT graphs were judged on the image quality of the printouts, retardation of the image, position of the plot relative to the distribution and symmetry of superior and inferior bundles and shape and maximum/minimum height of the TSNIT humps. To analyse the clinical benefit and use of the GDx analysers as glaucoma detection tools, the results of each TSNIT graph were compared with the other clinical data, which included the optic nerve head appearance, intra-ocular pressures and visual fields of each patient. The clinical data was extracted from the medical records of patients attending glaucoma specialty clinics.

METHOD

The clinical evaluation involved a judgment by two orthoptists who individually viewed each set of GDx data along with the ophthalmologists' clinical report. The orthoptists then pooled their findings to determine which subjects were to be included in the study. Allowing each Orthoptist to analyse and compare the results independently before coming to a conclusion was designed to reduce bias in the study.

The study population was recruited from the hospital glaucoma clinics and subjects had either established glaucoma or were glaucoma suspects. In the initial analysis of the data, the results of 33 patients were randomly selected and reviewed. Subjects ranged between the ages of 33 - 91 years with 21 females and 14 males. Subjects were of Caucasian and Asian ethnicity.

Subjects excluded from the analysis included those whose visual field results were judged by the reliability parameters on Humphrey field printout to produce an inadequate outcome . Patients with conditions that cause optic nerve changes such as multiple sclerosis were also excluded. In addition, scans which showed large optic discs, which required an ellipse size outside the standard calculation area, were excluded.

Conventional clinical test results: all subjects were tested on the Humphrey field analyser using the SITA-Standard 24-2 program. When two or more adjacent areas were depressed by 5dB or more in an area at risk of glaucoma loss (i.e. glaucoma hemi-field areas) these fields were treated as suspect or glaucomatous and used for comparison with the RNFL image. This selection was based on the presumption that areas of field loss and loss of the RNFL should correspond.

Optic nerve head appearance judged as suspicious included a cup/disc ratio greater than 0.3 for both colour and contour and any disc abnormalities consistent with glaucoma such as peripapillary atrophy, rim notching/ thinning or shelving. Pressures measured by Goldmann tonometry were considered suspect when above 21mmHg ± 1.22mmHg. This range accounts for the known variations in central corneal thickness[5].

GDX tests : each subject was scanned on both GDx analysers by the same orthoptist. Three single images were obtained on the GDx gss and the highest quality picture was kept for analysis. Only one image of RNFL was taken on the GDx vcc, which is consistent with the acquisition guidelines for this analyser. The results analysed compared the subjects' paired eyes and not individual eyes, as this was determined to resemble the clinical picture more closely. Examining both eyes also allowed for comparison of any asymmetry in RNFL between the two eyes and to determine if this asymmetry was also detected in the subjective data (cupping of discs, visual fields and pressures).

RESULTS

The results were assessed by clinical judgement, as normally conducted in clinical practice. The use of clinical judgement was considered to be appropriate as the orthoptists involved in the evaluation have five years experience in the use and evaluation of the original GDx. Choplin and Sanchez-Galeana[6,7] investigated the "power of expert judgments of the GDx printouts for detecting glaucoma " and concluded that clinical judgment of printouts was superior to the automatically generated parameters, such as 'The Number'.

Thirty three patients fulfilled the criteria for this study. Eleven (33%) had established glaucoma, and were on single or combination dose glaucoma treatment. Twenty two (67%) were identified as glaucoma suspects, defined by suspicious results on either tonometry, optic nerve head appearance or visual fields, these patients were not on any glaucoma treatment. Of the 11 patients with established glaucoma, ten (91%) showed corresponding nerve fibre loss on the TSNIT graphs in both GDx printouts with the clinical data. In the remaining subject there was no correspondence between either GDx or the clinical evidence.

Of the 22 glaucoma suspects, eight (36%) showed similar nerve fibre loss on the TSNIT graph between the two analysers and the RNFL thinning correlated with the visual field loss and optic nerve head appearance. Five of the 22 (23%) subjects showed nerve fibre loss that correlated closely with the TSNIT graph of the GDx vcc and the clinical data. In these subjects there was no correlation with the GDx gss.

In nine (41%) of the glaucoma suspects it was difficult to decide which of the two GDx models was the more accurate. In these subjects there was no correspondence between the two TSNIT printouts of either analyser, with the analysers eliciting nerve fibre loss in different quadrants of the TSNIT. In addition, the RNFL loss of both was not consistent with the clinical data presented, so a benchmark could not be determined. Table 1 lists the results of the study.

Table 1.

Defect	No. of patients	Correspondence of both GDx with clinical data	Correspondence of GDx vcc only with clinical data	Correspondence of GDx gss only with clinical data	Neither
Established glaucoma	11	10 corresponded	0	0	1
Glaucoma suspects	22	8	5	0	9

Table 1. Comparison of GDx results with clinical data in subjects with established glaucoma and glaucoma suspects.

DISCUSSION

In this study, ten subjects with established glaucoma as determined by conventional clinical tests had nerve fibre loss present on both TSNIT graphs of the GDx gss and GDx vcc, which corresponded with the clinical data. Detection rates of RNFL loss were higher in advanced glaucoma as opposed to early glaucoma with both analysers. The results confirm that the GDx gss and GDx vcc are useful tools for detecting advanced cases of glaucoma in 91% of patients.

In the glaucoma suspects, the GDx vcc, which compensates for anterior segment birefringence was a more effective tool than the GDx gss in 23% more cases for diagnosing RNFL loss that corresponds with clinical evidence.

In spite of the increased diagnostic value of the GDx vcc, the role of nerve fibre analysers in glaucoma screening is still subject to some scepticism as to the clinical value. Essentially, the cost benefit of screening needs to be decided, keeping in mind that 41% of glaucoma suspects may be missed with both GDx analysers, and perhaps clinicians may have to according to Colen et al[8] "...accept that some early cases of glaucoma may be undetected". To determine the cost effectiveness of this technology further research needs to be undertaken. Comparisons of the TSNIT graphs to results from the SWAP visual fields and/or Frequency Doubling Technique, which are accepted as detecting early glaucomatous changes prior to any abnormality appearing on the SITA-Standard visual field techniques should be conducted. A statistical evaluation of both analysers for glaucoma suspects also needs to be performed, comparing the sensitivity and specificity of each analyser in early glaucoma compared with a control age-matched normal group.

In conclusion, the GDx gss and GDx vcc are effective clinical tools for detecting RNFL loss in established glaucoma and have a positive correlation with the clinical data. In glaucoma suspects, evidence of glaucoma comparable to the clinical data has a higher frequency of detection with the GDx vcc compared with the GDx gss. However, from the results there is a significant possibility that 41% of glaucoma suspects may go undetected irrespective of which GDx analyser is used. Given that over 300,000 Australians currently have glaucoma and this proportion will increase with our aging population[9], the improved early detection of RNFL loss with the GDx vcc deserves consideration. The medical benefit to the patient and saved financial cost to the community of early detection in 23% of glaucoma suspects with the GDx vcc warrants the inclusion of this equipment in the management of glaucoma.

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Vision and Computer Use – a Literature Review

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ABSTRACT

Literature from international and national sources has been reviewed to establish whether there is evidence that vision is affected by computer use. The sources used include electronic databases, refereed articles, brochures, policy documents and conference presentations. The ocular function of computer users was also evaluated against Hazpak Occupational Health and Safety criteria[1].

The literature revealed that visual discomfort was caused by ocular and environmental problems. The ocular problems included a transient increase in accommodation, inappropriate focal length of spectacles and reduced lacrimation. The environmental factors included "time on task", surround luminance, screen qualities, screen position and document source position, as well as screen distance and work station contamination. The Hazpak analysis of risk for vision problems caused by computer use, revealed a low level of importance and low risk.

Strategies to support vision comfort included appropriate spectacle correction (focal length and single focus lenses), managing "time on task" to reduce stress on ocular function, actions to decrease dry eyes, and ensuring screen qualities assist easy visual appreciation and comfort of viewing. It is concluded that computer users may experience vision discomfort but this can be managed with appropriate vision treatment and judicious attention to environmental issues.

Key Words: computer use; vision; OHS assessment; environmental factors.

INTRODUCTION

Computers are increasingly being used by a wide range of people in the community for work, education, entertainment and pleasure. Interviews of employees during Occupational Health and Safety assessments (OHS) have revealed that computers are used for work purposes between 5 and 10 hours a day [2] with the hours of use for leisure purposes being unmeasured. This level of use places the computer under scrutiny as a potential work place hazard, particularly because it includes an electronic screen, which is potentially associated with radiation and it "requires sustained focus at a distance between 50 and 150 cms"[3]. Computer users may experience a range of symptoms which for the purposes of this review will be defined as visual discomfort. The symptoms include blurred vision, problems finding an appropriate focal length for the computer screen and aesthenopia. The Occupational Health and Safety Act [4] has raised awareness of safety in the work environment with an expectation that the workplace will be safe. To support this fines have been introduced for both the employing company and the supervisor to ensure compliance with standards[4]. These factors together raise the possibility that computers are harmful for the eyes and that users require special management strategies.

This review of the literature, which includes both broad based information from web sources and printed advertising material as well as evidence from peer reviewed publications, will consider whether the use of computers can cause problems for the eyes. It will explore the best strategies to support ocular comfort when using computers. The paper will also introduce an OHS method of evaluating the impact of the computer on vision.

COMPUTER TRIGGERED CHANGE TO EYE FUNCTION

Radiation

A computer is an electronic device, which emits rather than reflects light. The emission involves radiation and there is concern that this is harmful to the eyes. Several sources deny that the radiation is harmful[5,6] reporting that the "wavelengths are well below any exposure doses"[7] and that computers "emit little or no harmful ionizing radiation (X ray) or non ionizing radiation (ultraviolet)" and that in computer based equipment the radiation emitted is less than fluorescent lights". The Royal College of Ophthalmologists[6] comment that there is "no published evidence" that computers cause harm to the eyes. This view is further supported by the American Academy of Ophthalmology[5] which states that there is "no convincing evidence that computers are harmful to the eyes".

Dillon[8], Cole Maddocks and Sharpe[9] support that there is no relationship between the long term use of computer and permanent changes in the visual system. Cole et al[9] in a study of computer users compared to non computer users, reported that for the two groups there was no significant difference in the increases of diseases of the external eye, cornea, anterior chamber, iris, pupil, optic nerve head, vitreous or lens. The American Academy of Ophthalmology reports that the radiation from computers is below the levels that produces cataracts or other conditions that are susceptible to light[5]. When the recommendation from professional societies state that there is no evidence of harm to the eyes and evidence from research supports that there is no development of pathology, then it can be concluded that radiation from the screen is not a cause of adverse effect to the visual system.

Visual Discomfort / Computer Triggered Symptoms

Symptoms of discomfort, such as sore tired eyes, which arise in association with use of the computer, can suggest some form of harm being generated through use of the device. Systems Concept[10] in a web document relating to display screen regulations and Dillon[8], report the existence of short term visual discomfort, but no long term damage in people who use computers. Ocular fatigue is reported by many authors[8,11,12,13] but is then attributed to poor work station set up, general fatigue, excessive time spent on computer work, intensity of work and psychosocial issues. Management of these issues is recommended as a first step to reduce ocular discomfort. Other sources[8,14] reported computer users who experienced symptoms but did not undertake treatment and showed no evidence of change in their symptoms over a 24 to 30 month time frame. This suggests that continued use of a computer does not cause the ocular condition to deteriorate otherwise the symptoms would have increased or other visual changes would have occurred. In fact Dillon[8] suggests that "pre existing poor eyesight influences subjective reports of visual fatigue", rather than computer use causing sight problems. Oftedal, Nyvang and Moen[15] found an interesting response when filters with adaptations to screen out electric fields were fitted to the computer screen and without the knowledge of the user, were either not activated or activated. In both cases the symptoms decreased compared to working with the computer and no adaptive screen. The outcome supports a strong placebo / Hawthorne effect and reinforces that computers themselves do not cause ocular discomfort.

Visual Acuity

Wulff[14] found that computer operators (n=52) who had an initial and then a repeat assessment of their visual acuity after 2 years showed no significant difference in their vision. Cole et al[9] and Futyma[16] assessed two groups, one used computers and the other did not. Both studies found that the visual acuity standard was the same regardless of whether the computer was or was not used. The study by Futyma demonstrates no change over a period of between 5 and 12 years of computer use. These studies support the conclusion that computer use does not affect visual acuity.

Refractive errors

Grignolo, DiBari, Bellan, Camarino and Maina[17] carried out a long term study of computer operators (n = 6000) and found that changes in the refractive state of their eyes was not related to computer use but was largely age related. Rechichi and Scullica[18] found that over a 6 year period, employees (n = 23,000) who used a computer for 6 hours a day, did not induce or worsen their refractive state. Cole et al[9] reported a population matched study of computer users compared with non computer users and found no statistically significant difference between those who wore glasses or not. Cole did report a greater incidence of myopia in the computer users but concluded that the reported myopia was due to chance rather than related to computer use. As will be discussed later the myopia may be related to an increase in accommodation capacity following work activities. Rose, Morgan, Smith and Mitchell[19] reported an increase in myopia in children and hypothesised it to be related to an increase in long periods of close work but there is no similar report in adult computer users.

The correction of the refractive errors did however, raise discussion about the relationship between the focal length of spectacles and the conventional distance and position that the computer screen is from the eyes. Piccoli[20] found the preferred working distance of computer operators to range between 48.42 cms and 65.33 cms which is supported by the recommendation of the Royal College of Ophthalmologists[6] and the regulations of Systems Concept[10] that the distance be between 50 and 60 cms. This distance causes particular problems for presbyopic computer users who conventionally are prescribed spectacles with a focal length of 30 cms. This incompatible focal length, results in the computer screen being out of focus at the 50 cm range and raises the need for the user to move their head and eyes closer to the screen in order to see. This could results in neck, not vision, discomfort[21].

In addition the presbyopic people who have bi, tri or multifocals may find the position of the near correction in the lower part of the lens to be inappropriate. This is because the information on the screen is only clear when seen through the reading segment, which is positioned in the lower half of the spectacle lens. When the screen is set in an elevated position, the user has to position their near correction over the screen which results in raising the chin. The resultant "chin up posture" to see the screen can again cause neck discomfort. In reality the refractive error is not causing the problem, the format of the optical correction is the problem. Spectacles with a longer focal length are required and either a pair of single focus spectacles for computer use or adjustment of the screen height to be within the near add position is required. The only form of screen set up where conventional multifocals are appropriate is for people who use a lap top computers which are positioned on a desk so the screen is lower and in the field of the reading segment.

Accommodation

Several authors have considered accommodation and measured outcomes in different circumstances that is: computer use compared with non computer use[16,20]; short periods of use[22] compared to long periods of use[13,16], young users with responsive accommodation compared to older users with less responsive accommodation[13]; and use over several years[9]. Dillon[8] identified a significant statistical relationship between symptoms of visual fatigue and a change in accommodation in computer users. Piccoli[20] reported an excess of accommodation, measured by refraction, at the end of an hour of close work. The increase was more marked after computer use than other office activities. Gunnarsson[23] similarly found an increase in measured accommodation after a work session of 8 hours (8am to 4 pm) but only in younger employees. In the older employees there was no change. On the other side of the argument, Gray, Gilmartin & Winn[22] reported no change in accommodation in asymptomatic individuals after 25 minutes of computer or hard copy work. Futyma[16] also found no change in accommodation for people who used a computer 5.6 hours a day, 6 days a week for between 5 and 12 years. Cole et al[9] in a study of people who were followed up over several years, found no difference in the accommodation amplitude between computer and non computer users. Overall, there is no clear evidence that accommodation is permanently affected by computer use. There is some evidence that accommodation is temporarily affected if any near activity is undertaken, whether computer or general office work[12]. It is however more affected if the close activity is with a computer, is undertaken for one hour or more, and the person is in the age group where accommodation is flexible[12]. Potentially, when working on a computer, the ocular use is more concentrated in the one near position and this near activity is a precursor to the development of myopia[19] presumably through a link to sustained accommodation. The above studies identify some increase in accommodation associated with computer use but there is insufficient evidence to link to an ongoing change into myopia. The outcome supports short periods of computer use with breaks to decrease the accommodation effort.

Eye Movement disorders (incorporating heterophorias and convergence)

Cole et al[9] found that there was no difference in the near heterophorias between computer and non computer users. Grinoli[17] found that there was no change in the near hetrophoria over time and that office work helped to improve the condition although what was meant by this was not identified.

The reported convergence responses included all possibilities. Gunnarsson[13] reported that convergence increased with computer use and decreased following rest breaks. Piccoli[20] reported a decrease in convergence at the end of a work period. Futyma[16] reported no change in convergence in association with work sessions and Wulff[14] reported no change in the clinical measurement over a 2 year period. Dillon[8] and Iribarren[24] both report an association of symptoms with convergence defects. Matsouoka, Nakamura and Kobatake[25] reported that computer operators who had symptoms of ocular discomfort had a higher incidence of exophoria and convergence insufficiency.

These outcomes suggest that, for some computer users, there is no change, for some there is improvement and for other users there is a decrease in ocular function. As all computer users are not adversely affected, use of the computer, cannot be identified as the sole cause of eye movement problems. Decrease in the control of a heterophoria (particularly an exophoria) and convergence are commonly seen clinical condition. The reason for change is more likely to be associated with close activity that occurs with computer use.

Stereopsis

Futyma[16] reported no change in the stereopsis of non computer users compared with computer users when the use was 5.6 hours a day, 6 days a week over a period of 5 and 12 years. Wulff[14] reported a follow up after 2 years where there was no significant difference in the response.

Blink Rate and Tear Flow

Blink rate and tear flow are linked to dry eyes and general ocular symptoms. It is reported that computer tasks causes people to stare[26,27] and blink less[27,28,29]. Acosta[29] found that drying of the cornea and conjunctiva increased the blink rate but in computer users the blink rate was decreased. He hypothesised that the decreased blink rate that occurs in computer users is because the central neural mechanism over-road the peripheral sensory input and consequently led to a decreased blink rate. The position of the eyes also is reported to have an effect on blink rate with Doughty[30] reporting that when the eyes are in the reading position, the blink rate is less than when the eyes are looking in the primary position.

Reduced lacrimation when using a computer has been reported. Nakaishi Hitoshi, Yamada & Yuichi[31] reported 34% of computer users with symptoms had dry eyes compared to 10% of non computer users. Yaginuma[27] reported that the reduction in lacrimation that occurred at the time of using the computer had a long term effect (26% lacrimation decrease when a computer is used 100 hours a month and 36% decrease for use of greater than 100 hours a month).

Dry eyes, decreased blink rates and associated symptoms, such as a foreign body sensation, are reported[8,27,29,30,31] in association with computer use. Several authors suggest methods to overcome dry eyes will lead to an increase in comfort. These methods include instillation of elasto viscose drops[29]· the use of a gelatin rod[27] and an increase in blink rate[30].

The evidence in this area supports that computer users blink less, have reduced lacrimation, and experience symptoms associated with dry eyes. If this is acknowledged, then, mechanisms to assist increasing lubrication in the eyes of computer users are important especially if they are symptomatic. Strategies should include advice to blink as much as possible and to use some form of lubricant as the need arises.

THE ENVIRONMENT, THE EYES AND COMPUTER USE

Jackson, Barnett, Stevens, Mcclure, Patterson & McReynolds[32] reported that of 571 employees who used computers, the successful management of the users with problems required modification of the work-station ergonomics, variation in working pattern variation. In 5% of the employees there was a need for attention to vision problems. The issue of the environment is therefore an important consideration for all computer user.

"Time on Task"

Studies that investigate computer use report symptoms of ocular fatigue[8,10,23,24,32,33]. There is no consensus about the cause of the symptoms but time on task is raised as a major reason for the fatigue. A variety of hours undertaking computer tasks were linked to fatigue. Travers[33] reported a general increase of symptoms as computer usage increased. Dillon[8] citing Matthew reported a linear increase in discomfort with time and Tyrell and Liebowitz[8] reported continuous reading of computer text for just under 2 hours was linked to ocular fatigue. Systems concept[10] reported 4 hours computer use and Mourant[12] reported 2 to 3 hours of use was linked to discomfort.

A variation to "time on task" was exposure to computers over time. A number of authors[8,14,21] who have undertaken a longitudinal study of computer users reported no change in the level of visual symptoms, over an extended period.

These results support a change in vision function as the user is exposed to computer use. The exposure can be for a given period or over time. Ensuring breaks from using the computer would be a prudent way to minimise such symptoms.

Computer use compared with near tasks

There is a logic that computer use is the same as pen and paper tasks, reading, and general office duties. All these tasks are performed in the near position and can involve continuous focus. Therefore there should be no difference in the ocular discomfort that is experienced by computer and non-computer users. Several authors[8,9,14] report findings that support this. Piccoli[20] et al reported an increase in discomfort with computer use compared to other near tasks and Mourant[12] reported that computer use caused a more rapid onset of the discomfort. The intensity of the work activity also has been reported to have an impact with Jackson[32] reporting uninterrupted use of the computer being linked to a greater incidence of symptoms[5].

The issues of "time on task" and intensity of task being linked to ocular discomfort adds support to the guidelines presented by the National Safety Council of Australia[34] and the American Academy of Ophthalmology[5] that there should be regular rest breaks. The frequency and amount of the break varies with the National Safety Council recommending 15 minutes every hour and that employees should not spend more than half their working day on computer activities. Mourant[12] reported recovery from discomfort following a rest which supports the use of regular breaks.

Surround luminance

Glare appears to have an influence on ocular function. Wolksa and Switula[35] report a tendency for a change in ocular function particularly a reduction in accommodation amplitude. Dillon[8] and Travers[33] report a link between glare and visual symptoms with the symptoms ranging between problems with reflections to aesthenopic responses. Collins[21] reported no significant association between glare and visual symptoms and that problems from glare only arose when windows were in the users fields of view. Management of glare is advised to be that lighting should be set up to avoid reflections[5]. This can be evaluated by observing if the users reflection can be seen before the computer is switched on[36]. If this does occur there is too much reflection and indirect glare and discomfort is likely.

Low illumination has also been reported to be problematic for computere users. Dillon[8] reported problems reading the key board, source documents and other information as well as visual fatigue, in low illumination.

Screen qualities

Cathode ray tubes (CRT) are reported to be associated with better visual comfort than liquid crystal display screens (LCD)[35] with the LCD which have poor figure to background contrast and are more difficult to focus. The use of a filter over the screen is reported to result in a reduction in surround reflections and appreciation of screen flicker[15,21,33].

Screen and Document source

The American Academy of Ophthalmology[5] recommends that the distance of the computer screen should be "a little further away than normal reading distance". Dillon[8] reported that closer positioning of the screen induced more ocular and musculo skeletal strain. The best choice is reported by Jaschinski & Kylain[37] report that choice of screen distance is individual but is probably best between 60and 100 cms. This will of course be affected by, the optical correction and the effective focal length of any spectacles that are worn.

The position of the screen is advised by The American Academy of Ophthalmology[5] to be "at or a little below eye level" and Burt[36] recommends that the screen should be approximately at the middle of the forehead. Jaschinski[37] et al reported that when the screen was positioned at or above the straight ahead position (zero point) there was greater eye strain. They recommended that the screen should be positioned between horizontal and 16 degrees downward.

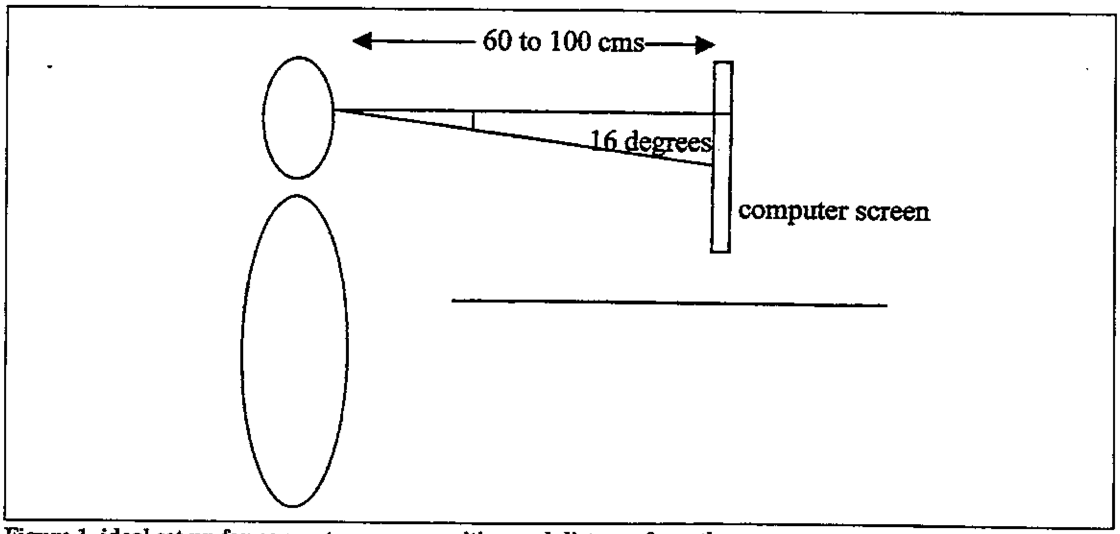

Figure 1, ideal set up for computer screen position and distance from the eyes

The position of the document source is recommended to be next to the computer screen[5,36] which ideally should be between 60 and 100 cms. As with the screen distance it was found that closer positioning of the source document induced more strain[8,37].

Text qualities

Collins et al[21] report screen legibility (character design, size and contrast) influenced the occurrence of visual symptoms. Ziefle[38] reported display resolution on a CRT screen of 60 to 120 dots per inch resulted in decreased performance for proof reading speed and accuracy compared with hard copy of 255 dots per inch. He also found that low resolution (dots per inch) increased fixation time, reaction time and symptoms. Dillon[8] reported less fatigue with low resolution. Miyao[39] found that for small characters high resolution was important for readability. The outcome suggests that overall high resolution of display material allows the user to be more effective and remain comfortable.

Work Station Contamination

Microbial samples taken from work stations showed the presence of bacteria and fungi[40]. Sites from which the samples were taken included the keyboard, mouse and screen. There was also high microbial pollution in the conjunctival sac of computer operators but less in the non-computer operators[40]. These contaminants could cause low-grade discomfort, which may be attributed to computer use or environmental issues such as glare. This result suggests a need for increased attention to the management of computer users with eye infections to prevent ongoing infection.

RISK ANALYSIS - OHS EVALUATION OF COMPUTER USE ON VISION

As mentioned earlier, computers are used for a significant part of the employment hours of many people. The computer has been identified as a potential hazard by professional[5] and union groups[34] Guidelnes for its use have been adopted in the workplace. For instance the Australian Council of Trade Union guidelines[34] recommend that computer users should not spend more than half their working day on computers. Table 1 presents a method of determining the risk level for visual problems arising from computer use. It is based on the document Hazpak which has been developed by Workcover. On the left side of the table are the Measurement Criteria that are used to determine whether a work situation has a level of risk attached to it. In the first Measurement section, "Severity Level Range", there are 4 choices. In the second Measurement section which addresses the "Liklihood of experiencing a severity level", there are 4 choices and in the final Measurement section the "Importance" can be ranked between 1 and 6. When a vision problem is analysed, it is matched to the most likely critera. An example is shown in the right hand columns. The "Severity Level" is minor, the "Liklihood" is minor (unlikely) and the "Importance" is at level 6.

Measurement Criteria	Likely outcome for Vision problems
Severity level range: • likely to kill/ cause permanent disability • long term illness / serious injury • medical attention several days off required • first aid required	Medical attention to manage reasons for discomfort could occur (change in spectacles, orthoptic treatment for convergence insufficiency). Time off from work is likely but only for a portion of a day. The total of days off might be 1 to 3 days
Likelihood of experiencing a 'severity level' range: • very likely • likely • unlikely • very unlikely	Unlikely
Importance of the issue: 1 = extremely important , 6 = may not need your immediate attention	Level 6

Table 1 test for computer use as a hazard based on the Hazpak1 model of analysis

It can be seen from the results that vision discomfort or dysfunction related to computer use is a minor problem. If visual problems arise in association with computer use, the treatment does not cause major disruption to work activities.

EYE COMFORT IN COMPUTER USE

The literature has shown that computer use does not directly affect the health of the eye. The impact of computer use is either to stress / tire the operation of the eyes (accommodation function, binocular single vision function, lacrimation) or to require a change in spectacles to meet the set up of the computer environment (working distance, document source distance). The literature supports appropriate management of the work environment to support comfortable use of the eyes ("time on task", surround light sources). Table 2 presents a summary of strategies, based on information from literature, to support comfortable ocular use for computer users.

Issue	Action
Spectacle correction	• The focal length of presbyopic lenses should be set to meet the working distance of the computer screen – 50 to 60 cms. • Single focus lenses will support eye movement between the screen, the source document and the key board, without having to move the head / neck to position the near add over the focal point
Time on task	Ensure regular breaks form computer use • 15 minutes non computer use every hour[34] • change from computer use to general office duties (telephone duties or consultation with colleagues)[34]
Convergence based aesthenopia	Orthoptic treatment
Lacrimation / dry eyes	• actively increase blink rate[30] • use lubricant drops[27,29]
Surround luminance	• reflection should be eliminated (added screen, change computer position) [5] • avoid light sources in the users field of view[21] • ensure light levels are sufficient to read the key board and source documents[8]
Screen qualities	• Good figure to background contrast[35] • High resolution text (dots per inch) to support speed and accuracy[38]
Computer Screen position	• Between 60 and 100 cms[37] • Between horizontal and 16 degrees downwards[37]
Source document position	• Between 60 and 100 cms[5,37] • At the same level as the screen[37]

Table 2 Strategies to support comfortable vision for computer users

DISCUSSION

This paper has looked at three aspects of computers and their impact on vision. Firstly, what literature has to say about the harm caused by computers and the basis for any visual discomfort that can arise. Secondly, the evaluation of computers as an OHS hazard for the eyes. Thirdly, the strategies that can be implemented to support safe and comfortable use of the eyes when using computers.

Jackson[32] has identified that 5% of computer users who experienced computer related problems have a vision problem, which indicates that the issue is minor. Consideration of all the information from literature supports that the possibility of computers actually causing a change to vision function is minimal. There is no impact from radiation[5,6], computer use does not change any ocular responses such as measurement of visual acuity[9,14,16], the function of the physical components of the eye (retina, cornea, lens[6]) ocular movements and binocular single vision[9,14,17]. There is a reported link between computer use and dry eyes[26,27] which appears in part to be related to use of the eyes in the near position[30]. This is managed by the computer user actively increasing their blink rate or using appropriate drops. There is also some evidence that a transient impact on accommodation occurs but this normalises once computer activity has ceased[12]. Vision discomfort is strongly linked to factors such as time on task[8,33] and intensity of the computer use[10], although it should be noted that all near tasks can be linked to ocular discomfort[8,10,14] particularly if carried out intensively and for a long period of time. Environmental factors such as surround luminance, screen qualities, screen position can be linked to ocular discomfort[9,33,35]. Incorrect or inappropriate spectacles prescription may also cause discomfort particularly when the computer user is presbyopic. The focal length needs to match the screen distance and the near lens needs to be aligned to the position of use.

The information from literature provides support that the impact of computer use on the eyes is unlikely to cause an OHS hazard. Analysis shows that in the event of discomfort arising it is likely to be ongoing, at a low level of annoyance and require medical attention by a non-urgent consultation[1]. Any problems can be managed through a minimal number of appointments and should not total more than one or two days. The liklihood of a computer based vision problem being a major safety issue is minor.

Strategies to assist computer users to be comfortable largely centre on managing the environment rather than managing ocular function. The environmental issues such as surround lighting, organisation of the computer setup, including the screen presentation and appropriate management of the duration of computer sessions all impact on vision operation and comfort. When these are not in control visual symptoms occur.

When managing a patient experiencing ocular discomfort associated with close work, attention should be given to any existing eye defects and the relevant treatment given. Attention should be also be paid to computer use and the environmental issues that can cause discomfort. Counseling about time on computer task, lighting, computer set up and lacrimation can support comfortable computer use. These relatively simple approaches should ensure ocular comfort for computer users.

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1961	Ann Macfarlane	Case history "V" Syndrome
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1966	Gwen Wood	Miotics in practice
1967	Sandra Hudson Shaw	Orthoptics in Genoa
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1969	Sandra Kelly	The prognosis in the treatment of eccentric fixation
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