



Queensland University of Technology
Brisbane Australia

This may be the author's version of a work that was submitted/accepted for publication in the following source:

[Webber, Ann & Wood, Joanne](#)
(2005)

Amblyopia: Prevalence, Natural History, Functional Effects and Treatment.
Clinical and Experimental Optometry, 88(6), pp. 365-375.

This file was downloaded from: <https://eprints.qut.edu.au/11934/>

© Copyright 2005 Optometrists Association Australia

This work is covered by copyright. Unless the document is being made available under a Creative Commons Licence, you must assume that re-use is limited to personal use and that permission from the copyright owner must be obtained for all other uses. If the document is available under a Creative Commons License (or other specified license) then refer to the Licence for details of permitted re-use. It is a condition of access that users recognise and abide by the legal requirements associated with these rights. If you believe that this work infringes copyright please provide details by email to qut.copyright@qut.edu.au

Notice: *Please note that this document may not be the Version of Record (i.e. published version) of the work. Author manuscript versions (as Submitted for peer review or as Accepted for publication after peer review) can be identified by an absence of publisher branding and/or typeset appearance. If there is any doubt, please refer to the published source.*

<https://doi.org/10.1111/j.1444-0938.2005.tb05102.x>

Amblyopia: Review of Prevalence, Natural History, Treatment and Outcomes

***Ann L. Webber BAppSc (Hons) MSc**

***Joanne Wood PhD**

School of Optometry, Queensland University of Technology, Australia

Corresponding Author:

Ann L. Webber BAppSc (Hons) MSc
webbopt@ozemail.com.au
1/134 Oxford Street, BULIMBA Q 4171
Phone: 07 3899 4044 Fax: 07 3899 4644

RUNNING TITLE: Amblyopia Review

KEY WORDS: Amblyopia
 Strabismus
 Anisometropia
 Natural History
 Prevalence
 Treatment
 Compliance
 Disability

ABSTRACT

Amblyopia, defined as poor vision due to abnormal visual experience early in life, affects approximately three percent of the population and carries a projected lifetime risk of vision loss of at least 1.2%. The presence of amblyopia or its risk factors, mainly strabismus or refractive error, have been primary conditions targeted in childhood vision screenings. The continued support for such screenings requires evidence-based understanding of the prevalence and natural history of amblyopia and its predisposing conditions, and proof that treatment is effective in the long term with minimal negative impact on the patient and their family.

This review summarises recent research relevant to the clinical understanding of amblyopia, including prevalence data, risk factors, the functional impact of amblyopia and optimum treatment regimes and their justification from a visual and life skills perspective. Collectively, these studies indicate that treatment for amblyopia is effective as it reduces overall prevalence and severity of vision loss. Correction of refractive error alone has been shown to significantly reduce amblyopia and lesser amounts of occlusion can be just as effective as greater amounts. Occlusion or penalisation in amblyopia treatment can create negative changes in behaviour in children impact on family life and these factors should be considered in prescribing treatment, particularly because of their influence on compliance with prescribed treatment. Treatment trials regarding the maximum age at which amblyopia treatment can still be effective and the importance of near activities during occlusion are ongoing. This review highlights the expansion of current knowledge regarding amblyopia and current treatment of amblyopic patients and aims to keep clinicians abreast of this knowledge.

Introduction

Amblyopia has been defined as a unilateral or bilateral decrease of visual acuity caused by deprivation of pattern vision or abnormal binocular interaction, for which no cause can be detected by physical examination of the eye and which can in some cases be reversed by therapeutic measures(1). Amblyopia is a disorder of development of the visual system that can present with varying levels of severity and usually affects one eye only, although the non-amblyopic eye often has an array of small but measurable deficits(2). There is no obvious ocular pathology underlying the reduced visual acuity but rather, there is some pre-disposing condition that influences the development of visual acuity after birth. The most common pre-disposing conditions for amblyopia are strabismus (causing disruption of binocular vision development), refractive error (particularly anisometropia or hyperopia), or, more rarely, media opacification causing reduction in image quality (such as congenital cataracts). The earlier in post-natal visual experience the predisposing condition presents, the greater the potential impact on vision. In addition, the longer the duration of abnormal visual experience the more profound the level of amblyopia.

Amblyopia is usually classified according to the presenting visual condition believed to have caused the impaired visual development. An example of this classification is that used by Attebo et al(3), where amblyopia was identified in their population cohort as (1) anisometropic if there was a difference in the sphere or cylinder between the two eyes of one dioptre or more and no strabismus was present; (2) strabismic if heterotropia or micro-squint was present without anisometropia or high refractive error; (3) mixed if anisometropic amblyopia and strabismic amblyopia co-existed or (4) stimulus deprivation if there was some obstruction to vision during the sensitive period of visual development (this included high refractive errors).(3)

Clinically, amblyopia is usually defined by one or more lines difference in visual acuity between the eyes(4), however, other monocular visual functions are also affected, including grating acuity, vernier acuity and contrast sensitivity. Amblyopic eyes can also have defective accommodation and can display oculo-motor deficits including unsteady fixation and inaccurate tracking; the tracking of the non-amblyopic eye can also be less accurate than in age-matched controls(5). Binocular vision adaptations may be present including suppression, eccentric fixation or abnormal retinal correspondence(6,7). Deficits in stereopsis are present under normal binocular conditions and may represent the main functional difference between patients with amblyopia and those without. Most strabismic amblyopes lack any measurable stereopsis even if visual acuity has recovered, while many anisometropic amblyopes have some residual stereopsis that may be as good as the resolution of the amblyopic eye permits(7).

The different patterns of monocular and binocular visual loss seen in strabismic versus anisometropic amblyopia suggests the existence of two distinct developmental anomalies(6-8). A recent review explores the literature pertaining to the physiological locus of amblyopia and indicates that the specific neurophysiologic mechanism underlying amblyopia may be inter-ocular image conflict that reduces inter-ocular summation while promoting inter-ocular inhibition. This is interpreted as reducing the effectiveness of excitatory neural connection in the cortex while sparing inhibitory connections(2). More recent psychophysical studies have suggested that the visual dysfunction in amblyopia may begin at the retina(9).

During the past 20 years, different critical periods have been demonstrated for different visual functions during the development of the visual system. Visual functions processed at

higher anatomical levels within the system have a later critical period than functions processed at lower levels. This general principle suggests that treatments for amblyopia should follow a logical sequence, with treatment for each visual function starting before its critical period is over. However, critical periods for some visual functions, such as stereopsis, have not yet been completely defined, and the optimal treatment has, therefore, not been fully determined(10).

The prognosis for obtaining and maintaining essentially normal vision in an amblyopic eye depends on many factors, including the age of the patient at detection, the cause and severity of amblyopia, the presence of complicating factors, the interval between the onset of amblyopia and the beginning of treatment and compliance with treatment. Treatment success may also be a function of the duration of abnormal visual experience under the influence of the predisposing amblyogenic condition, rather than simply the age at treatment.

The mainstay of amblyopia treatment is management of the underlying amblyogenic condition, thereby increasing visual stimulation of the amblyopic eye and removal of barriers leading to abnormal visual input to the brain. This is followed by occlusion or penalisation of the dominant eye that aims to enhance cortical processing of visual input from the amblyopic eye by temporarily limiting cortical input from the dominant eye. Penalisation may take the form of image degradation by instillation of atropine drops, refractive blur or translucent patching of the better eye.

Pre-school vision screenings have for many years aimed to provide a safety net by identifying children with amblyopia risk factors whilst they are still within the critical period of treatment efficacy (traditionally believed to be up to eight years of age). Refractive error and non-cosmetically obvious strabismus have been targeted conditions of screenings, with the premise that the amblyopia risk factors of media opacity or large angle strabismus would have been identified by a parent or primary health provider during infant or early child health assessments. A 1997 review of literature into the conditions targeted in pre-school vision screening, namely refractive error, amblyopia and non-cosmetically obvious strabismus, concluded that there is a lack of good quality research into the natural history of these conditions, the disability associated with them and the efficacy of available treatments(11). Following its publication, the review's conclusions were much debated in the ophthalmological literature, with criticism that recommendations made by the review lacked objectivity and that a lack of adequate data on the effectiveness of amblyopia treatment may result in a premature disassembly of preschool vision screening programmes(12-14). A positive outcome of the publication is that the randomised controlled trials that it called for have now appeared in the literature.

The aim of this review is to present recent research regarding the prevalence and natural history of amblyopia, the efficacy of treatment and its impact on the patient. In doing so, a balanced representation of these studies is provided that can contribute to the clinical understanding of optimum treatment regimes for amblyopia and their justification relative to a whole of life consideration of a patient's needs.

Prevalence

The reported prevalence of amblyopia depends upon both the study population and the definition of amblyopia used. Adult population studies have reported the prevalence of amblyopia to range from 1% to 5%,(3,4) however, population selection bias may influence prevalence rates. For example, studies from clinical ophthalmic populations are not

representative of the general population and typically present with higher prevalence rates of amblyopia. Recent Australian adult population-based cohort studies that aimed to avoid such bias reported the prevalence of unilateral amblyopia to be 3.06% (n=4721)(15) and 3.2% (n=3654) (3) when amblyopia was defined as best corrected VA of 6/9 or worse.

The pre-disposing cause for amblyopia has been shown to vary between studies dependent upon the characteristics of the study sample, particularly how amblyopia was defined. In the unselected adult population study of Attebo(3), where amblyopia was defined as best corrected VA of 6/9 or worse, the main cause was anisometropia (50%), with strabismus being the pre-disposing condition in 19%, mixed (both strabismus and anisometropia) in 27% and visual deprivation in 4%. While in a cohort of children with moderate amblyopia (amblyopic VA was 6/12 to 6/30; n=409; mean age 5.3 years) the causes were found to be strabismus in 38%, anisometropia in 37% and mixed in 24%(16) and in children with severe amblyopia (amblyopic VA 6/30 to 6/120; n=175; mean age 4.8 years) the causes were found to be anisometropia in 34%, strabismus in 27% and mixed in 38%(17).

Recent data regarding the prevalence of amblyopia at 7.5 years of age is provided by the Avon longitudinal study of parents and children (ALSPAC), which is a UK population birth cohort study(18). Of 6,081 children, 16.7% had attended preschool vision screening (age 3-4 years) and all the children had been offered vision screening in the school reception class (age 4-5 years). The prevalence of amblyopia was significantly lower in those children who had received preschool screening compared with those who had not (1.1% v 2.0%, p=0.05). This finding confirms that of a large Israeli study which found a 1% prevalence of amblyopia in 8 year old children previously screened and treated for amblyopia compared with 2.6% in a matched population that had not received treatment(19).

In summary, the most recent population studies of amblyopia indicate a prevalence of approximately 3% in untreated childhood and current adult populations. With detection and treatment of the amblyogenic condition by five years of age, the prevalence of clinically significant amblyopia reduces to around 2%. With detection and treatment before three years of age, the prevalence of clinically significant amblyopia reduces to around 1%. The results of the ALSPAC and Israeli childhood amblyopia studies suggest that early screening for and treatment of conditions that pre-dispose amblyopia reduce the prevalence of amblyopia in school-aged children.

TABLE 1: Reported Prevalence of amblyopia in selected populations

Risk Factors for Amblyopia

Amblyopia is more than four times as common in infants who are premature, small for gestational dates or who have a first degree relative with amblyopia. In infants with neuro-developmental delay the prevalence of amblyopia is six times greater than in healthy, full-term infants(20,21). Patients at greatest risk for amblyopia are infants who experience early stimulus deprivation. Visual deprivation prior to three months of age need not be prolonged to cause amblyopia and is highly correlated with later development of sensory nystagmus in bilateral cases and strabismus in both monocular and bilateral cases.

In strabismus, the diplopia caused by the misalignment can lead to binocular rivalry and suppression of input from the non-dominant eye at the level of the visual cortex. Infantile esotropia (i.e. congenital esotropia) generally presents before six months of age when the

developing visual system can be most at risk for amblyopia. If not corrected early, the resultant amblyopia can be profound and difficult to reverse. In patients who have had early surgery with an outcome of good visual acuity in both eyes, very poor stereopsis can still result due to the early disruption of binocular vision(7).

Refractive error represents a risk for developing amblyopia, either due to creation of dissimilar images in anisometropic amblyopia, or as a driving factor for accommodative esotropia. Children identified at screening as at risk for amblyopia due to hyperopia $>$ or $=$ 3.5 D in any meridian were 13 times more likely to become strabismic and six times more likely to show measurable acuity deficits by four years compared with controls(22). Wearing a partial spectacle correction reduced these risk ratios to 4:1 and 2.5:1 respectively and did not interfere with the process of emmetropisation (the reduction in magnitude of refractive error seen in children aged between 9 months and 4 years)(22).

Most studies report best-to-worst ranking for visual acuity at initial visit and outcome at the end of treatment as anisometropic (best), strabismic and combined strabismic/anisometropic amblyopia (worst) and the same ranking for least-to-most post-treatment deterioration in long-term follow-up(2). Complicating the interpretation of expected treatment outcomes is the inter-relationship between strabismus and amblyopia as each can be causal of the other. Similarly, strabismus and anisometropia commonly co-exist and it may be difficult to determine which is the primary condition.

Natural History

The studies of early treatment intervention regimes allow better understanding of the natural history of amblyopia. The finding that those populations that undergo early intervention and treatment have lower prevalence of amblyopia than those that do not, implies that amblyopia does not improve of its own accord(18,19).

Further evidence that treatment is necessary for optimum visual acuity outcomes is provided by the randomised controlled treatment trial by Clarke et al (23) where best corrected acuity was compared in those who had received one year of treatment with those who had not. 177 children aged 3-5 years, identified at pre-school vision screening as having monocular reduction in VA worse than 6/9, were randomly assigned to either a no treatment group, were treated with glasses alone or with glasses and patch occlusion. Of the total sample, 173 (98%) had a significant refractive error, 127 (72%) of whom had anisometropia. Children in either treatment group had better visual acuity at follow up than children who received no treatment (mean improvement 0.11 logMAR - just over one line of acuity). The effects of treatment depended on initial acuity, with those children with initial acuities in the range of 6/18 to 6/36 improving on average 0.20 logMAR following treatment. After twelve months the no treatment group then received the treatment, with subsequent improvement in visual acuity and stereopsis equal to that of patients who had initially received treatment(24). This latter finding indicates that in a group of mainly refractive amblyopes, treatment does improve final vision, however, delay of treatment until five years of age does not influence the final visual outcome.

To investigate the natural history of amblyopia without treatment, Simons and Preslan (25) reported longitudinal data on the course of amblyopia in a group of 18 children who were identified as amblyopic in a screening study but who either did not receive or did not comply with recommended treatment and then were retested a year later. Improvement in visual acuity in the amblyopic eye was reported in one child, in seven children visual acuity had deteriorated in the amblyopic eye, and the rest of the group showed no change.

These authors also reanalysed data from three other studies (26-28) and found that the visual acuity outcomes for those patients who had been compliant with treatment were significantly better than those who were not. They concluded that untreated children with either amblyopia or its risk factors are likely, at best, to show no improvement in the amblyopic eye if untreated and, in many cases, develop amblyopia if not treated.

Recent randomised controlled treatment trials, together with reviews of patients who have not been compliant with treatment, indicate that the natural history of amblyopia is not that of spontaneous recovery. Intervention is required to maximise potential visual acuity in the affected eye. The age at which that intervention will still be effective has not been confirmed and is the subject of on-going studies(29).

Disability Associated with Amblyopia

Amblyopia is often considered to be a childhood condition as this is when it is most often diagnosed and treated. Thus clinicians need to know which life skills relevant to a child may be affected if amblyopia is left untreated and be aware of any functional difficulties that a child may experience during and following treatment.

At least 64% of parents of amblyopic children have been reported to express concerns regarding disability associated with amblyopia. Parents of children with early diagnosis (before age five years) were more likely to consider amblyopia a very serious problem (58% versus 39%), while parents of children with late diagnoses more frequently reported that their child had problems attributed to amblyopia (80% versus 64%). Reported problems were typically those of school performance rather than related to social or athletic activities(30).

These findings contradict those of Snowdon and Stewart-Brown (31) who conducted semi-structured interviews on a small number of parents of children with amblyopia (n=11). The authors concluded that these parents did not regard amblyopia as a disabling condition, with little impact on career choice or motor function. However, they report that adults with amblyopia found certain aspects of driving problematic, with driving at night being particularly identified as difficult. This study also reports that practitioners who treat amblyopia generally agree that amblyopia may limit career choices due to visual standards and that there is a need to promote maximum vision in each eye to decrease lifetime risk of visual impairment. Their overall conclusions were that treatment of amblyopia by patching may result in more disabling outcomes than the condition itself; however, the small sample population limits the relevance of this study, as does the lack of information regarding visual acuity, stereopsis or aetiology and lack of data from a control group.

Potential disability in amblyopia has also been investigated by assessing the risk of visual impairment attributable to loss of vision in the non-amblyopic eye. The projected lifetime risk of vision loss for an individual with amblyopia has been found to be at least 1.2%. Rahi et al(32) found that of 370 individuals with amblyopic VA of worse than 6/12 who had newly acquired vision loss in their non-amblyopic eye, 104 (28%) had socially significant visual impairment (VA between 6/12 and 6/18), 180 (49%) had visual impairment (VA between 6/18 and 6/60) and 86 (23%) had severe visual impairment or blindness (VA less than 6/60). Only 36 (35%) of 102 people previously in paid employment were able to continue to work. The authors argue that the risk of visual loss in the non-amblyopic eye and its consequences are greater than that previously assumed.

The patient's perception of quality of life associated with unilateral versus bilateral good vision has been calculated by utility analysis, which is a variation of cost-effectiveness analysis incorporating the value (improvement in the length of quality of life, quality of life or life) conferred by an intervention against the cost associated with that intervention. Good vision in both eyes provides a substantial improvement in utility value as compared with good vision in only one eye. Patient feedback indicates that the psychological stress of having only one good seeing eye on which to rely upon and the apprehension induced by knowing that many eye diseases eventually affect both eyes is likely to play a major role in decreasing an individual's quality of life(33). When specifically modelled in amblyopia, the cost of amblyopia treatment combined with the increase in utility value created by restoration of better vision in the second eye indicates that amblyopia treatment is highly cost-effective from the third-party insurer viewpoint and contributes to the earning power of affected individuals(34).

In summary, the potential visual disability due to loss of visual function of the non-amblyopic eye can be calculated and is an argument for amblyopia treatment to maximise visual potential in each eye. The benefit of improvement in visual capacity of the amblyopic eye can also be quantified by quality of life scores and can result in positive cost-analysis of treatment. Whilst parental concern regarding their amblyopic child's performance has been reported, specific research into which life skills may be impaired by amblyopia is limited to studies with only small sample sizes.

Impact of Amblyopia on Visuomotor Skills

Reduced stereopsis is the most common visual deficit associated with amblyopia. Whilst much is known about the visual basis of stereopsis, the functional significance of reduced stereopsis has rarely been reported (35). Studies that have investigated this issue have compared performance under monocular and binocular conditions(36,37), generally concluding that individuals with binocular vision have advantages in situations requiring spatial certainty when compared with monocular individuals(36), that binocular vision facilitates control of manipulation, reaching and balance(37) and that people with no stereopsis have difficulty performing tasks which rely on three dimensional visual clues(38). However, there are individuals who have better manual dexterity than can be predicted by stereoacuity measures alone(38).

Parents of strabismic children whose eyes have been aligned surgically have reported that the child's visuomotor skills have suddenly and vastly improved following surgery(1). This observation was confirmed in a study that assessed infants' performance on the Bayley Scale of Infant Development both before and after surgery for infantile esotropia. Following surgery, 35% of children showed an increase in performance on tests of fine motor skills and 41% of children recorded an improvement in visually directed reaching and grasping. The greatest post-operative improvement was found in the subtest item that involves depth perception, where the child is required to identify a depression in a piece of wood without monocular clues (such as a difference in colour) (39).

Of relevance to the question of how the restoration of binocular vision affects visuomotor skills, is the study of Ross et al (40) who tested for developmental delay in patients who had undergone treatment for retinoblastoma; 75% of the test group was monocular resulting from enucleation. Whilst on average the children's mental and motor ability scores were in the normal range, approximately 40% of the mainly monocular test group was referred for delays of visuo-motor development, including tasks that require eye-hand

coordination and depth perception, such as placing pegs into holes or putting puzzle pieces into foam boards.

There is little published evidence regarding the relationship between stereopsis and motor skills in children with amblyopia. An exception is that of Hrisos et al(41), who found that stereoacuity, independent of visual acuity, significantly influenced performance on tasks requiring fine visuo-motor control (bead threading task) in non-strabismic amblyopic pre-school children with reduced acuity in one eye (6/9 to 6/60). No significant differences were found between these children and age-matched controls on other items in the battery that measured visuo-motor integration, visual spatial processing, visual attention, and gross visuo-motor skills.

In summary, while it is assumed that reduced depth perception results in poor fine motor skill performance, there is little published evidence to support these assertions. Fine motor skill performance underlies many tasks of importance to pre-school and school-aged children, such as hand-writing and scissor skills. Exploring the relationship between reduced stereopsis and poor ocular-motor control, common findings in children with amblyopia, and fine motor skills is necessary to determine how amblyopia may impact upon early educational development.

Impact of Amblyopia on Psychosocial development

The psychosocial implications of strabismus and amblyopia on an individual's quality of life have gained recent attention in the literature. Anecdotal references to the undesirable cosmetic appearance associated with an obvious strabismus have more recently been superseded by studies looking at the effect of strabismus and amblyopia on an individual's self-esteem, interpersonal relationships and employability.

In their review paper, Tolchin and Lederman (8) discuss ways in which congenital or infantile esotropia may affect the parent-child relationship during the first years of life, and how this, in turn, can have profound psychological consequences for the developing child. They concluded that there was evidence in the literature that the child's appearance plays a profound role in the developing parent-child relationship and that the cosmetically obvious ocular misalignment with infantile esotropia is one barrier to the eye contact necessary for a proper relationship to take place.

Eustis and Smith (42) found that 41% of parents whose children underwent strabismus surgery believed that their child's psychological development or personal self-esteem was adversely affected by strabismus and 17% of parents believed that the cosmetic stigma of strabismus was the single most important problem for their child. This parental belief was confirmed by Satterfield et al (43), who found that patients with strabismus reported difficulty with self-image, securing employment, interpersonal relationships, school, work and sports. The difficulties experienced continued and intensified in the teenage and adult years where patients with strabismus demonstrated higher levels of stress compared to age and sex-matched controls. This contrasts with the findings of Gray et al (44) who found that individuals seeking surgery for strabismus, that they considered cosmetically unacceptable, were not in general "neurotic" or experiencing high levels of social anxiety. Patients who underwent surgery for longstanding horizontal strabismus perceived that their psychosocial functions had improved post surgery, but felt that other people would still rate them less highly than they rated themselves(45).

Satterfield et al's finding regarding difficulty securing employment was confirmed by two more recent studies which demonstrated that cosmetically obvious strabismus creates a significant negative social prejudice in patients which can significantly reduce an applicant's ability to obtain employment (46,47).

Patients with amblyopia but without strabismus reported that amblyopia interfered with school, work to some degree, and felt it affected their lifestyle(48). Sixty percent were concerned by associated teasing or ridicule, with the majority of patients reporting some concern that amblyopia had an effect on self-image. Whilst most patients reported that their monocular condition had not affected their job choices, half reported that being monocular affected their lifestyle. Amblyopic subjects were also found to experience more distress in the areas of somatization, obsession-compulsion, interpersonal sensitivity, anxiety and depression than control subjects.

While these studies provide an understanding of the adults' perspective on the psycho-social impact of amblyopia, further research is needed to investigate the impact of treatment for amblyopia or any disability associated with amblyopia on the psychological well-being of the child.

AMBLYOPIA TREATMENT

The treatment of amblyopia generally involves correction of the underlying pre-disposing condition followed by a period of deprivation of the dominant eye to promote normal visual experiences for the amblyopic eye. Refractive correction is also required for strabismic patients with accommodative esotropia and patients with anisometropia. The results of randomised controlled treatment trials for various aspects of amblyopia treatment are now available. The younger the child is when treatment commences, the more rapid the response to treatment and the better the visual outcome. In strabismic amblyopia the rate of improvement in amblyopia treated with full time occlusion fell steadily from over 90% at age 28 to 33 months to near zero when therapy was initiated at age 12 years(49). Individual patients, however, may achieve improved vision after the age of 10 years, with reports of improvement with treatment or after loss of the non-amblyopic eye even into adulthood(50).

Refractive correction

Correction of any underlying refractive error has long been established to be critical in amblyopia treatment(6). However, it is only more recently that the extent to which the correction of refractive error alone might reduce amblyopia has been specifically explored(51,52). Correction of refractive error alone in newly diagnosed amblyopic children (n=65; mean age 5.1 years) for a period of 18 weeks resulted in significant improvement in amblyopic visual acuity (mean improvement of 0.24 logMAR). This improvement did not significantly differ as a function of amblyopia type or age of the patient(52). This has led to the conclusion that refractive adaptation is a distinct component of amblyopia treatment and that the beneficial effects of refractive adaptation need to be fully identified. Allowing refractive adaptation prior to commencement of occlusion or penalisation therapy may have significant benefits. The consequences of these findings for clinical practice are that following a period of refractive correction, children can start occlusion with improved visual acuity, possibly enhancing compliance, and in some cases unnecessary patching can be avoided(53).

Correction of abnormal ocular alignment or opacity

It has been conservatively estimated that 17% of patients with amblyopia will undergo alignment surgery, 1.5% require cataract extraction and 1.5% require ptosis surgery(34). Whilst no large population-based study addressing the distribution and incidence of each type of strabismic amblyopia is available, a cost-utility analysis study has assumed from case series and anecdotal experience that approximately 60-75% of strabismic amblyopes are accommodative, with 60% of accommodative esotropes not fully correctable with spectacles and requiring surgery for ocular alignment(34). The subgroup of strabismus patients with amblyopia who will undergo alignment surgery was estimated to be from 48% to 62% of all amblyopic patients who have strabismus.

Occlusion and Penalisation

The mainstay of treatment for the last quarter of a century has been occlusion of the better eye by an opaque patch. However, therapeutic regimes have lacked standardisation with the length of patching ranging from a few minutes a day to all waking hours and in some cases treatment may last many months. Recent studies that have investigated the relative merits of occlusion and atropine penalisation have commented on the considerable variation in treatment practices with regard to the number of hours of initial patching prescribed(54). Whilst the number of hours prescribed had no relationship to patient age, it was found to be related to the acuity in the amblyopic eye (i.e. depth of amblyopia). On average optometrists prescribed fewer hours of patching than ophthalmologists(54).

Recent randomised controlled treatment trials have aimed to evaluate different treatment modalities for different levels of amblyopia. Trials of occlusion treatment by the Pediatric Eye Disease Investigator Group (PEDIG) have concluded that both atropine penalisation and patch occlusion are effective treatments for moderate amblyopia in children aged three to seven years(55); that when patching is prescribed, two hours of daily patching is as effective for moderate amblyopia as six hours; and that for severe amblyopia, six hours of daily patching is just as effective as full-time patching(17). Weekend atropine provides an improvement in VA of a magnitude similar to that of the improvement provided by daily atropine in treating moderate amblyopia in children three to seven years old(56).

When occlusion is objectively (electronically) monitored, the overall compliance with prescribed patching treatment has been found to be 48% with considerable variation within and between participants. When six hours of patching per day was prescribed, on average the patient actually received a “dose” of 2.8 hours, with only fourteen percent actually patching to an amount within 30 minutes of that prescribed(53). Dose-response functions have been developed based upon how much patching the patient actually received and the initial and final visual acuity. From these dose response functions, the relationship between visual acuity and treatment dose has been found to be monotonic, with 82% of the improvement in VA being achieved by six weeks of patching, but with some further improvement up to 12 weeks. Dose rates of two to six hours per day resulted in the same final outcomes, although those with a high dose rate achieved a successful outcome more rapidly(53).

Whilst randomised controlled treatment trials have shown occlusion and penalisation therapy to be successful in treating amblyopia in children younger than seven years, the question of the upper age limit of successfully treating amblyopia has still not been fully addressed. A pilot study of treatment in children aged 10 to 18 years has indicated that visual acuity can be improved in older children and adolescents. Randomised controlled trials are underway to determine if there is an upper age limit for which amblyopia treatment can still be successful(29).

Passive versus active treatment

While a preliminary study found an average of one logMAR line extra improvement when the patient performed near activities during occlusion or penalisation(57), the benefits of active versus passive therapy during occlusion are yet to be confirmed by randomised controlled treatment trials. Despite this the protocols of PEDIG has been to prescribe at least one hour of near visual activities during patching, for example, hand-eye activities, computer or Internet, reading, homework, accommodative tasks. Preliminary studies have indicated that the use of video display treatment and biofeedback can achieve improvements in amblyopic visual acuity in adults, however, nearly all of the improvement in visual acuity achieved with treatment appears to regress if patients are followed up over an 18 month period(2). Although patching alone may be sufficient for improvement of visual acuity, it has been suggested that binocular performance is significantly better when vision therapy is included in the treatment regimen(58).

Medical Treatment

Attempts have been made to involve catecholamines in amblyopia treatment, as they appear to extend or reactivate the visual system's "sensitive period" of neural plasticity. Both levodopa(59-61) and CDP-choline which stimulate availability of a variety of neurotransmitters and modulators, including dopamine, have been used. Whilst improvements in visual function in amblyopic eyes have been reported in both children and adults, long term follow-up indicates that a significant regression of improvement in visual function occurs(62).

Treatment outcome

Numerous studies have examined the visual acuity outcomes that can be achieved with treatment for amblyopia(7,23,63-67), however, this may diminish after treatment is completed. A recent prospective study which monitored the level of visual acuity following the finalisation of treatment concluded that approximately a quarter of successfully treated amblyopic children experience a reduction in visual acuity within the first year of treatment(68). This recurrence rate was similar among patients who had previously been treated by patching and those who had been treated by penalisation with atropine and occurred more frequently during the first 13 weeks following commencement of treatment. Other studies have shown that about 2/3 of both strabismic and anisometropic amblyopes maintain, or even improve, visual acuity more than four years after treatment completed(69,70), however anisometropia of greater than 1.5 dioptres appears to be a risk factor for regression(71). The implication for clinical practice is that follow-up is warranted for at least 12 months following the completion of occlusion or penalisation treatment. Further randomised clinical trials are needed to investigate the long-term risk of amblyopia recurrence.

Quality of binocular vision can also be used as an outcome indicator. In a retrospective study of occlusion treatment outcomes, stereopsis was found to improve linearly with improved amblyopic visual acuity irrespective of the cause of amblyopia(72). In comparison, in a large scale study of adults with amblyopia or with a history of risk factors for amblyopia, 90% of those who were believed to have had disruption of binocular vision during early visual development (ie those with a history of strabismus) failed tests of binocular function, even if visual acuity was within normal limits. By comparison, 64% of adults with anisometropia and 35% of amblyopes with anisometropia passed these binocular tests(7).

Emotional Impact of Treatment

Many parents of children undergoing occlusion treatment for amblyopia, even for relatively short periods of time, report distress or an increase in conflict at home. Most parents associated occlusion with reduced confidence seen in their child due to poor vision under occlusion conditions(73). Whilst not all parents report that their child's activities are affected, the degree of compliance with treatment and observations of changes in patterns of behaviour has been found to differ depending on the level of amblyopia(74). No evidence of significant developmental delay or increased behavioural problems was found in a case-control study of congenital monocular cataract patients, who had their only normally seeing eye patched for a significant percentage of their early childhood years. However, the sample size was limited in this study and the use of siblings for the control group introduced the possibility of parental bias in their subjective assessment of the two children(75).

It has now been shown in a randomised control trial of treatment that children undergoing occlusion patching were more upset and showed more resistance to their treatment than those prescribed glasses alone. In addition, many parents experienced difficulty with occlusion therapy and were significantly more likely to be upset by this treatment than parents with children in glasses alone, however, the levels of distress and difficulty reported by parents were quite low(76). This is in accord with a repeated measures study that recorded carer's perception of stress and psychosocial well-being of the child prior to and following commencement of treatment. Carers of children undergoing occlusion therapy did not experience significantly more stress or perceive their child as exhibiting less psychosocial well-being than the non-occluded group. In addition, within the occluded group, carers' stress level and child's psychosocial well-being did not significantly change following onset of occlusion therapy(77). Similarly, the PEDIG group found that both penalisation modalities, patch occlusion and atropine, were well tolerated by the child and family, although treatment impact scores were consistently worse in the occlusion group compared with the atropine group(78).

Recent studies confirm that penalisation in amblyopia treatment creates negative changes in behaviour in many children and has an impact on family life. These changes appear to be more profound in children with a greater level of amblyopia. Whether this is due to greater visual impairment under penalised conditions or due to a longer duration of penalisation has not been established. The behaviour of the child under penalisation conditions influences compliance with treatment, which raises the possibility that the efficacy of treatment could be reduced by poor compliance in those children with the greatest need.

Functional Impact of Treatment

While often cited as the reason for poor compliance with occlusion or penalisation, the ability to perform everyday tasks under monocular conditions with reduced visual acuity has not been documented in children with amblyopia. Studies that have investigated performance on fine motor skills tasks under monocular versus binocular conditions suggest that performance would be impaired by the penalisation phase of amblyopia treatment due to loss of residual binocular vision. It is likely that if amblyopic acuity is less than 6/12 then functional tasks would be further impaired. However, there are a lack of studies specifically investigating functional disability in areas of importance to children of the age most likely to be treated for amblyopia. Future studies need to address disability imposed by the treatment, especially performance under impaired monocular conditions imposed by penalisation. Also, once a child has been dismissed from amblyopia treatment

they may still have some visual function anomaly such as reduced stereopsis, abnormal accommodation or poor ocular-motor function. The impact of these binocular vision anomalies on tasks important to children warrants investigation.

Costs of Treatment

The medical costs associated with amblyopia treatment can be calculated based on estimates of consultation fees, non-surgical and surgical fees. Specific costs in nominal US dollars in 2001 varied between \$1452 and \$2628 (dependant upon surgical or non-surgical treatment of the underlying cause) and averaged \$1623 per patient(34). This same study weighed the cost of amblyopia treatment against quality of life utility value gained due to improved visual acuity in the amblyopic eye and concluded that amblyopia therapy is particularly cost-effective to a large degree because the visual acuity benefit derived is acquired at a very young age.

Compliance with Treatment

Compliance with occlusion treatment is essential for an optimum outcome and has been the subject of numerous studies (79-82). The level of compliance to treatment has been shown to be influenced by patient age(80,81), social deprivation(82), level of visual acuity(81), parental understanding of the condition and treatment(83) as well as by the financial and emotional cost to patient and family(76,84,85). Strategies used to enforce patch wear include encouraging, ordering, pleading, threatening, bribery, hospital administration, arm restraint by use of plaster cast and eye lid suturing (79,86). Beardsall et al (87) found that most parents of children with amblyopia were highly motivated to undertake recommended treatment after becoming aware of the reduced visual acuity at the initial vision examination. As non-compliance with treatment sometimes delayed effective treatment, Beardsall et al (87) suggest an occlusion protocol aimed at giving maximum support for parents in the early stages of treatment. This was supported by Searle et al(85) who found parental compliance improved if they believed treatment was producing positive results and decreased if there was perceived restriction of the child's activities by patching. Similarly, it has been suggested that increased parental awareness of the rationale and urgency of occlusion treatment, with reinforcement of details of the regimen, would help to reduce non-compliance(83). This has been tested in a randomised controlled trial of written information which concluded that a large proportion of patients would benefit by increasing parental knowledge in key areas such as the critical period, importance of occlusion and potential negative consequences of not treating amblyopia (88). Low socio-economic status, measured by qualification for Medicaid assistance, has been reported to indicate reduced likelihood for success for amblyopia therapy. Patients whose family qualified for Medicaid assistance (n=71) had poorer final visual acuity, greater number of missed visits and lower estimate of compliance than those whose families did not qualify for Medicaid (n=209) (28).

Summary

Recent randomised controlled trials of treatment for amblyopia and early screening and treatment studies have provided evidence regarding the natural history of amblyopia and efficacy of treatment. These studies indicate that treatment of amblyopia reduces the incidence of amblyopia and results in better final visual acuity in the amblyopic eye. Studies have also indicated that the earlier amblyogenic factors are detected and treated, the lower the prevalence and severity of amblyopia. In the context of overall outcomes for the population, it can be concluded that the results justify the treatment. Occlusion or penalisation in amblyopia treatment can create negative changes in behaviour in children and have an impact on family life, more so in children with greater level of amblyopia. As

the child's behaviour influences compliance, it is essential to address this issue with the parent supervising the treatment when instigating the occlusion or penalisation therapy. Allowing refractive adaptation prior to commencement of occlusion or penalisation therapy may have significant benefits for the child such as starting occlusion or penalisation with improved visual acuity, possibly enhancing compliance, and in some cases unnecessary patching will be avoided.

Reports of disability for the patient with amblyopia are not conclusive and do not specifically address skills that are of importance to the childhood population. Whilst the balance between possible disabilities attributable to the condition versus the treatment has not been established, the potential disability of incapacitating vision loss later in life, due to loss of visual function of the non-amblyopic eye, can be calculated and is an argument for treatment to maximise visual potential in each eye

The studies of PEDIG have provided clinicians with more distinct guidelines with respect to the "how" and "when" of occlusion and penalisation therapy in amblyopia. Randomised treatment trials in child and adolescent age groups older than what has traditionally been considered the critical period within which treatment is effective are currently ongoing. Similarly, the outcome of ongoing randomised treatment trials examining the influence of near activity during patching will provide direction to "active" versus "passive" patching. The importance of parental education and support to maximise compliance with treatment has now been established and should be part of the treatment plan(88).

Importantly, this review highlights the need for evidence-based guidelines for treatment of amblyopia to be developed so that clinicians can provide optimal advice and treatment for amblyopia with minimal impact for the patient. It also highlights the amount of recent research activity in this area and the need for clinicians to keep up to date with recent literature in order to provide the best level of care for their amblyopic patients that current knowledge allows.

References:

1. Von Noorden GK. Binocular Vision and Ocular Motility: theory and management of strabismus - 5th edition. St Louis, Missouri: Mosby - Year Book, Inc; 1996.
2. Simons K. Amblyopia Characterization, Treatment, and Prophylaxis. *Survey of Ophthalmology* 2005; 50: 123-66.
3. Attebo K, Mitchell P, Cumming R, Smith W, Jolly N, Sparkes R. Prevalence and causes of amblyopia in an adult population. *Ophthalmology* 1998; 105: 154-9.
4. Thompson JR, Woodruff G, Hiscox F, Strong N, Minshull C. The incidence and prevalence of amblyopia detected in childhood. *Public Health* 1991; 105: 455-62.
5. Bedell HE, Flom M, Barbeito R. Spatial aberrations and acuity in strabismus and amblyopia. *Investigative Ophthalmology and Vision Science* 1985; 26: 909.
6. Bloch D, Wick B. Differences between strabismic and anisometropic amblyopia: Research findings and impact on management. *Problems in Optometry* 1991; 3: 276-92.
7. McKee SP, Levi DM, Movshon JA. The pattern of visual deficits in amblyopia. *J Vis* 2003; 3: 380-405.
8. Tolchin JG, Lederman ME. Congenital (infantile) esotropia: psychiatric aspects. *Journal of Pediatric Ophthalmology and Strabismus* 1977; 15: 160-3.
9. Westheimer G. Center-surround antagonism in spatial vision: retinal or cortical locus? *Vision Research* 2004; 44: 2457-65.
10. Daw NW. Critical periods and amblyopia. *Arch Ophthalmol* 1998; 116: 502-5.
11. Snowden SK, Stewart-Brown SL. Preschool Vision Screening. NHS R&D HTA Program; 1997.
12. Rahi JS, Dezateux C. The future of preschool vision screening services in Britain. *BMJ* 1997; 315: 1247-8.
13. Williams C, Harrad RA, Sparrow JM, Harvey I, Golding J, Lee J, et al. Future of preschool vision screening. *BMJ* 1998; 316: 937a-.
14. Stewart-Brown SL, Snowden SK. Evidence-based dilemmas in pre-school vision screening. *Arch. Dis. Child.* 1998; 78: 406-7.
15. Brown SA, Weih LM, Fu CL, Dimitrov P, Taylor HR, McCarty CA. Prevalence of amblyopia and associated refractive errors in an adult population in Victoria, Australia. *Ophthalmic Epidemiology* 2000; 7: 249-58.
16. The Pediatric Eye Disease Investigator Group, Repka MX, Beck RW, Holmes JM, Birch EE. A randomized trial of patching regimens for treatment of moderate amblyopia in children. *Archives of Ophthalmology* 2003; 121: 603-12.
17. The Pediatric Eye Disease Investigator Group. A Randomized Trial of Prescribed Patching Regimens for Treatment of Severe Amblyopia in Children. *Ophthalmology* 2003; 110: 2075-87.
18. Williams C, Northstone K, Harrad RA, Sparrow JM, Harvey I. Amblyopia treatment outcomes after preschool screening v school entry screening: observational data from a prospective cohort study. (Extended Report). *British Journal of Ophthalmology* 2003; 87: 988-94.
19. Eibschitz-Tsimhoni M, Friedman T, Naor J, Eibschita N, Friedman Z. Early screening for amblyogenic risk factors lowers the prevalence and severity of amblyopia. *Journal of AAPOS* 2000; 4: 194-9.
20. van Hof-Van Duin J, Evenhuis-van Leunen A, Mohn G, Baerts W, Fetter WP. Effects of very low birth weight (VLBW) on visual development during the first year after term. *Early Human Development* 1989; 20: 255-66.
21. Pike MG, Holmstrom G, de Vries LS, Pennock JM, Drew KJ, Sonksen PM, et al. Patterns of visual impairment associated with lesions of the preterm infant brain. *Developmental Medicine And Child Neurology* 1994; 36: 849-62.

22. Atkinson J, Braddick O, Anker S, Ehrlich D, King J, Watson P, et al. Two infant vision screening programmes: prediction and prevention of strabismus and amblyopia from photo- and videorefractive screening. *Eye* 1996; 10: 189-98.
23. Clarke M, Wright C, Hrisos S, Anderson JD, Henderson SE, Richardson SR. Randomised controlled trial of treatment of unilateral visual impairment detected at preschool vision screening. *British Medical Journal* 2003; 327: 1251-4.
24. Richardson SR, Wright CM, Hrisos S, Buck D, Clarke MP. Stereoacuity in unilateral visual impairment detected at preschool screening: outcomes from a randomized controlled trial. *Investigative Ophthalmology & Visual Science* 2005; 46: 150-4.
25. Simons KA, Preslan M. Natural history of amblyopia untreated owing to lack of compliance. *British Journal of Ophthalmology* 1999; 83: 582-7.
26. Hiscox F, Strong N, Thompson JR, Minshull C, Woodruff G. Occlusion for amblyopia: a comprehensive survey of outcome. *Eye* 1992; 6: 300-4.
27. Williamson T, Andrews R, GN D. Assessment of an innercity visual screening programme for preschool children. *Br J Ophthalmol* 1995; 79: 1068-73.
28. Hudak D, Magoon E. Poverty predicts amblyopia treatment failure. *Journal of AAPOS* 1997; 4: 214-5.
29. The Pediatric Eye Disease Investigator Group. A prospective, pilot study of treatment of amblyopia in children 10 to <18 years old. *American Journal of Ophthalmology* 2004; 137: 581-3.
30. Campbell LR, Charney E. Factors associated with delay in diagnosis of childhood amblyopia. *Pediatrics* 1991; 87: 178-85.
31. Snowden SK, Stewart-Brown SL. Amblyopia and disability: a qualitative study. 1997.
32. Rahi J, Logan S, Timms C, Russell-Eggitt I, Taylor D. Risk, causes, and outcomes of visual impairment after loss of vision in the non-amblyopic eye: a population-based study. *the Lancet* 2002; 360: 597-602.
33. Brown MM, Brown GC, Sharma S, Busbee B, Brown H. Quality of life associated with unilateral and bilateral good vision. *Ophthalmology* 2001; 108: 643-7.
34. Membreno JH, Brown MM, Brown GC, Sharma S, Beauchamp GR. A cost-utility analysis of therapy for amblyopia. *Ophthalmology* 2002; 109: 2265-71.
35. Fielder AR, Moseley MJ. Does stereopsis matter in humans? *Eye* 1996; 10: 233-8.
36. Joy S, Davis H, Buckley D. Is stereopsis linked to hand-eye coordination? *British Orthoptic Journal* 2001; 58: 38-41.
37. Jones RK, Lee DN. Why two eyes are better than one: the two views on binocular vision. *Journal of Experimental Psychology: Human Perception and Performance* 1981; 7: 30-40.
38. Murdoch JR, McGhee CN, Glover V. The relationship between stereopsis and fine manual dexterity: pilot study of a new instrument. *Eye* 1991; 5: 642-3.
39. Rogers GL, Chazan S, Fellows R. Strabismus surgery and its effect upon infant development in congenital esotropia. *Ophthalmology* 1982; 89: 479-83.
40. Ross G, Lipper EG, Abramson D, Preiser L. The development of young children with retinoblastoma. *Archives of Pediatrics and Adolescent Medicine* 2001; 155: 80-3.
41. Hrisos S, Clarke M, Wright C. Visuo-motor skills in pre-school children with a unilateral visual acuity deficit. *AAPOS* 2003.
42. Eustis S, Smith DR. Parental understanding of strabismus. *Journal of Pediatric Ophthalmology and Strabismus* 1987; 24: 232-6.
43. Satterfield D, Keltner JL, Morrison TL. Psychosocial aspects of strabismus study. *Archives of Ophthalmology* 1993; 111: 1100-5.
44. Gray C, Ansons AM, Kincey J. Psychological characteristics of orthoptic patients being assessed for cosmetic strabismus surgery. In: 22nd meeting of the European Strabismological Association, 1995; Cambridge UK: p. 91-5.
45. Burke JP, Leach CM, Davis H. Psychosocial implications of strabismus surgery in adults. *Journal of Pediatric Ophthalmology and Strabismus* 1997; 34: 159-64.

46. Olitsky SE, Sudesh S, Graziano A, Hamblen J, Brooks SE, Shaha SH. The negative psychosocial impact of strabismus in adults. *Journal of AAPOS* 1999; 3: 209-11.
47. Coats DK, Paysse EA, Towler AJ, Dipboye RL. Impact of large angle horizontal strabismus on ability to obtain employment. *Ophthalmology* 2000; 107: 402-5.
48. Packwood EA, Cruz OA, Rychwalski PJ, Keech RV. The psychosocial effects of amblyopia study. *Journal of AAPOS* 1999; 3: 15-7.
49. Epelbaum M, Milleret C, Buisseret P, Dufier JL. The sensitive period for strabismic amblyopia in humans. *Ophthalmology* 1993; 100: 323-7.
50. Klaeger-Manzanell C, Hoyt CS, Good WV. Two step recovery of vision in the amblyopic eye after visual loss and enucleation of the fixing eye. *The British Journal Of Ophthalmology* 1994; 78: 506-7.
51. Moseley MJ, Neufeld M, McCarry B, Charnock A, McNamara R, Rice T, et al. Remediation of refractive amblyopia by optical correction alone. *Ophthalmic and Physiological Optics* 2002; 22: 296-9.
52. Stewart CE, Moseley MJ, Fielder AR, Stephens DA, MOTAS C. Refractive adaptation in amblyopia: quantification of effect and implications for practice. *The British Journal Of Ophthalmology* 2004; 88: 1552-6.
53. Stewart CE, Moseley MJ, Stephens DA, Fielder AR. Treatment Dose-Response in Amblyopia Therapy: The Monitored Occlusion Treatment of Amblyopia Study (MOTAS). *Invest. Ophthalmol. Vis. Sci.* 2004; 45: 3048-54.
54. The Pediatric Eye Disease Investigator Group. The Clinical Profile of Moderate Amblyopia in Children Younger than 7 years. *Archives of Ophthalmology* 2002; 120: 281-7.
55. The Pediatric Eye Disease Investigator Group. A Randomized Trial of Atropine vs Patching for Treatment of Moderate Amblyopia in Children. *Archives of Ophthalmology* 2002; 120: 268-77.
56. The Pediatric Eye Disease Investigator Group. A randomized trial of atropine regimens for treatment of moderate amblyopia in children. *Ophthalmology* 2004; 111: 2076-85.
57. The Pediatric Eye Disease Investigator Group. A Randomized pilot study of near activities versus non-near activities during patching therapy for amblyopia. *Journal of AAPOS* 2005; (in press).
58. Krumholtz I, FitzGerald D. Efficacy of treatment modalities in refractive amblyopia. *Journal Of The American Optometric Association* 1999; 70: 399-404.
59. Leguire LE, Rogers GL, Bremer DL, Walson PD, McGregor ML. Levodopa/Carbidopa for childhood amblyopia. *Investigative Ophthalmology and Vision Science* 1993; 34: 3090-5.
60. Leguire LE, Rogers GL, Walson PD, Bremer DL, McGregor ML. Occlusion and levodopa-carbidopa treatment for childhood amblyopia,. *Journal of American Association for Pediatric Ophthalmology and Strabismus* 1998; 2: 257-64.
61. Leguire LE, Walson PD, Rogers GL, Bremer DL, McGregor ML. Longitudinal study of levodopa/carbidopa for childhood amblyopia. *Journal of Pediatric Ophthalmology and Strabismus* 1993; 30: 354-60.
62. Leguire LE, Komaromy KL, Nairus TM, Rogers GL. Long-term follow-up of L-dopa treatment in children with amblyopia. *Journal Of Pediatric Ophthalmology And Strabismus* 2002; 39: 326-30; quiz 45-46.
63. The Pediatric Eye Disease Investigator Group. The Course of Moderate Amblyopia Treated with Atropine in Children: Experience of the Amblyopia Treatment Study. *American Journal of Ophthalmology* 2003; 136: 630-9.
64. The Pediatric Eye Disease Investigator Group. The Course of Moderate Amblyopia Treated with Patching in Children: Experience of the Amblyopia Treatment Study. *American Journal of Ophthalmology* 2003; 136: 620-9.
65. The Pediatric Eye Disease Investigator Group. A Randomized Trial of Atropine vs Patching for Treatment of Moderate Amblyopia in Children. *Archives of Ophthalmology* 2002; 120: 268-77.

66. The Pediatric Eye Disease Investigator Group. A Comparison of Atropine and Patching Treatments for Moderate Amblyopia by Patient Age, Cause of Amblyopia, Depth of Amblyopia and Other Factors. *Ophthalmology* 2003; 110: 1632-8.
67. Campos EC. Update on strabismus and amblyopia. *Acta Ophthalmologica Scandinavica* 1995; 17-24.
68. The Pediatric Eye Disease Investigator Group. Risk of amblyopia recurrence after cessation of treatment. *Journal of American Association for Pediatric Ophthalmology and Strabismus* 2004; 8: 420-8.
69. Rutstein RP, Corliss DA. Long-term changes in visual acuity and refractive error in amblyopes. *Optometry And Vision Science: Official Publication Of The American Academy Of Optometry* 2004; 81: 510-5.
70. Leiba H, Shimshoni M, Oliver M, Gottesman N, Levartovsky S. Long-term follow-up of occlusion therapy in amblyopia. *Ophthalmology* 2001; 108: 1552-5.
71. Levartovsky S, Oliver M, Gottesman N, Shimshoni M. Long-term effect of hypermetropic anisometropia on the visual acuity of treated amblyopic eyes. *The British Journal Of Ophthalmology* 1998; 82: 55-8.
72. Lee SY, Isenberg SJ. The relationship between stereopsis and visual acuity after occlusion therapy for amblyopia. *Ophthalmology* 2003; 110: 2088-92.
73. Searle A, Vedhara K, Norman P, Frost A, Harrad R. Compliance with eye patching in children and its psychosocial effects: A qualitative application of protection motivation theory. *Psychology, Health & Medicine* 2000; 5: 43-55.
74. Parkes LC. An investigation of the impact of occlusion therapy on children with amblyopia, its effect on their families, and compliance with treatment. *British Orthoptic Journal* 2001; 58: 30-7.
75. Smith KH, Baker DB, Keech RV, Adams LW, Rosa RH, Austin CJ, et al. Monocular congenital cataracts: psychological effects of treatment. *Journal of Pediatric Ophthalmology and Strabismus* 1991; 28: 245-9.
76. Hrisos S, Clarke M, Anderson JD, Wright C. Emotional Impact of amblyopia treatment on preschool children. 2003.
77. Choong YF, Lukman H, Martin S, Laws DE. Childhood amblyopia treatment: psychosocial implications for patients and primary carers. *Eye (London, England)* 2004; 18: 369-75.
78. The Pediatric Eye Disease Investigator Group. Impact of Patching and Atropine Treatment on the Child and Family in the Amblyopia Treatment Study. *Archives of Ophthalmology* 2003; 121: 1625-32.
79. Fielder AR, Irwin M, Auld R, Cocker KD, Jones HS, Moseley MJ. Compliance in amblyopia therapy: objective monitoring of occlusion. *British Journal of Ophthalmology* 1995; 79: 585-9.
80. Oliver M, Neumann MD, Chaimovitch Y, Gotesman N, Shimshoni M. Compliance and results of treatment for amblyopia in children more than 8 years old. *American Journal of Ophthalmology* 1986; 102: 340-5.
81. Nucci P, Alfarano R, Piantanida A, Brancato R. Compliance in anti-amblyopia occlusion therapy. *Acta Ophthalmologica* 1992; 70: 128-31.
82. Smith LK, Thompson JR, Woodruff G, Hiscox F. Factors affecting treatment compliance in amblyopia. *Journal of Pediatric Ophthalmology and Strabismus* 1995; 32: 98-101.
83. Newsham D. Parental non-concordance with occlusion therapy. *British Journal of Ophthalmology* 2000; 84: 957-62.
84. The Pediatric Eye Disease Investigator Group. Impact of Patching and Atropine Treatment on the Child and Family in the Amblyopia Treatment Study. *Archives of Ophthalmology* 2003; 121: 1625-32.
85. Searle A, Norman P, Harrad R, Vedhara K. Psychosocial and clinical determinants of compliance with occlusion therapy for amblyopic children. *Eye* 2002; 16: 150-5.
86. Edelman PM. Common Pitfalls in amblyopia management. *American Orthoptic Journal* 1989; 39: 57-61.

87. Beardsell R, Clarke S, Mill M. Outcome of Occlusion Treatment for Amblyopia. *Journal of Pediatric Ophthalmology and Strabismus* 1999; 36: 19-24.
88. Newsham D. A randomised controlled trial of written information: the effect on parental non-concordance with occlusion therapy. *British Journal of Ophthalmology* 2002; 86: 787-91.

Populations	Percentage
Recruited soldiers	
Irvine*	1.0
Helveston*	1.0
Theodore et. al.*	1.4
Evens and Kuypers*	1.8
Glover and Brewster*	2.4
Downing*	3.2
Preschool and school-age children	
Friedman et. al. *	0.5
Russell et. al. *	1.3
DaCunha and Jenkins*	1.7
Flom and Neumaier*	1.8
McNeil*	2.7
Frandsen*	3.1
Vereecken et. al.*	3.5
Thompson et. al.(4)	3.0
ALSPAC – early screening(18)	1.1
ALSPAC – late screening(18)	2.0
Eibschitz-Tsimhoni et al(19) – early screening	1.0
Eibschitz-Tsimhoni et al(19) – late screening	2.6
Older population	
Vinding et. al. *	2.9
Brown et. al.(15)	3.06
Attebo et al (3)	3.2
Ophthalmic patients	
Irvine*	4.0
De Roeth*	4.5
Cole*	5.3

TABLE 1: Reported Prevalence of amblyopia in selected populations

*From Von Noorden(1) with recent studies by Thompson(4), Attebo et al (3), Brown et al(15), ALSPAC(18) and Eibschitz-Tsimhoni et al(19) added into table

STATEMENT OF AUTHORSHIP RESPONSIBILITY

I certify I have participated sufficiently in the conception and design of this work and the interpretation of the data (when applicable), as well as the writing of the manuscript, to take public responsibility for it. I believe the manuscript represents valid work. I have reviewed that final version of the submitted manuscript and approve it for publication. Neither this manuscript nor one with substantially similar content under my authorship has been published or is being considered for publication elsewhere, except as described in an attachment. If requested, I shall produce that data on which the manuscript is based, for examination by the editors or their assignees.

STATEMENT OF FINANCIAL DISCLOSURE

I certify that any affiliation with or involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the manuscript (for example, employment, consultancies, stock ownership, honoraria, expert testimony) are disclosed below.

COPYRIGHT TRANSFER

In consideration of the action of Optometrists Association Australia in reviewing, editing and publishing this submission (manuscript, tables and figures), the author(s) undersigned hereby transfers, assigns or otherwise conveys all copyright ownership to Optometrists Association Australia in the event that the work is published in Clinical and Experimental Optometry.