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Invited Review

A critical evaluation of the evidence supporting the practice of behavioural vision therapy

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Abstract

In 2000, the UK's College of Optometrists commissioned a report to critically evaluate the theory and practice of behavioural optometry. The report which followed Jennings (2000; Behavioural optometry – a critical review. *Optom. Pract.* **1**: 67) concluded that there was a lack of controlled clinical trials to support behavioural management strategies. The purpose of this report was to evaluate the evidence in support of behavioural approaches as it stands in 2008. The available evidence was reviewed under 10 headings, selected because they represent patient groups/conditions that behavioural optometrists are treating, or because they represent approaches to treatment that have been advocated in the behavioural literature. The headings selected were: (1) vision therapy for accommodation/vergence disorders; (2) the underachieving child; (3) prisms for near binocular disorders and for producing postural change; (4) near point stress and low-plus prescriptions; (5) use of low-plus lenses at near to slow the progression of myopia; (6) therapy to reduce myopia; (7) behavioural approaches to the treatment of strabismus and amblyopia; (8) training central and peripheral awareness and syntonics; (9) sports vision therapy; (10) neurological disorders and neuro-rehabilitation after trauma/stroke. There is a continued paucity of controlled trials in the literature to support behavioural optometry approaches. Although there are areas where the available evidence is consistent with claims made by behavioural optometrists (most notably in relation to the treatment of convergence insufficiency, the use of yoked prisms in neurological patients, and in vision rehabilitation after brain disease/injury), a large majority of behavioural management approaches are not evidence-based, and thus cannot be advocated.

Keywords: alternative/complementary therapies, behavioural optometry, vision training, visual therapy

Introduction

What is behavioural optometry? While no single, agreed definition appears to exist, behavioural optometry is often portrayed as an extension of traditional optometric practice that requires its practitioners to take a holistic approach in the treatment of visual disorders. This 'extension' is apparent from Forrest (1976) in which it is stated that '*Optometry, as a clinical profession, made its great leap forward when its direction shifted from aiding and reducing asthenopia to the enhancement of perception, performance and problem-solving through the more efficient operation of the visual process*'. Thus, in the behavioural approach, the role of the optometrist is considered to extend far beyond the provision of optimal refractive correction and the screening/referral for ocular and systemic disease. In short, behavioural optometrists believe that optometrists can influence the visual process in ways that are not taught as part of traditional UK optometric education programmes.

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The practice of behavioural optometry began in the middle of the last century. It is generally accepted that its origins lie more in clinical experience built up over an extended period of time than in robust scientific evidence. The founding father of behavioural optometry is Arthur Marten Skeffington (1890–1976) who was born in the English village of Skeffington in Leicestershire. One of Skeffington's lasting legacies is his famous '4-circles model' in which vision is considered not in isolation, but rather as being inextricably linked to spatial, motor and intellectual functions. In the words of Birnbaum (1993) (p.34), Skeffington portrayed vision as the 'product of the interaction of four component sub-processes'. These sub-processes are anti-gravity, centring, identification and the speech-auditory process.

The anti-gravity system is concerned with balance and posture, whereas the centring system is described as an attentional and orienting system for selecting where the body, head and eyes are directed (Birnbaum, 1993). Convergence is the overt oculomotor component of the centring process (Skeffington, 1964). The identification system derives meaning from those areas of space which are selected for attention by the centring system, and accommodation is the overt oculomotor component of this process (Skeffington, 1964). Finally, the speech-auditory process is responsible for analysing and communicating what is seen. The model is referred to as a '4-circles model' because the circles are mutually overlapping and vision is represented by the area where all four circles intersect. While different practitioners of behavioural optometry often interpret the model in different ways (Paul Adler, personal communication), the 4-circles model continues to represent the cornerstone of the behavioural optometry approach to patient management.

According to the British Association of Behavioural Optometrists (BABO), behavioural optometrists '*use lenses and vision training to facilitate the development of a more efficient and complete visual process*' (BABO, 2008). The term 'vision therapy' needs to be explained and distinguished from 'orthoptics' (but see below): '*vision therapy can be defined as therapy that is designed to arrange conditions that will allow the perceiver to gain new insights and an alternative way of doing things, thus improving his or her perception on the world and becoming more efficient. It requires the patient to participate and be active in the therapy and should be transferable to other skill areas. It requires a degree of true learning and ends in automaticity of the vision task in order to provide stability and consistency. The end result is a reliable visual system which correctly interprets visual and visual-spatial data and enables good integration of this skill with other body senses*' (Gilman, 1988, cited by Paul Adler, personal communication).

Behavioural optometrists consider vision therapy to be something more than orthoptics which they see as placing too little emphasis on functionality, and therefore less likely to transfer to general viewing outside the clinical setting. More fundamentally, behavioural optometry and traditional* approaches to optometry view the origin and significance of heterophorias in very contrasting ways. Whereas traditional optometry views near heterophoria as a possible *cause* of signs/symptoms (the so called 'vergence stress' model), the behavioural view is that near heterophoria arises as a *consequence* of near point stress. In particular, in behavioural approaches, near exophoria is thought to be beneficial because it protects the visual system against over convergence and consequent diplopia (Birnbaum, 1993). However, although orthoptics and behavioural vision therapy differ in their underlying rationale, they share a considerable number of clinical investigative and treatment techniques. Near retinoscopy (for assessing accommodative lag; Haynes, 1960) and positive- and negative-lens flippers (for assessing/treating accommodative infacility; Griffin, 1982; Pierce and Greenspan, 1971) are just two examples of clinical procedures that initially found favour amongst advocates of vision therapy (e.g. Cooper *et al*., 1983) but are now considered to be standard orthoptic tools that traditional optometrists might choose to use (Barrett and Elliott, 2007). Given the many overlaps between the techniques used, some would argue that the point at which orthoptics ends and vision therapy begins is fluid or indistinct. For example, in recent studies of the effectiveness of treatment for convergence insufficiency (Scheiman *et al*., 2005a,b reviewed below), the treatment is constantly referred to as 'orthoptics/vision therapy'.

A number of recently published textbooks, emanating mainly from the USA (Scheiman, 2002; Scheiman and Rouse, 2006), set out a view of optometry that differs considerably from the traditional view. For example, Scheiman (2002) (p. 47) describes a hierarchical model of vision which consists of three components. Component one is concerned with acuity, refractive anomalies and ocular health. Component two is called visual efficiency, and it refers to the '*effectiveness of the visual system to clearly, efficiently, and comfortably allow an individual to gather visual information at school, work, or play*'. Visual efficiency includes accommodation, binocular vision and ocular motility. Scheiman's (2002) (p. 69) view is that a vision problem can exist even when an individual has good visual acuity (VA), no refractive

*Throughout this review, the term 'traditional optometry' is used to describe the practice of optometry by practitioners who do not subscribe to or follow the behavioural view of optometric practice as outlined in this Introduction. In using this term, it is recognised that 'traditional optometry' differs depending upon where in the world the clinician received his/her training and upon where he/she practices optometry.

error/ocular disease, normal accommodation, normal binocular vision and normal ocular motility because '*an individual must [also] be able to analyze, interpret and make use of the incoming visual information in order to interact with the environment*'. This is component three in the model and it refers to visual information processing skills. There are many different such skills but examples include the evaluation of laterality/directionality. Laterality refers to the ability to distinguish left from right on one's own body or on someone else, and directionality refers to the ability to distinguish between left and right for the location of objects in space. The model is hierarchical because problems at one level can give rise to difficulties with tasks at higher levels in the hierarchy. For example, problems with visual efficiency (level 2) can give rise to deficits in visual information processing skills (level 3), which according to Scheiman (2002) (p. 83), '*are the most likely to be neglected by eye care professionals*'. Treatment and management strategies are also described in these textbooks (Scheiman, 2002; Scheiman and Rouse, 2006).

Whether UK behavioural optometrists fully subscribe to the US-based approach outlined above is not entirely clear but, from my reading of the literature, it seems that there is a great deal of overlap between the two perspectives on the role of the optometrist and the scope of vision therapy to benefit diverse patient groups.

There is a long list of patient groups which behavioural optometrists claim that they may be able to treat successfully. For example, the BABO website lists the following 'problems' as potentially benefiting from behavioural vision care: '*Dyslexia, dyspraxia, any learning problem in the classroom (poor concentration, poor handwriting, low reading, poor comprehension, poor maths, fidgety etc.), eye strain in the office including computer eye strain, improving sports performance, traumatic brain injuries, strabismus and amblyopia, headaches, double vision, fatigue, attention deficit disorder (ADD) and attention deficit hyperactivity disorder (ADHD), children with behavioural problems, poor co-ordination, clumsy, poor at sports especially ball games and team games*' (BABO, 2008).

According to Paul Adler (personal communication), referrals to UK behavioural optometrists are on the increase, and referrals for behavioural vision investigation/therapy are coming from an increasingly diverse range of health/educational professionals, including occupational therapists, general practitioners and special educational needs co-ordinators. However, the theory and practice of behavioural optometry remain controversial, especially when considered from the perspective of the traditional optometrist. This is because many of the patients that behavioural optometrists are treating would not exhibit any abnormality under clinical assessment using traditional optometric approaches and also because some of the behavioural assessment/treatment practices might be considered to fall well outside the realm of traditional optometry. In 2000, the College of Optometrists commissioned a report to critically appraise the evidence in support of behavioural optometry. The report which followed (Jennings, 2000) concluded that '*much of the theory is unconvincing*' and the lack of controlled clinical trials of behavioural management strategies was noted. The purpose of this report was to evaluate the evidence in support of the behavioural approach as it stands in 2008.

Nature and scope of this review

Rather than concentrating upon the historical and theoretical aspects of behavioural optometry which were elegantly dealt with in the report by Jennings (2000), the approach adopted here is to review the evidence for and against the claims made by behavioural optometrists in relation to the different patient groups/conditions that they appear to be evaluating/treating. I have constructed this list of patient groups/conditions based upon my discussions with a behavioural optometrist who was appointed in this advisory role by the College of Optometrists (see Acknowledgements) and upon my reading of the literature. The approach I have taken is to concentrate upon the evidence for or against different behavioural management approaches rather than upon the specific details of the treatments themselves.

One area that is not covered here relates to use of coloured/tinted lenses or overlays for dyslexia. I have taken this approach because, although behavioural optometrists in the UK may adopt this approach in the evaluation and treatment of their patients with reading/learning difficulties, this practice does not fall exclusively within the domain of behavioural optometry, and because several research reports on this topic can be found elsewhere (Evans and Drasdo, 1991; Lightstone *et al*., 1999; Bouldoukian *et al*., 2002; Scott *et al*., 2002; Williams *et al*., 2004).

Particular emphasis is placed in this review upon publications in the mainstream literature (i.e. journal articles that are indexed in the Web-of-Science or PubMed literature search engines) that have appeared since the report by Jennings (2000). However, a search was also made for relevant journal articles appearing in the behavioural vision journals which tend not to be abstracted by any of the major literature search programs (see Appendix).

Vision therapy for accommodation/vergence disorders

von Noorden (1996) stated that '…*most published studies attempting to evaluate the results of orthoptic therapy are largely based on clinical impressions rather than solid* *evidence and do not stand to scrutiny*'. Recently, however, strong and persuasive evidence has emerged to support the efficacy of orthoptics/vision training in managing convergence insufficiency. Notably, randomised clinical trials have appeared in the recent literature (Birnbaum *et al*., 1999; Scheiman *et al*., 2005a,b) and the results of these studies have confirmed the findings from the many published studies (e.g. Griffin, 1987; Grisham, 1988; Adler, 2002; Gallaway *et al*., 2002) that had employed less scientifically-sound study designs (e.g. retrospective studies, or prospective studies without control groups). Birnbaum *et al*.'s (1999) study was the first controlled trial to show that convergence insufficiency was a treatable condition. They studied 60 men aged 40 years and above and divided them into three groups. Group 1 received 'office'-based and home-based vision therapy exercises, whereas group 2 participants were prescribed only home-based vision therapy. Group 3 received no therapy. Birnbaum *et al*. (1999) reported overall success rates of around 62%, 30% and 10% for groups 1, 2 and 3, respectively. However, this study has been criticised on the grounds that the amount of attention paid to each group was directly linked to the amount of vision therapy prescribed: this is the so-called Hawthorne effect (Mayo, 1993), and it represents a potential source of bias. More recent randomised controlled trials (RCT) have included placebo treatment groups to address this issue. Scheiman *et al*. (2005a) randomly allocated the 47 children aged 9–18 years who participated in their study into three groups. Group 1 received office-based orthoptics/vision therapy (i.e. in the clinical setting) which consisted of a wide range of exercises including binocular accommodative facility, 'string' convergence (where the patient is asked to accurately converge on targets placed on a string), 'barrel' convergence (where the patient is asked to accurately converge on targets on a handheld card) as well as various fusional vergence procedures. Group 2 also attended the clinic regularly but they received placebo orthoptics/vision therapy. Group 3 received home-based pencil-push up therapy (i.e. simple pencil to nose exercises). Scheiman *et al*. (2005a) found that only the office-based orthoptics/vision therapy group (i.e. group 1) showed clinically significant improvements in signs and symptoms of convergence insufficiency. A similar conclusion was reached by the same research team investigating convergence insufficiency treatment in adults aged 19–30 years (Scheiman *et al*., 2005b).

While the studies by Scheiman *et al*. (2005a,b) have been widely welcomed because they represent good examples of how the effectiveness of orthoptics/vision therapy can be rigorously tested, they have also been criticised on a number of grounds, one of which was the manner in which the home group were instructed to perform their pencil to nose exercises (Sethi *et al*., 2006). Another major criticism relates to the fact that the group that carried out pencil push-ups at home (group 3) received treatment that was much less intensive than the group that was found to benefit from treatment (group 1); effectively the criticism here is that the difference in treatment benefits may have resulted from a difference in the amount of treatment received rather than from the increased range of exercises offered in the clinic (Jethani, 2005; Kushner, 2005). These concerns were accepted by Scheiman *et al*. (2005c) who have indicated that a 'full-scale' randomised clinical trial is now underway (Scheiman *et al*., 2008), the results of which will address the question of dosage of prescribed orthoptics/vision therapy in the treatment of convergence insufficiency. It is also hoped that the participants in the study will be subjected to long-term follow-up in order to assess whether signs and symptoms of convergence insufficiency can be permanently resolved in an individual or whether repeated treatments are needed.

Although a considerable volume of research into the treatment of convergence insufficiency is ongoing, it is now safe to conclude that this condition is amenable to treatment. Unfortunately, the treatment of accommodation disorders and other vergence disorders has not been subjected to the same level of attention in the recent scientific/clinical literature. It is true to say, however, that some controlled trials of therapy for accommodative dysfunction have appeared in the literature. Weisz (1979) reported improved accommodative performance in an experimental group relative to a control group. This conclusion is strengthened by the fact that the control group undertook placebo exercises. In a larger sample ($n = 48$), Hoffman (1982) found that therapy for accommodative dysfunction was effective (as measured objectively) in 5–8 year olds, but not in older children (8–13 years).

Based upon the synopsis of the literature presented above, the available evidence suggests that accommodation disorders and a number of vergence disorders [in particular convergence insufficiency and decompensating exophoria (Aziz *et al*., 2006)] may respond to treatment, and that, when they accrue, treatment effects are durable (Rouse, 1987; Grisham *et al*., 1991; Sterner *et al*., 1999; Ciuffreda, 2002). The role of orthoptic exercises in the treatment of esophoria, however, remains unclear and needs further study (Aziz *et al*., 2006).

Several recent studies investigating accommodative dysfunction have employed cross-over study designs in which half of the participants start out on placebo/sham treatment and then swap over during the study to receive full treatment, whereas other participants start to receive treatment immediately (Cooper *et al*. 1987). This approach was adopted by Sterner *et al*. (2001) who concluded that accommodative facility training (using positive and negative flipper lenses) was effective in children. The results of a very recent study by Brautaset *et al.* (2008) are consistent with the study by Sterner *et al.* (2001). In a small ($n = 24$) sample of children (average age ~10 years) with accommodative insufficiency, Brautaset *et al.* (2008) compared the effects of prescribing plus lens (+1.00 D) reading additions with spherical flipper (±1.50 D) treatment. They found that both methods improved the accommodative amplitude, but that bigger improvements were obtained with spherical flipper treatment. While these results and the results from the many earlier studies of this nature are believable (Rouse, 1987), further, large-scale controlled trials are needed to support definitive claims that treatment is effective, and to identify the patient groups and patient age ranges most amenable to successful treatment.

The under-achieving child

A large and growing proportion of referrals to behavioural optometrists are children who are under-achieving at school (Paul Adler, personal communication). As listed in the Introduction, the BABO website indicates that children with the following conditions may benefit from behavioural vision therapy: *Dyslexia or any learning problem in the classroom; Dyspraxia, Attention Deficit Disorder (ADD) and Attention Deficit Hyperactivity Disorder (ADHD); children with behavioural problems; problems of poor co-ordination; clumsiness, poor at sports especially ball games and team games* (BABO, 2008). But what is the evidence that optometrists adopting a behavioural approach can offer therapy that will positively influence the lives of children with these signs or formally diagnosed conditions? Demonstrating treatment efficacy is especially important here because these children and their parents represent a vulnerable group. Given that there is such a huge diversity of treatment approaches in relation to each of these conditions (e.g. Sigmundsson *et al.*, 1998; Hyman and Levy, 2005; Levy and Hyman, 2005; Rojas and Chan, 2005), the onus is clearly on treatment providers to produce the evidence in support of the treatment(s) that they are offering. Without such evidence, parents inevitably run the risk of wasting their time, effort and resources, and they and their children may become disillusioned if expectations are repeatedly raised and then dashed.

In the sections below, the evidence supporting vision therapy is summarised in relation to dyslexia, dyspraxia and attention-deficit hyperactivity disorder (ADHD)/attention-deficit disorder (ADD). It is worth pointing out that behavioural optometrists believe that vision therapy can be beneficial in these conditions, not because the condition is being 'cured', but because it enables the child to operate more efficiently in spite of the condition (Paul Adler, personal communication). Behavioural therapy for improving sporting performance is summarised in the section titled 'Sports vision therapy'.

Dyspraxia

Dyspraxia (also known as developmental co-ordination disorder, DCD) is recognised as a specific learning disorder (e.g. Kirby, 1999) in which children typically exhibit, amongst other deficits, poorly timed movements that are lacking in rhythm (Savelsbergh *et al.*, 2003). In most children with DCD, the integration of sensory information in the planning of movements appears to be a problem (Blauw-Hospers and Hadders-Algra, 2005; Mijna Hadders-Algra, personal communication). Dyspraxia is the subject of considerable current research attention. For example, Richardson and Montgomery (2005) have recently completed a RCT of dietary supplementation with fatty acids in children with DCD. Another research theme in this area concerns the question of what perceptual (i.e. sensory) problems might exist in these children. A relatively recently published meta-analysis of research findings suggested that perceptual problems, particularly in the visual modality, are associated with difficulties in motor coordination (Wilson and McKenzie, 1998). This work is continuing and the contribution of visual, and in particular visuo-motor/visuo-spatial, deficits to the motor problems, represents an area of particular research interest. For example, van Waelvelde *et al.* (2004) examined the links between motor-free visual perceptual deficits, different visual-motor integration deficits and different motor skills in children with DCD. They found the association between visual–perceptual deficits and motor tasks to be task-specific. In a very recent study, Crawford and Dewey (2008) found that the number of co-occurring disorders present with DCD (e.g. reading/learning difficulties, attention deficit hyperactivity disorder) is associated with the severity of the visual perceptual dysfunction.

However, while there is evidence that perceptual problems may exist in children with dyspraxia, there is a paucity of evidence to show that they play a causal role in dyspraxia, or that vision training can lead to an improvement in signs/symptoms. A single case study published in the ophthalmic literature in 2006 (Hurst *et al.*, 2006) represents the only report I could find advocating vision therapy as a means of treatment for dyspraxia. Therefore, very little concrete evidence exists to support the role of vision therapy in the management of this condition.

ADHD/ADD

It is claimed that behavioural vision therapy can be beneficial in children with ADHD and ADD. In fact, there appears to be little in the way of evidence to support these claims. A small-scale, questionnaire study conducted by Farrar *et al.* (2001) found that ADD/ADHD children undergoing medical treatment exhibit more visual and quality of life symptoms than do a similar group of non-ADD/ADHD children. More recently, the results of a study by Borsting *et al.* (2005) suggested that school-aged children with symptomatic accommodative dysfunction or convergence insufficiency have a higher frequency of ADHD behaviors compared with a control sample, and, in the USA, Granet *et al.* (2005) have reported that the prevalence of convergence insufficiency in the ADHD population may be three times higher than in the population at large. However, Granet *et al.* (2005) acknowledge that this may simply represent an association rather than a causative relationship. In other words, it is not known if the ADHD is the cause of visual anomalies, or vice-versa. It is also possible, of course, that ADHD and visual anomalies are merely associated with each other and not causally linked at all. To successfully develop and validate a therapy for ADHD/ADD based upon vision therapy, it would be necessary to know, first, that the visual difficulties are contributing to the disorder, and second, that the visual anomalies are amenable to modification. Neither of these issues is resolved in the literature.

Dyslexia

There is considerable ongoing controversy surrounding the role of behavioural vision therapy in the treatment of dyslexia. Although few would argue that vision problems can interfere with reading/learning, what it is not well established is the extent to which visual problems represent an underlying cause of the dyslexia. In the USA, there appears to be a significant difference of opinion between the professional organisations that represent optometry and ophthalmology in relation to the prevalence of visual disorders (excluding refractive error) in the paediatric population, the amenability of these visual disorders to treatment, and their association with reading/learning disabilities (e.g. Bowan, 2002; Ciuffreda, 2002; Gallaway, 2002; Press, 2002; Helveston, 2005). Much of this division of opinion seems to stem from a belief by groups representing US ophthalmologists that optometrists are claiming that the therapy which they can offer (i.e. lenses, prisms and vision therapy) can 'cure' dyslexia. However, the US optometric organisations dispute ever having made such a claim. In the policy statement on '*Vision, Learning and Dyslexia*' that was jointly published by the American Academy of Optometry and the American Optometric Association (1997), a multidisciplinary approach to managing the patient with dyslexia is advocated. Specifically, this document states that '*People with learning problems require help from many disciplines to meet the learning challenges they face. Optometric involvement constitutes one aspect of the multidisciplinary management approach required to prepare the individual for lifelong learning*.'

However, the main area of disagreement appears to be centred on the issue of whether vision therapy is at all beneficial, especially in relation to children with learning difficulties. The report by the American Academy of Optometry and the American Optometric Association (1997) states that vision therapy '*does not directly treat learning disabilities or dyslexia*', but rather '*is a treatment to improve visual efficiency and visual processing, thereby allowing the person to be more responsive to educational instruction*'. The ability to enhance reading/learning performance by vision therapy was directly challenged by a 1998 report titled *Learning disabilities, dyslexia and vision* (American Academy of Paediatrics, 1998) which was jointly published by the American Academy of Pediatrics in association with the American Academy of Ophthalmology and the American Association for Pediatric Ophthalmology & Strabismus. This report concluded that '*no scientific evidence exists for the efficacy of eye exercises in the remediation of these complex paediatric developmental and neurologic conditions*'. A statement of re-affirmation for this policy was published on 1 August 2008. The same sentiment is evident in other publications. For example, the report by the American Academy of Ophthalmology (2001) concluded that '*to date there appears to be no consistent scientific evidence that supports behavioural vision therapy, orthoptic vision therapy, coloured overlays or lenses as effective treatments for learning disabilities*'. The report summarised the available literature on eye movements and visual perception in individuals with dyslexia as follows: '*…several studies in the literature demonstrate that eye movements and visual perception are not critical factors in the reading impairment found in dyslexia, but that brain processing of language plays a greater role*'. The report also bemoaned the lack of '*well-performed randomized controlled trials*' in the literature. This situation appears to have altered little in recent times. For example, the authors of the 2005 American Academy of Ophthalmology Focal Points report concluded that '*claims that vision therapy can improve all aspects of life [including emotional, physical, educational, social & psychologic problems] for children with learning disabilities are without merit and have not been proven by well-controlled prospective clinical trials*' (Hertle *et al.*, 2005).

In the UK, the Cochrane Collaboration has commissioned a literature survey to examine the effects of ocular interventions (excluding correction of significant refractive error) on reading speed and accuracy in 'specific reading disorders'. Although commissioned in 2004 (details of the protocol for the review can be viewed online (Robinson *et al*., 2004)), the report has yet to appear but it is likely to be greeted with significant interest from optometrists, both from within and outside the behavioural sphere. In the recent literature, several references have been made to work by a group in Australia that have conducted a controlled trial of the benefits of vision therapy (Leslie, 2004; Helveston, 2005). Although some results have appeared, they have been published in abstract form only (Sampson *et al*., 2005). Until the results of studies such as these appear in print, it remains far from clear whether visual deficits in children are causally linked to reading/learning difficulties. At present, the only consensus appears to be that RCTs investigating the benefits of vision therapy in reading/learning are lacking (Helveston, 2005; Rawstron *et al*., 2005). For this reason, vision therapy cannot currently be considered as an evidence-based treatment for reading or learning disorders and this conclusion is supported by other contemporary reviews of the literature (e.g. Wright, 2007).

Yoked prisms for near binocular disorders and for producing postural changes

The term 'yoked prisms' describes prisms of equal power that have their bases in the same direction. For example, vertical yoked prisms consist of prism power that is oriented either base-up in front of both eyes, or base-down in front of both eyes. The purpose of yoked prisms (sometimes also referred to as 'conjugate' prisms or 'ambient lenses', e.g. Kaplan *et al*. (1996); Kaplan and Carmody (1997)) is not therefore to address a vertical or horizontal imbalance between the eyes, but, in the words of Birnbaum (1993) (p.186), '*their effect is rather to create spatial change*' (see below). While the main effect of looking through yoked prisms is that the entire visual field is displaced in the direction of the apex, an additional visual effect relates to their production of non-uniform magnification across the visual field (Ogle, 1964). Specifically, the images of objects located towards the apex of the prisms appear magnified whereas the images of objects near the prism bases appear minified. In addition to the purely visual effects, viewing through yoked prisms has a predictable effect upon one's posture/stance and, consequently, upon one's centre of gravity (Gizzi *et al*., 1997). Considering the visual and postural effects together, behavioural optometrists expect that base-down yoked prisms will '*create an upward spatial shift and consequent upward gaze shift associated with divergence, expanded peripheral awareness, relaxation, backwards and outwards body thrust, and increased near point working distance*' (Birnbaum, 1993; p. 186). Base-up yoked prisms, on the other hand, are viewed as '*spatially compressive, creating decreased size, decreased distance, downward spatial shift and downwards gaze shift, associated with convergence and inwards body thrust*' (Birnbaum, 1993; p. 186).

Some behavioural optometrists consider yoked prisms to be useful across a wide range of clinical scenarios/patient groups and the evidence supporting their use appears to vary considerably depending upon the precise condition being treated. They appear to be used more widely by behavioural optometrists in the USA than in the UK (Paul Adler, personal communication).

Treating binocular disorders at near

For the reasons outlined above, behavioural optometrists believe that base-up yoked prisms can be used to treat exophoria or convergence insufficiency, and conversely, that base-down prisms can be used to treat esophoria or convergence excess. In addition, it is suggested that base-down prisms may be useful in cases where low plus lens power is needed at near but is not tolerated (Horner, 1972/3, cited by Birnbaum, 1993).

Rather than being prescribed for long-term use, vertical yoked prisms used to treat exophoria/convergence-insufficiency or esophoria/convergence-excess should be low in power (e.g. 3^{Δ} down for convergence excess, and 2^{Δ} up for convergence insufficiency (Kaplan, 1978/9, cited by Birnbaum, 1993)) and are provided only as training lenses to be used when, for example, specific activities are being carried out. When used in this fashion, the purpose of the yoked prisms is to induce spatial and postural changes that are favourable to the individual. Importantly, however, Birnbaum (1993) conceded that no controlled studies had taken place to investigate the effectiveness of vertical yoked prisms in patients with these conditions and there appears to have been little change in this regard in the intervening time. No controlled trials of this nature appear in the BABO bibliography (see Appendix) and none were revealed following a search using scientific literature databases.

One study (Lazarus, 1996) examined the effectiveness of yoked base-up prisms together with base-in prisms in alleviating asthenopia associated with computer use. The rationale was simply that this prism combination would reduce the amount of elevation and convergence required by the computer user. Lazarus' (1996) study employed a double-blind design in which spectacles that combined prism power with plus lens power were compared with those with plus lens power alone. Overall, there was a statistically significant preference for the spectacles containing the prisms. However, no subsequent studies have appeared to corroborate this result. Thus, the use of yoked prism power for treating exophoria/convergence-insufficiency or esophoria/

convergence-excess or for preventing/reducing eyestrain at the computer must be viewed as unproven.

Link between posture and refractive error

According to Kraskin (1985, cited by Birnbaum, 1993), vision disorders are the end result of postural problems. Birnbaum (1993) summarises this thinking as follows: '*When, in coming to balance with gravity and the task at hand, an individual increases the tonicity of the lower back musculature, the centre of gravity shifts forward, necessitating a series of counterbalancing adjustments in the upper body that culminate in an upward, forward thrust of the chin. Myopia, according to Kraskin, is an ocular end product of these postural adjustments*'. Similarly, significant hyperopia is thought to result directly from '*hypotonicity of the lower back musculature that permits a backwards shift of the centre of gravity*', (Birnbaum (1993) (p.187)). This thinking is consistent with Skeffington's view that a balanced, stress-free posture is essential for efficient visual processing, and, more generally, with the holistic view of behavioural optometry practitioners that vision, posture, balance and gravity closely interact with one another.

Kraskin advocated the use of yoked prisms in cases when he believed that a change in posture was needed to alter visual status. To establish the base direction for the yoked prisms, he compared stereopsis measures when low powered (3^{Δ} or 4^{Δ}) prisms are placed base-up vs base-down. Base-right and base-left yoked prisms are used only in patients with '*lateral asymmetries, such as strabismus, anisometropia, and amblyopia*' (Birnbaum, 1993; p. 188). In cases where no difference exists in the level of stereopsis between the base directions, yoked prisms are not employed. However, if a difference in stereopsis is revealed when the base-direction is reversed, Kraskin advocates the use of yoked prisms. Interestingly, the base direction that Kraskin prescribes is not the base direction that yields optimum stereopsis but rather the reverse direction. This, according to Birnbaum (1993), is done so as to deliberately '*exaggerate postural stress and thus to rebound by organising a postural response to the counter-induced stress*'. Thus, Kraskin's approach is to use yoked prisms in the short-term only as a means of inducing postural stress and thus creating a stimulus for change. Birnbaum (1993) points out that the base direction for the yoked prisms chosen on the basis of Kraskin's approach is frequently the complete reverse of that which would be selected using Kaplan's approach (see above). Kraskin's approach to the use of yoked prisms has never been scientifically validated, and thus the use of yoked prisms as a means of altering posture in neurologically normal patients with the ultimate aim of influencing visual status remains highly questionable.

Yoked prisms in patients with postural problems

The approach advocated by Kraskin (described above) is to generate changes in posture that will impact upon visual status. Recently, there has been interest in the possibility that changes in visual input achieved through the use of yoked prisms can produce beneficial postural changes in adolescent patients with idiopathic scoliosis (Wong *et al*., 2002). However, it appears that only one report exists concerning the use of yoked prisms for this purpose and their use in this condition must, therefore, be viewed as experimental.

The use of yoked prisms in neurological patients is newer (and more promising) and is discussed in the section titled 'Neurological disorders and neuro-rehabilitation after trauma/stroke'.

Near point stress and low-plus prescriptions

Skeffington's near point stress model underpins much of the practice of behavioural optometry but the main text describing this model was written by Birnbaum (1993). In this text, Skeffington's thinking on this issue is encapsulated by the statement that '*the near work demands imposed by our culture are incompatible with our physiology and provoke a stress response characterised by a drive for convergence to localize closer than accommodation*' (Birnbaum, 1993; p. 33). Birnbaum highlights a major difference between traditional optometry which views refractive, binocular and accommodative anomalies as the *causes* of difficulties at near, and Skeffington's approach in which these anomalies are the *end-result(s)* rather than the sources of near-point stress. In Skeffington's model, appropriately powered low-plus lenses for use at near relieve the drive for convergence to localise closer than accommodation. This is said to improve overall visual efficiency, not only because it eliminates the mismatch between vergence and accommodation, but also because of additional benefits which may result such as improved posture when reading (e.g. Greenspan, 1970). A key aspect of the near point stress management approach is that low-plus prescriptions are advocated before anything appears to be abnormal on evaluation using a traditional optometric approach. The 'low-plus for relief of near point stress' is therefore a controversial approach because in many instances it suggests that refractive correction should be worn even when the patient is wholly asymptomatic.

Jennings (2000) also discussed the near point stress model and concluded that '*overall the literature reveals no convincing evidence of any benefits from a low-plus prescription*' (Jennings, 2000). The present author concurs with this synopsis of the literature that was available at the time. In the intervening time little additional research appears to have been published in the mainstream ophthalmic/optometric literature concerning the use of low-plus lenses in relation to Skeffington's near point stress model.

A small number of studies have appeared in behavioural optometry journals which have investigated the physiological benefits of low-plus lenses and the optimum near point lens prescription (e.g. Price and Maples, 2005). Another area of interest relates to methods by which it can be determined whether or not low-plus lens correction is indicated for near work in individual pre-presbyopic patients (Tassinari, 2005).

Overall, therefore, the evidence supporting low-plus prescriptions for the alleviation of near point stress defined in terms of Skeffington's model remains unproven. However, it should be pointed out that controversy associated with the issuing of low-plus corrections in pre-presbyopic individuals, particularly in children, also extends to traditional optometric practice (e.g. Donahue, 2004; Robaei *et al*., 2006; Ip *et al*., 2006; Filips, 2008). For example, in a recent, large-scale study of over 2300 12-year-old Australian children, Robaei *et al*. (2006) concluded by saying that '*despite the lack of firm supportive evidence, the prescription of low plus lenses to children seems to be practiced widely in Australia*'.

O'Leary and Evans (2003) highlighted large variations between UK optometric practitioners in relation to the criteria they adopt for prescribing interventions and they blamed a lack of guidelines that are based upon evidence-based research. More recently, Robaei *et al*. (2006) called for rigorous clinical trials to be conducted that will investigate the merits of low plus lenses in pre-presbyopic individuals. Successful completion of this research could offer significant patient benefit because it should lead to evidence-based guidelines in the prescribing of spectacles (in particular for those refractive errors that do not lead to a reduction in vision). Thus, research appears warranted in this area, not only in relation to the behavioural approach to low-plus prescription but in relation to optometry more generally.

Use of low-plus lenses at near to slow the progression of myopia

In the words of Birnbaum (1993) (p. 62) '…*the Skeffington model sees myopia as an adaptation to near point stress. Myopia resolves the drive for convergence to localise closer than accommodation by changing the inner optics of the eye*…'. Birnbaum (1985) (p. 63) further explains this thinking by stating that myopia reduces the accommodation required at near, and in so doing, it reduces the associated over convergence. Indeed, '*myopia is viewed as the most effective adaptation to near point stress, serving in most cases to obtain comfortable, efficient near point function*'.

There are a number of aspects of the behavioural approach to explaining the origins of myopia with which the research and traditional optometric communities might agree. Firstly, the behavioural approach is that environmental factors play a major role in myopia onset and development. This is consistent with the extant view that while genetic factors are important (Mutti *et al*., 2007), near work is also implicated (Zadnik, 1997; Rosenfield and Gilmartin, 1998). Secondly, consistent with Skeffington's view that over convergence is a causal agent for myopia, data from Goss (1991) suggest that prior to the onset of myopia, children who become myopic often exhibit more esophoria (or less exophoria) at near, and lower positive relative accommodation, relative to children who remain emmetropic.

Given that near point stress is assumed to cause myopia, a direct prediction of the behavioural approach is that appropriately powered low-plus lenses worn for near work should relieve the stress and prevent, or halt, the development of myopia. This prediction has been tested in a multitude of research studies that began with Miles (1957). These studies have produced conflicting results, and although halting or slowing myopia progression continues to be a subject of intense research interest to this day (e.g. Fulk *et al*., 2000; Chung *et al*., 2002; Gwiazda *et al*., 2003), the majority of recent research on this topic has examined whether substantial, uniformly prescribed reading additions (e.g. 1.5 DS or greater) reduce myopia progression; comparatively little mention is made in the recent literature to the behavioural approach of prescribing patient-specific, low plus-lens powers (e.g. +0.50 DS, +0.75 DS) at near (Press, 2000).

The evidence from the recent research is that substantial reading additions (e.g. +2.00 D) provided to pre-presbyopic patients can slow the progression of myopia by a statistically significant, but not a clinically significant amount (Gwiazda *et al*., 2003). In relation to the behavioural optometry prediction that esophoria will be present in individuals with progressing myopia, it is interesting to note that there is now a good deal of evidence showing that more slowing of myopia progression occurs in patients with esophoria at near (Goss, 1991; Fulk *et al*., 2000; Brown *et al*., 2002) . However, while these results are broadly consistent with the behavioural standpoint on myopia origin and progression, they are also consistent with other explanations. For example, as pointed out by Birnbaum, the fact that reading additions of higher power than advocated by behavioural optometrists produce this result, is also in keeping with the view that myopia results from the excessive use of the eyes for close work (the so-called '*use-abuse theory*', Birnbaum, 1993; p. 11).

To sum up, slowing myopia progression to a limited extent appears possible through the use of plus-lens power at near. While behavioural optometry can explain this result, this does not necessarily mean that the behavioural view is correct since other, non-behavioural, approaches may also explain it. In any case, it may be something of a moot point to fixate upon the relative merits of behavioural vs non-behavioural approaches to halting myopia since, whatever the explanation, the rate of slowing possible appears extremely limited (Bullimore, 2003).

Therapy to reduce myopia

The results from several studies indicate that when myopes remove their refractive correction (or when emmetropes are blurred), both letter acuity and contrast sensitivity measures which are initially reduced show an increase as a function of time (Mon-Williams *et al*., 1998; George and Rosenfield, 2004; Rosenfield *et al*., 2004). For example Rosenfield *et al*. (2004) found an average improvement in acuity of around 0.2 logMAR following 3 h without correction in a group of 22 individuals with moderate myopia. This improvement in vision cannot be attributed to a reduction in refractive error since no change in refractive error (as measured by autorefraction) took place over the defocus period. Improvements in letter acuity and other clinical measures following exposure to blur have traditionally been dismissed as reflecting nothing more than increased tolerance to blur and increased practice at interpreting blurred images. For example, in a controlled trial of biofeedback visual training, Angi *et al*. (1996) found an increase in letter acuity in the treated group which they attributed to a learning effect because no improvement was evident when a computer generated optotype was used for letter acuity determination. In other words, any 'improvements' in letter acuity in unaided myopes probably resulted only from increased familiarity with the letter sequences on the test chart. A similar pattern of results was obtained by Rupolo *et al*. (1997), and the report on '*Visual Training for Refractive Errors*' by the American Academy of Ophthalmology (2004) dismisses the effectiveness of visual therapy in myopia.

Recently, however, there is a growing volume of research evidence to suggest that genuine neural adaptation may be taking place in unaided myopes, even when no visual training is provided. For example, Webster *et al*. (2002) showed that the perception of the extent to which an image is in focus changes substantially with time following exposure to blur. Related to this work is the study by Vera-Diaz *et al*. (2004) in which myopes showed a statistically significant increase in their accommodative response to a near target following the introduction (for 3 min) and then removal of blur. The results for emmetropes who underwent the same exposure to blur were different in that accommodation to the near target did not change as a result of the blur.

Thus, although the nature and characteristics of the adaptation that takes place in blurred/unaided myopes is yet to be determined, there does appear to be growing evidence for a genuine neural adaptation to blur. It is still far too early to say where this research will lead, but the behavioural view that changes in performance in unaided myopes following prolonged exposure to blur reflect something more than an improvement in the ability to interpret blurred retinal images may have some basis. Therapy to reduce myopia is apparently much more widely practiced by behavioural optometrists in the USA than in the UK (Paul Adler, personal communication).

Behavioural approaches to the treatment of strabismus and amblyopia

In the words of Groffman (1993), Skeffington's viewed strabismus '*as an extreme adaptation in binocularity in order to cope with a stressful near point environment*'. Jennings (2000) reviewed behavioural approaches to the management of strabismus and amblyopia and concluded that he found it '*… impossible to assess the success of behavioural vision therapy for strabismus and amblyopia from the literature*'.

Although the range of behavioural management strategies for patients with these conditions appears to vary considerably between practitioners (e.g. in relation to whether full-plus should be prescribed in strabismic patients; Getz, 1990; Frantz and Sherman, 1995), behavioural optometrists take the view that strabismus should not be managed by surgery, except as a last resort. Since surgery is employed less frequently by ophthalmologists in cases of intermittent deviations, it may be possible to assess the overall effectiveness of non-surgical approaches by examining the treatment success in patients with intermittent tropias. For example, in the case of small angle exo-deviations, Cooper and Leyman (1976) advocate the use of fusion exercises and minus lenses. However, the effectiveness of these treatments is still open to question (Rosenbaum, 1993; von Noorden, 1996).

Since the report by Jennings (2000), I could find no reports in the mainstream vision literature that have advocated, or even tested, a purely behavioural approach to strabismus management (i.e. one that is based upon active vision therapy). It is true that there has been a substantial decline in the number of strabismus surgeries performed in the UK (Arora *et al*., 2005) and elsewhere (Long and O'Brien, 2005) over the past 20 years. However, rather than representing a shift of opinion towards the behavioural position that non-surgical approaches are more effective, Arora *et al*.

(2005) point out that the decline in strabismus surgical procedures may simply reflect increasing subspecialisation amongst the ophthalmological profession which has resulted in an improved quality of surgery and hence a reduced need for re-operation.

A number of case studies have recently been published, mainly in the behavioural literature (e.g. Lee, 1999). For example, a case of intermittent esotropia was successfully treated using therapy that incorporated peripheral awareness training (Tong, 1999). Aside from such isolated case reports, however, there appears to be a complete absence of evidence-based research to support claims that behavioural vision therapy is more effective than other forms of strabismus management, or that the behavioural approach is more effective than the 'no treatment' alternative. Although behavioural optometrists in the UK do apply behavioural management strategies to strabismic patients, they form a small proportion of the patient base (Paul Adler, personal communication).

Interestingly, many of the criticisms that are directed here towards behavioural optometry concerning the lack of rigorous scientific evidence to support their approach, have also been levelled against the wider clinical community which takes a more conventional approach to strabismus management. A recent review of surgical and non-surgical interventions for intermittent exotropia conducted for the Cochrane Database (Hatt and Gnanaraj, 2006) concluded that the available literature consists mainly of retrospective case reviews which are difficult to reliably interpret and analyse. A similar conclusion was reached in another Cochrane report concerning interventions for infantile esotropia (Elliott and Shafiq, 2005). The authors of both reviews concluded that there remains a need for more carefully planned clinical trials to be undertaken to improve the evidence base for the management of these conditions.

In relation to amblyopia treatment, behavioural optometrists support active therapy approaches rather than the passive approach to therapy that is normally employed and which consists only of wearing appropriate refractive correction and occlusion/optical penalisation where indicated. A number of recent, large-scale studies have examined whether children with amblyopia who are patched and instructed to perform near activities, respond better to treatment than those who receive patching but no specific instructions about carrying out near activities (Holmes *et al.*, 2005; Scheiman *et al.*, 2005d). These studies have been conducted by the Pediatric Eye Disease Investigator Group, a consortium of researchers based in the USA who have addressed a whole series of questions aimed at identifying the optimum means to treat amblyopia. In the study by Scheiman *et al.* (2005d), 53% of children aged 7–12 years in the optical correction plus near-activities group responded to treatment compared with only 25% children in the same age range who received optical correction alone. These results are complemented by laboratory research studies showing that, with extensive practice, performance on positional tasks (which is particularly poor in amblyopes) can be improved substantially in children with amblyopia (Li *et al.*, 2005). In addition to results in children, there are laboratory (Li and Levi, 2004) and clinical (Wick *et al.*, 1992) studies suggesting that vision therapy and/or extensive task repetition in adults with amblyopia can also produce significant improvements in VA, binocular function and positional acuity measures.

On the surface these results would appear to lend support to the proponents of active vision therapy for the treatment of amblyopia. However, there are a number of issues to consider. First, the contribution of the 'near activities' element to the success of treatment is difficult to characterise since the 'optical correction only' group obviously cannot be prevented from carrying out near activities. The results of Scheiman *et al.* (2005d) have attracted criticism on these grounds and a considerable debate has followed their publication (Hunter, 2005a,b; Phillips, 2006; Scheiman *et al.*, 2006). Second, it is not clear whether adult amblyopes can show improvement without undergoing active vision therapy. Third, carrying out one's normal near activities may have therapeutic value but it is not the same as the programme of active therapy that is advocated by behavioural optometrists. Lastly, there is a growing body of research evidence indicating that the value of refractive correction alone in the treatment of amblyopia may have been underestimated. The results of many large-scale, recent studies point to the benefits of simply providing appropriate refractive correction, and the need to wait until VA has ceased to improve following refractive correction before prescribing any additional treatment (e.g. occlusion) is started (Stewart *et al.*, 2004; Steele *et al.*, 2006). For example, Cotter *et al.* (2006) found that refractive correction resulted in resolution of amblyopia in around one-third of their sample of 84 children aged 3 to < 7 years with untreated anisometropic amblyopia. The value of refractive correction alone is also discussed in Chen *et al.* (2007). There are also recent claims that strabismic amblyopia may be partially or even wholly treated by refractive correction alone (Cotter *et al.*, 2007).

Thus, in agreement with a recent review by Rawstron *et al.* (2005), it is concluded that the benefits of vision therapy in amblyopia treatment over those which accrue from passive modes of therapy alone are as yet unproven. Indeed, the behavioural view runs contrary to a considerable volume of recent research evidence which indicates that refractive correction alone, or in combination with patching/penalisation (that is started after refractive correction has ceased to improve VA) is frequently associated with a high level of treatment success (Webber, 2007).

Training central and peripheral awareness and syntonics

According to Birnbaum (1993) (p. 309), '*central-peripheral organisation is an important aspect of visual information-processing style*'. The central–peripheral distinction relates to the relative amounts of attention given to the central and peripheral field; individuals who pay more attention to central aspects '*prefer to gather and process information in small bits, with greater emphasis on detail*', whereas those who are more 'peripheral' are said to '*prefer to gather information from broad areas of space, favouring a simultaneous, all-at-once, global approach*'. There are consequences for the refractive and oculomotor status if an individual emphasises 'peripheral' too much (exophoria or hyperopia might result) or over-emphasises 'central' aspects (esophoria or myopia).

The achievement of an appropriate weighting between central and peripheral processing is thought to be critical for important visual processing (Marrone, 1991), and Birnbaum (1993) advocates the use of vision therapy to '*enhance weak or underused processing strategies*' (p. 310). Individuals who emphasise central processing may benefit from procedures that emphasise '*peripheral awareness, visual imagery, and tachistoscopic training, to improve [the] ability to use peripheral, global and simultaneous processing*'. Similarly, individuals who emphasise '*peripheral, global simultaneous processing may benefit from procedures that emphasise the attention to detail, sequential processing, and visual analysis*'.

However, the author finds the language used by Birnbaum and others (e.g. Forrest, 1976, 1981) to describe the vision therapy in respect of central–peripheral organisation to be extremely vague and unconvincing. For example, Birnbaum states that '*the goal [of treatment] is not to change the individual's processing style but rather to expand abilities and permit greater flexibility*' (Birnbaum, 1993; p. 310). More importantly, there appears to be little evidence to support such treatment practices in the mainstream scientific literature, and thus the importance of central–peripheral organisational style in the manner described in behavioural optometry texts (e.g. Birnbaum, 1993) is not known, and the need or ability to influence it in individual patients remains equally unproven.

One therapeutic approach that is relevant to the issue of central–peripheral organisation but which was not described by Birnbaum (1993) is the practice of syntonics. Syntonics is defined as 'balance', and the term 'syntonic phototherapy' is used to describe a form of vision therapy which aims to '*bring the visual system into balance*' (ACBO, 2008). Syntonic phototherapy can be recommended as a stand alone treatment or it can form one part of a complete vision therapy programme. It involves the use of coloured light, usually in an otherwise empty field. It is claimed that therapy will increase the visual field size. For example, Liberman (1986) claimed that children underachieving at school (especially in the area of reading) exhibit constricted visual fields and that 'significant' enlargements in the field size can follow the onset of therapy within 'a short time'. Similar claims were made by Kaplan (1985). Advocates of the technique claim that syntonic therapy can produce additional benefits such as increased visual memory for 'objects and abstract symbols', and that it can be beneficial not only in patients with reduced visual fields but also in '*learning disabilities of varied origin, migraine as well as general headaches, memory dysfunctions, reduced attention span and/or hyperactivity, ocular edema of any type, ocular pain with or without trauma, and secondary affects of head trauma*' (Liberman, 1986; p. 14). I could find no evidence to support any of these assertions in a search of the mainstream scientific literature, and the claims by Liberman (1986) and Kaplan (1985) that visual field enlargements result from syntonic therapy have been subjected to a variety of criticisms by Evans and Drasdo (1991). Although syntonics does have some advocates amongst UK behavioural optometrists it effectiveness is highly contested, and the proportion of behavioural optometrists utilising it in their practice in this country is, apparently, small (Paul Adler, personal communication).

Sports vision therapy

Sports vision therapy accounts for an increasing proportion of the work conducted by UK behavioural optometrists (Paul Adler, personal communication). This may be due to increased awareness amongst the public following announcements by a number of high-profile UK professional sporting organisations (e.g. English's rugby world cup winning squad, and English Cricket) that their sports men and women are undergoing, or have undergone, vision therapy to improve sporting performance.

Despite growing interest in vision therapy for improving sporting performance, there is a paucity of scientific evidence to show that therapy produces any beneficial effect. Only two controlled trials appear to have been published in mainstream scientific literature (Wood and Abernethy, 1997; Abernethy and Wood, 2001). In the first of these studies (Wood and Abernethy, 1997), 30 participants were divided into three groups, a treatment group, a placebo and a control group. The authors found no evidence that vision training improved either visual or motor performance beyond what would be expected from increased test familiarity. In the second study (Abernethy and Wood, 2001), 40 participants were divided into four groups, three of which received visual training while the final group received placebo therapy. While the authors reported that significant pre- to post-training differences did take place for some of the measures, these differences were not group-dependent. Overall, they concluded that by there was '*no evidence that the visual training programmes led to improvements in either vision or motor performance above and beyond those resulting simply from test familiarity*'. This is consistent with a number of reviews of the effectiveness of vision therapy for sport (e.g. Hazel, 1995; Rawstron *et al*., 2005) which have generally concluded that the evidence is either inconclusive or lacking altogether. However, given the belief that appears to exist about the value of vision therapy in elite sport, research into this area is certainly warranted.

It is interesting to note that there is a growing body of research aimed at understanding how, for example, eye movements and arm movements during reaching movements are linked and inter-dependent (e.g. Harris and Wolpert, 1998). As yet, however, this area of research has not expanded to encompass differences in movement patterns between novice, elite and non-elite sportspersons. Indeed, very little research has been directed at the question of whether visual performance in elite athletes exceeds that of non-elite performers. In one study by Laby *et al*. (1996), the visual function of 387 professional baseball players was tested and they claimed that VA, distance stereoacuity, and contrast sensitivity are significantly better in this group than in the 'general population'. However, while this study and a small number of other studies (e.g. Stine *et al*., 1982; Christenson and Winkelstein, 1988) suggest that visual abilities are superior in athletes, the issue is far from settled. One of the main issues affecting the interpretation of results from studies of this nature is that typically a substantial overlap exists between the results for athletes and non-athletic groups (Hazel, 1995). Interestingly, even if it emerges that visual performance is superior in elite vs non-elite athletes, important questions will follow, including: are differences in visual abilities the cause or the consequence of differences in sporting performance? Can differences in visual abilities be trained in the clinical setting? And if so, does this training transfer to the sporting arena?

Neurological disorders and neuro-rehabilitation after trauma/stroke

There is considerable research interest in the possibility that yoked prisms and/or vision rehabilitation may be beneficial in patients with developmental or acquired neurological disorders. The suggestion that optometrists may be able to play a useful role in the rehabilitation of patients with head trauma is not new (e.g. Cohen and Rein, 1992). Despite this, many would argue that the assessments and treatments described below may fall more naturally within the remit of other disciplines (in particular, occupational therapy). However, given that behavioural optometrists in the UK appear to be receiving an increasing number of referrals of neurological patients (Paul Adler, personal communication), it is worth considering whether vision therapy administered by optometrists can, as part of a multi-disciplinary approach, aid rehabilitation after trauma/stroke. Interestingly, Scheiman's (2002) textbook written for US Occupational Therapists provides considerable detail about the visual difficulties that may exist in neurological patients [and other patient groups that may be treated/managed by UK behavioural optometrists (see Introduction)], and the role that optometric vision therapy can play. But what is the evidence to support the efficacy of optometric involvement in visual rehabilitation after stroke/trauma?

Most studies of the nature described below have appeared in neurological or neuropsychological literature but, more recently, research articles on these topics are beginning to appear in the mainstream ophthalmic literature (e.g. Reinhard *et al*., 2005; Ciuffreda *et al*., 2007). Furthermore, the role that optometrists can play in assessing/treating patients in these categories has recently been summarised by Han (2007), and several chapters of Scheiman's (2002) book contain sections on optometric evaluations and treatment methods that may be appropriate in these patients.

Use of yoked prisms in neurological disorders and in neuro-rehabilitation

In addition to the various uses of yoked prisms long advocated by behavioural optometrists (and described in the earlier section on 'Yokel prisms'), a number of newer uses for yoked prisms are being suggested, principally in the non-ophthalmic literature. These are briefly described below, not because the case supporting their usefulness in these clinical conditions is proven at this point in time, but because some UK behavioural optometrists are already using yoked prisms in this fashion (Paul Adler, personal communication) and because patients of all optometrists may seek their opinion about these applications of yoked prisms.

Autism. Recently, a number of reports suggest that yoked prisms may be useful in children with autistic spectrum disorders (ASD). Children with ASD often exhibit abnormal body postures including head tilting

(Kohen-Raz *et al*., 1992), and disturbances in motion and gait (Vilensky *et al*., 1981). Reports that yoked prisms may be useful in ASD first appeared in the 1980s but definitive evidence to support this view has been slow to emerge. More recently, however, several studies by Kaplan and colleagues (Kaplan *et al*., 1996, 1998; Carmody *et al*., 2001) suggest that yoked prisms lead to a change in head angle, and that in turn this can help to promote eye contact and thus foster improved social interaction. In addition to psychosocial benefits, it is claimed that yoked prisms lead to improvements in behaviour, attention and visuo-motor skills such as ball-catching abilities. The studies by Kaplan have included double-blind designs in which behaviour and performance with yoked prisms oriented correctly, yoked prisms oriented incorrectly, and placebo lenses have been compared. Although these results are interesting there are a number of factors to consider in relation to their interpretation. First, in one study (Kaplan *et al*., 1998), yoked prisms were found to produce benefits in behaviour patterns after 1.5 and 2 months but which were less apparent after 3 and 4 months. Second, all of the recent studies advocating yoked prisms in ASD have come from the same research group, and the case for their use for this purpose would obviously be strengthened if corroborated by other research teams. Finally, it is noteworthy that recent reviews of the many treatments suggested for ASD make no mention of yoked prisms (e.g. Levy and Hyman, 2005). Thus, while yoked prisms may have a role to play in ASD, this practice remains somewhat controversial because the evidence to support their use in this fashion is currently limited (Kenneth Ciuffreda, personal communication).

Pathologic pain. There has been considerable recent research attention devoted to the issue of how appropriately oriented yoked prisms can influence the perception of pain. This approach emerged following experimental results showing that pathologic pain can lead to altered visuo-spatial perception revealed when a visual subjective body-midline task is carried out (Sumitani *et al*., 2007a). This task simply requires the patient to indicate when a small dot of light projected onto a screen and presented in an otherwise darkened room crosses the straight-ahead position when moving in from a starting position that is clearly on the right or left. Essentially, this study and others like it (e.g. Ernst *et al*., 2000) are showing evidence that human visual and somatosensory systems are interdependent, something which would not come as a surprise to behavioural optometrists because it appears to be consistent with the 4-circles model (see Introduction). The pain is believed to shift the perceived straight-ahead position to one side. In further support of this claim, Sumitani *et al*. (2007b) showed in five patients that a change in visual status achieved using appropriately oriented yoked prisms can significantly modify the perception of pain. Specifically, they showed that prismatic displacement of 20 degrees of the visual field towards the unaffected side alleviated pathologic pain as assessed by a numerical rating scale. To support this result, the authors also showed that the perception of pain was exacerbated when the prismatic shift was toward the affected side. The explanation for these results is speculative at this point but the 'pull' of the visual subjective midline towards the affected side produced by the pain is thought to be a key component. However, while these results look promising, the authors acknowledge that RCTs are needed to establish that the beneficial effects upon the perception of pain are indeed due to the presence of the prisms (Sumitani *et al*., 2007b).

Visual neglect. Rossetti *et al*. (1998) investigated the effects of yoked prisms in hemisphere stroke patients, a large proportion of whom show left-hemispatial neglect (also known as left 'visual neglect'). They studied the effects of prism adaptation on various neglect symptoms, including the pathological shift of the subjective midline to the right. Their results were striking: all six patients exposed to the optical shift of the visual field to the right demonstrated improved performance on a manual body-midline task and on classical neuropsychological tests. A large volume of research in this area has followed (reviewed by Rode *et al*., 2006), much of which appears to support Rossetti *et al*.'s (1998) original findings. Although controlled trials are again lacking, the weight of evidence does seem to support claims concerning the beneficial effects of yoked prisms in visual neglect patients.

One final but important issue that deserves consideration relating to the use of yoked prisms concerns the issue of adaptation. In visual normals, rapid adaptation to vertical yoked prisms has been demonstrated by Huang and Ciuffreda (2006). If the same happened in neglect patients, for example, the value of the therapy would obviously be extremely short lived. However, the evidence in neglect patients and in patients with pathologic pain suggests the benefits of yoked prisms take time to accrue (e.g. Sumitani *et al*., 2007b). The reasons why patients appear not to adapt whereas visual normals do is uncertain. Kapoor *et al*. (2001) speculated that the reason may be due to the fact that, in normals, the yoked prisms introduce a discrepancy between subjective and objective egocentric space which the adaptation seeks to reduce or eliminate. However, in patients, there is thought to be a pre-existing, neurologically based spatial discrepancy between the objective and subjective egocentric midlines (Stein, 1989) and adaptation does not take place because appropriately oriented yoked prisms serve to reduce/eliminate this discrepancy (Kapoor *et al*., 2001).

Vision restoration therapy

Since 2000, there has been a large amount of interest in the possibility that some restoration of vision can be achieved in patients who have suffered optic nerve or post-chiasmatic injuries but who have some residual vision (Sabel and Kasten, 2000). The treatment is referred to as 'visual restoration therapy' and it involves selecting areas of residual vision which are then stimulated during computer-assisted training (e.g. Julkunen *et al*., 2003). Some very impressive visual field enlargements have been reported. For example, in a trial of 19 prechiasmatic injury patients, a 74% increase in visual field size was reported; in 19 post-chiasmatic patients, the results were less dramatic (30% increase) but still impressive, because no improvement in field size occurred in a no-treatment control group (Sabel and Kasten, 2000). These findings have been corroborated and extended by more recent work which has shown that the improvements in visual field represent genuine neuroplasticity because they cannot be explained as artefacts induced by eye movements (Kasten *et al*., 2006), and because the field-size increases are accompanied by improvements in patient-questionnaire responses (Sabel *et al*., 2004). It is still far too early to say where this research will lead, or to speculate about any possible future role that optometrists might play in the administration/evaluation of this kind of therapy. However, the available evidence suggests that claims about the efficacy of vision therapy in neurologically damaged patients may not be unfounded.

The need for high-quality research studies

Throughout this review, a large number of areas have been identified where sound research evidence is lacking to support behavioural optometry approaches to treatment and management. Of particular concern is the almost-complete absence of RCTs from the literature. Double-blind RCTs are widely regarded as representing the 'gold standard' in clinical research. Such studies typically contain two or more groups, only one of which receives the full therapeutic intervention. The other group(s) represent the control group(s), which receive no treatment or 'sham' treatment [e.g. see Sterner *et al.* (2001) who used sham treatment in their accommodative-facility study]. The 'double-blind' aspect of RCTs relates to the fact that participants are randomly assigned to different groups in such a way that neither the researcher, who deals directly with the participant, nor the participant themselves is aware of whether or not they are in the 'treatment' group. One of the most important aspects of a well-designed RCT is that it will reveal the extent to which any benefits that accrue are due to a placebo effect. The placebo effect relates to any non-specific factor (i.e. any factor not directly linked to the actions/mechanisms of the therapy) which may produce a desirable outcome (Sandler, 2005). Such non-specific effects could result from many sources, for example, bias on the part of the examiner, or from participants' beliefs about the efficacy of the treatment. Placebo effects can be extremely powerful, and to demonstrate the efficacy of any therapy, it is therefore necessary to show that the therapeutic effects exceed those which result from placebo effects alone. There are several examples in the general optometric/ophthalmic literature concerning results which, on initial inspection, appeared very promising but which, in later controlled trials, were shown to be little better than existing treatments, or placebo treatments. For example, promising results were originally described for the first anti-cataract agents that became available but controlled trials of these substances subsequently revealed that they were no more effective than placebos (Toh *et al*., 2007). Similarly, amblyopia treatment results initially appeared impressive when the rotating grating treatment (CAM) method was first tested (Banks *et al*., 1978). However, in subsequent controlled trials (e.g. Nyman *et al*., 1983), CAM treatment was found to be no more effective than occlusion therapy. Indeed, the benefits of the treatment may have been due only to the occlusion which was undertaken when the CAM treatment was being administered (Tytla and Labow-Daily, 1981). The point here is not that behavioural optometry approaches are ineffective but that we can only be confident about the efficacy of any treatment or management approach once it has been subjected to the rigorous scientific testing of an RCT. As indicated throughout this review, there have been very few such studies of behavioural optometry management/treatment approaches, and for this reason, it must be concluded that they currently exist without a sound evidence base.

Although double-blind RCTs represent the gold standard in the scientific testing of therapies/management approaches, it is recognised here that not every form of therapy is amenable to the strictest RCT design. For example, it is not always possible to implement a strict double-blind design because it can be difficult to offer placebo 'treatments' which participants in the control group recognise as credible. Another issue is that strict RCTs are considered by many to be reductionist in the approach to therapy testing, because a key stipulation is that each patient in the treatment group receives exactly the same treatment. However, there is growing acceptance that such a reductionist approach may not always be appropriate and that controlled study designs can be employed to test the effectiveness of therapy even when different participants in the treatment groups receive slightly different treatments (e.g. Hilsden and Verhoef, 1999; Richardson, 2000). This is particularly important in the study of behavioural optometry approaches because practitioners appear to place particular emphasis upon designing patient-specific approaches to treatment rather than applying uniform management/treatment strategies for particular conditions (Paul Adler, personal communication). In short, it is suggested here that the practices advocated by behavioural optometrists in the UK *are* amenable to study using controlled trials. However, the required studies have not yet been conducted and, for this reason, the practices advocated by behavioural optometrists cannot be recommended.

Conclusions

In a previous review of the behavioural optometry literature (Jennings, 2000), it was concluded that there was a lack of controlled clinical trials of behavioural management strategies. Unfortunately, there has been little change in this regard in the intervening period. Although there are areas where the available evidence is consistent with behavioural optometry approaches (most notably in relation to the treatment of convergence insufficiency, the use of yoked prisms in neurological patients, and in vision rehabilitation after brain injury), a large majority of behavioural management approaches do not possess a solid evidence base, and thus they cannot be advocated. In this respect, this review is consistent with a number of recent literature reviews that have arrived at similar conclusions (e.g. Helveston, 2005; Rawstron *et al*., 2005).

There have been attempts to improve the ability to assess the efficacy of behavioural vision therapy. For example, Maples and Bither (2002) designed a checklist/questionnaire as a tool to assist in the documentation of the improvements following a course of vision therapy. Overall, however, the advances made by behavioural optometrists in generating the evidence to support their claims are extremely modest. Behavioural optometrists are enthusiastic advocates of their approach to optometry, and they seem to derive great satisfaction from the diverse work that they conduct. However, the continued absence of rigorous scientific evidence to support behavioural management approaches, and the paucity of controlled trials in particular, represents a major challenge to the credibility of the theory and practice of behavioural optometry.

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Appendix

In the UK, the practice of behavioural optometry is advocated by the British Association of Behavioural Optometrists (BABO) which has approximately 75 members (Paul Adler, personal communication). The BABO Chair is Mrs Caroline Hurst (contact details available at: http://www.babo.co.uk/). As well as representing the views of behavioural optometrists, BABO organises seminars and conferences. BABO is also responsible for the syllabus content, the delivery and the examinations that lead to their *Certificate in Behavioural Optometry*. In addition to behavioural management approaches, the syllabus contains a large volume of material that would normally be considered under the heading of orthoptics. Around 10% of BABO members are currently completing, or have successfully gained, the *Certificate in Behavioural Optometry* (Paul Adler, personal communication).

Journals

The '*Journal of Behavioural Optometry*' (J. Behav. Optom., ISSN: 1045-8395) (Irwin B. Suchoff, Editor-In-Chief) publishes articles that are of interest to the membership of its sponsoring organisation, the Optometric Extension Program Foundation (OEPF). Although the contents of the journal are not abstracted on PubMed, WoS, PsycInfo or Ophthalmic Literature, abstracts from previously published papers can be found by entering author, title or keyword search terms at the following location: http://www.oepf.org/jbo/index.php?pid=search. The website also suggests that papers of interest can be requested simply by e-mailing oepf@oepf.org. It is also abstracted at VisionCite and Visionet, both of which are optometry indexes set up by individual American universities. In the UK, it is only available via the British Library and from Cardiff University.

The journal '*Optometry & Vision Development*' (Optom. Vis. Dev., ISSN: 1557-4113) (Dominick M. Maino, Editor) is the official quarterly publication of the College of Optometrists in Vision Development, and was known as the 'Journal of Optometric Vision Development' (ISSN 0149-886X). It can be located at: http://www.covd.org/Home/OVDJournal/tabid/104/Default.aspx.

Non-COVD members can access journal articles that are more than 6 months old. The contents of the journal are not abstracted on PubMed, WoS, PsycInfo or Ophthalmic Literature, but abstracts are listed on VisionCite and Visionet. In the UK, it is only available via the British Library and from Cardiff University.

The journal '*Behavioural Optometry*' (ISSN 1035-7637) is published by the Australasian College of Behavioural Optometrists (ACBO). It may also appear under the name of the '*Journal of the Australasian College of Behavioural Optometrists*'**.** It is abstracted at VisionCite and Visionet. Cardiff University holds issues between 1992 and 1995.

The journal *Optometry* (ISSN: 1529-1839) (Editor-in-Chief: Paul B. Freeman), formerly known as the *Journal of the American Optometric Association* (J. Am. Optom. Assoc. ISSN: 0003-0244; the journal's name changed in 2000) also publishes journal articles in the area of behavioural optometry. It is now published by Elsevier and details can be found online at: http://www.elsevier.com/wps/find/journaldescription.cws_home/705659/description#description. Both the *J. Am. Optom. Assoc*. and *Optometry* are abstracted by PubMed (back to 1930), Web of Science (back to 1977) and both are fairly widely available in UK libraries.

Organisations

The Optometric Extension Programme (OEP) Foundation is an organisation based in the USA (1921, E. Carnegie Ave., Suite 3-L, Santa Ana, CA 92705-5510, USA, http://www.oepf.org) that provides information about vision from a behavioural optometry perspective to patients, practitioners and educators. It describes itself as 'an international organisation dedicated to the advancement of the discipline of optometry through the gathering and dissemination of information on vision and the visual process'. It offers a number of training courses to optometrists.

The College of Optometrists in Vision Development (COVD) is also a USA-based organisation (College of Optometrists in Vision Development, 215 West Garfield Road, Suite 210 Aurora, OH 44202, USA) that was established in 1971 and which describes its mission as being to 'serve as an advocate for comprehensive vision care emphasising a developmental and behavioural approach'. The website also states that 'COVD certifies professional competency in vision therapy, serves as an informational and educational resource, and advances research and clinical care in vision development and therapy.' The web address for the College of Optometrists in Vision Development is: http://www.covd.org/.

The web address for the '*College of Syntonic Optometry*' is: http://www.syntonicphototherapy.com/online/index.cfm.

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