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A critique of behavioural vision therapy techniques for children with reading difficulties including dyslexia

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ABSTRACT

Specific learning disabilities affect the brain's ability to process verbal and non-verbal information efficiently and accurately. The most common learning disability is reading disability which includes dyslexia. Evidence supports that dyslexia is a language-based disorder. The core deficit of dyslexia is the phonological component of language that interferes with reading development. Therefore early, intense and specific remedial therapy should address the underlying cause of the difficulty. Behavioural optometry is controversial and purports to make children more responsive to education by improving visual conditions conducive for learning with eye exercises, tinted/coloured lenses and movment-based exercises. However, the theoretical basis for behavioural therapies have not been well established. Literature which favours behavioural approaches suffers from serious methodological and interpretive flaws. There is currently insufficient evidence to support behavioural approaches which therefore should not be recommended.

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1. Introduction

Specific learning difficulties (SLD) are characterised by persistent difficulties in areas of learning and academic skills, despite normal intelligence and adequate educational opportunity (American Psychiatric Association, 2013). The prevalence of SLD among school-age children is estimated to be at 5–15% across the academic domains of reading, writing and mathematics (American Psychiatric Association, 2013). Reading disability, including dyslexia, also known as developmental dyslexia (DD), is one of the most common learning disabilities (American Psychiatric Association, 2013; Ganivet et al., 2014). There are multiple theories as to the cause or factors contributing to dyslexia. The published evidence consistently supports the view that dyslexia is primarily

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a language-based disorder (Bellocchi et al., 2013; Goswami, 2015; S. M. Handler & Fierson, 2017; Peterson & Pennington, 2012; Ramus et al., 2003; Rayner, 1998; S. E. Shaywitz, 1998; Stephenson & Wheldall, 2008; Vellutino et al., 2004). Specifically, a child with dyslexia has difficulty with the linguistic task of decoding words due to a lack of recognition that the individual sounds of words (phonemes) match the written version representing those sounds (graphemes), i.e. sound-letter correspondence (Gabrieli, 2009; Peterson & Pennington, 2012; S. E. Shaywitz, 1998; Vellutino et al., 2004). Associated phonological deficits include poor short-term verbal memory and slow automatic naming, as well as difficulties with related skills such as spelling and writing (Bellocchi et al., 2013; Ramus, 2003; Shovman & Ahissar, 2006).

There is a genetic bias to dyslexia with characteristic changes to brain structure noted (Demonet et al., 2004; Gabrieli, 2009; Peterson & Pennington, 2012). Neuroanatomical and neuroimaging studies show changes primarily affecting the language-related areas in the left hemisphere (Eckert et al., 2017; Galaburda et al., 1985; S. M. Handler & Fierson, 2017; Klingberg et al., 2000; Peterson & Pennington, 2012; Simos et al., 2002; Vellutino et al., 2004). A tendency to improve or normalise dyslexia-specific brain changes has been demonstrated in functional brain imaging after intensive remedial phonology-based reading programs, reflecting neural plasticity (Aylward et al., 2003; Olulade et al., 2013; B. A. Shaywitz et al., 2004; Simos et al., 2002; Temple et al., 2003).

Other factors known to contribute to reading difficulties include prematurity and low birth weight, male sex, maternal smoking (American Psychiatric Association, 2013; Creavin et al., 2015), a low level of maternal education (Creavin et al., 2015), and socioeconomic disparities, where children of a lower socioeconomic background with less home literary exposure experience slower reading development (Collins et al., 2017). There may also be a background in language delay and speech therapy (Peterson & Pennington, 2012; S. E. Shaywitz, 1998; B. A. Shaywitz & Waxman, 1987; Snowling, 2001).

Unlike speaking a language, reading must be taught, with explicit instruction in concepts such as phonemic awareness (S. E. Shaywitz, 1998). National inquiries into the teaching of reading in the United States, United Kingdom and Australia and a meta-analysis of randomised controlled trials have emphasised the importance of systematic and repetitive instruction in the areas of phonemic awareness, phonics, vocabulary, fluency and comprehension in improving reading ability in children with reading difficulties (American National Institute of Child Health and Human Development, 2000; Galuschka et al., 2014; Rose, 2006; Rowe, 2005). In addition, the earlier the intervention with remedial reading programs, the better the outcome (Bellocchi et al., 2013; S. Handler & Fierson, 2011).

Behavioural optometry is a controversial branch of optometry which purports to "incorporate everything about the individual" to develop a tailored vision therapy (VT) program (The Australasian College of Behavioural Optometrists, 2011) to enhance the efficiency of the visual system, and ultimately make children more responsive to educational instruction (https://www.acbo.org.au/). As a result of VT, behavioural optometry claims younger children are "usually . . . able to improve school grades . . . self-confidence improves and they are able to attend to tasks for longer" and that "Most people find they read more easily" (https://www.acbo.org.au/images/About_Vision/Pamphlets/ACBO_Vision_Therapy_Explained_Final.pdf p1-2). VT broadly includes eye and whole-body exercises as well as glasses. Specific behavioural strategies and exercises are unfamiliar to mainstream practitioners but are referred to in promotional material as cross-pattern walking, finger thinking games, map making, matching with blocks, reading letters in words, triangle line jumping, hanging a ball and bug on a string (https://www.acbo.org.au/images/About_Vision/Pamphlets/ACBO_Vision_Therapy_Explained_Final.pdf). Weak plus lenses, also referred to as "training glasses", are often prescribed, sometimes incorporating bifocals which have the effect of magnifying reading texts. Glasses may include prisms that shift the perceived location of an object. A specific and individualised combination of the above therapies are said to improve "tracking" eye movements, relieve vague symptoms such as headache and fatigue, and generally promote a visual environment conducive to learning (https://www.acbo.org.au/).

Tinted/coloured lenses, purportedly designed to block out poorly tolerated wavelengths of light, can be prescribed to relieve "visual stress" (H. Irlen, 1991, 2010; Leslie, 2016; Wilkins et al., 2004). Visual stress is not defined on the Australasian College of Behavioural Optometry (ACBO) website; however, a Google search for the term unearths multiple hits for behavioural optometry practices who describe "visual stress" as hypersensitivity and intolerance to stripes, patterns and glare.

There appears to be confusion within behavioural optometry as to the role and value of VT. While the ACBO states that the role of VT is to enhance the efficiency and comfort of visual function and not treat dyslexia per se, publications on the ACBO website claim that "by identifying and treating the visual problem, often reading speed and comprehension improve without direct reading instruction" (Leslie, 2016, p. 1) In addition, Australian behavioural optometrists' websites advertise that VT improves learning skills: "Research has demonstrated that children can improve in reading skills and mathematical ability from visual therapy alone" (Fitzroy North Eye Centre, 2024)(https://fitzroynortheyecentre.com.au/eyecare/behavioural-optometry/vision-therapy/); "A common outcome of taking part in a behavioural optometry program is that children tend to find it easier to learn" (https://www.stephendaly.com.au/services/behavioural-optometry), "Improving just one visual skill can be the difference that makes riding a bike, writing everything the right way around or getting 100% in a spelling test, possible" (Panoptic Vision Therapy, 2024) (https://www.panopticvision.com.au/vision-therapy), "we screen for phonological difficulties" (Pezzimenti Nixon Optometrists, 2024) (https://www.pezzimentinixon.com.au/vision-and-learning/dyslexia) and "behavioural optometry deals with a variety of processing disorders such as dyslexia and concentration issues" (Stephen Daly Optometrist, 2024) (https://www.microprismoptics.com.au/services/behavioural-optometry/#read-more). This results in the frequent prescription by behavioural optometrists of weak plus lenses, prisms and vision therapy for children with specific learning difficulties.

However, a review by Fletcher and Currie found that there was "little evaluation of whether even the experience of more comfort carries over to the classroom or is a sustained practice" (Fletcher & Currie, 2011, p. 5), and Rucker & Philips also questioned whether VT translates to improved school performance (Rucker & Phillips, 2018).

The theoretical basis for behavioural optometry techniques has not been well established, and the literature which favours these approaches suffers from serious methodological and interpretive flaws. Hence, many past reviews have been critical of the behavioural methodology. This paper will provide a brief overview into early reviews of behavioural optometry before critiquing more recent publications, primarily from the last 10–15 years. This paper has been divided into sections which reflect areas in which proponents of behavioural optometry believe they have a role, and concludes that the required progress has not been made in producing credible and compelling scientific evidence to support their techniques. It is concluded that behavioural interventions cannot be recommended for children with learning difficulties at this time. Nonetheless, behavioural optometry remains a persistent presence in conversations regarding children and reading difficulties. Teachers need to be aware that educational and parental resources should be directed towards evidence-based treatment modalities instead of unsubstantiated behavioural approaches.

2. Early reviews of behavioural optometry

Early reviews (Barrett, 2009; Cockburn, 1992; Helveston, 2005; Jennings, 2000; B. K. Keogh, 1974; B. Keogh & Pelland, 1985; Rawstron et al., 2005) of behavioural optometric treatment of children with learning difficulties found a "lack of substantive and comprehensive evidence" (B. Keogh & Pelland, 1985, p. 228) for the efficacy of such treatments. Keogh and Pelland noted a lack of consistency of visual training programs, commenting that "there appears to be almost as many different training programs as there are vision trainers" (B. Keogh & Pelland, 1985, p. 230). This confusion, along with the ambiguity and equivocal findings in many of the studies, as well as inconsistencies in methodology and study design, including small sample sizes, meant that comparisons between studies were difficult to assess and statistical significance could not be demonstrated. The authors concluded that in regard to visual training for learning difficulties, there was "little definitive evidence to argue for its effectiveness" (B. Keogh & Pelland, 1985, p. 234).

In 1992, Cockburn from the Department of Optometry, University of Melbourne, highlighted the need for evidence of the efficacy of vision therapy and called for large, masked randomised controlled trials to reduce the effect of placebo and observer bias (Cockburn, 1992).

In 2000, Jennings published a critical review on behavioural optometry, commissioned by the College of Optometrists (UK). He noted that behavioural optometry differed fundamentally from traditional academic optometry and found much of the theory of behavioural vision therapy unconvincing, as it could not pass evidence-based scrutiny (Jennings, 2000). In a follow-up review in 2009 and again commissioned by the UK College of Optometrists, Barrett noted that there had been little progress since the Jennings review regarding validation of the efficacy of behavioural VT with many of the treatment approaches lacking a solid evidence base. He concluded that "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" (Barrett, 2009, p. 19).

3. Recent reviews of behavioural optometry

Handler and Fierson in 2011 comprehensively reviewed behavioural optometry, VT, coloured lenses and overlays, and "training glasses". In their Joint Technical Report on Learning Disabilities, Dyslexia and Vision for the American Academy of Pediatrics, American Academy of Ophthalmology, American Association of Pediatric Ophthalmology and Strabismus, and the American Association of Certified Orthoptists, they stated "there is inadequate scientific evidence to support the view that subtle eye or visual problems cause or increase the severity of learning disabilities" and "scientific evidence does not support the claims that visual training, muscle exercises, ocular pursuit-and-tracking exercises, behavioural/perceptual vision therapy, "training"' glasses, prisms, and colored lenses and filters are effective direct or indirect treatments for learning disabilities" (S. Handler & Fierson, 2011, p. e818). Vision therapy therefore could not be advocated as it was not evidenced based.

Creavin et al. (Creavin et al., 2015) carried out the first large population-based study investigating whether there was any association between reading difficulties and ophthalmic abnormalities. In a cohort of 5,822 children (age 7–9 years), they found an incidence of 3% of severe reading impairment (SRI). They found no association between SRI and any ocular parameters except for a weak association between SRI and stereoacuity (depth perception), a finding very unlikely to have any functional impact on a child learning to read. The authors concluded that there was "no evidence that vision- based treatments would be useful to help children with SRI" (Creavin et al., 2015, p. 1057).

The Royal Australian and New Zealand College of Ophthalmologists' policy statement on Learning Disabilities, Dyslexia and Vision (2014) states: "Primary dyslexia and learning disabilities are complex neurocognitive conditions and are not caused by vision problems. There is no evidence to suggest that eye exercises, behavioural vision therapy, or special tinted filters or lenses improve the long-term educational performance of people affected by dyslexia or other learning disabilities" (The Royal Australian and New Zealand College of Ophthalmologists, 2014, p. 2).

Multiple other reviews on VT for learning disabilities have reached the same conclusion (Fletcher & Currie, 2011; Ganivet et al., 2014; Quercia et al., 2013; Rucker & Phillips, 2018; Stephenson & Wheldall, 2012).

3.1. Reading and eye movements

Reading is accomplished by a series of co-ordinated horizontal jump movements called saccades, which "land" the eyes on a particular word. Primarily, saccades are directed forward, but about 15% are backward saccades (regressions), with the steady fixation pause between saccades allowing for information to be recognised and processed by an individual (Granet, 2011; S. M. Handler & Fierson, 2017; Olitsky & Nelson, 2003; Rayner, 1998).

Poor readers and children with dyslexia have similar eye movements when reading as to a beginner reader or those of an adult reading complex text, showing shorter saccades, longer and more frequent fixation pauses and an increased number of regressions (Bellocchi et al., 2013; Boden & Giaschi, 2007; S. M. Handler & Fierson, 2017; Hutzler et al., 2006; Kirkby et al., 2011; Olitsky & Nelson, 2003; Quercia et al., 2013; Rayner, 1998; Vagge et al., 2015) and hence the changes to eye movements are not specific to dyslexia. This pattern of eye movements can be explained in terms of comprehension failure, representing the necessity of re-reading a passage to verify its meaning (Hoyt, 1999; Olitsky & Nelson, 2003; Rayner, 1998). As a reader becomes more proficient in reading, fixation duration decreases, saccadic length increases, and the number of fixations and frequency of regressions decreases (Granet, 2011; Rayner, 1998).

Bilingual readers are noted to read more proficiently in their dominant language, with shorter fixations, larger saccades and fewer regressions (Rayner, 1998). Likewise, when dyslexic readers are given text appropriate to their reading level, rather than their chronological age, their eye movements are similar to that of normal readers (Bellocchi et al., 2013; Boden & Giaschi, 2007; Bucci et al., 2009; Rayner, 1998; Webber et al., 2011).

Australian behavioural optometry reports include subjective terms such as "poor eye tracking", "jerky eye movements" or "extremely poor eye tracking skills" in their assessments of children, with the subsequent implication that this could contribute to difficulties with reading. The ACBO purports that VT will improve a child's ability to read and write by improving skills such as tracking eye movements (https://www.acbo.org.au/). However, as noted above, reading is not accomplished by "tracking", being the slow smooth pursuit eye movements of following a target steadily from one point to another such as watching a ball thrown, but rather by a series of saccades. As discussed by Vellutino et al., "the visual tracking theory of reading disability has been discredited by well-controlled eye movement studies finding no difference between poor and normal readers on visual tracking of non-verbal stimuli" (Vellutino et al., 2004, p. 9). Other authors have noted similar findings (Blythe et al., 2018; Bucci et al., 2009; Hutzler et al., 2006; Kirkby et al., 2011; Medland et al., 2010; Vagge et al., 2015).

Various methods have been used to assess "tracking" and the eye's ability to view and process information when reading. The most widely used tool by behavioural optometrists in the assessment of saccadic eye movements is the Developmental Eye Movement (DEM) test (Garzia et al., 1990). However, there are concerns regarding the validity of the test, including the level of false positives, false negatives and poor repeatability (Medland et al., 2010; Orlansky et al., 2011).

Ayton et al. (Ayton et al., 2009) from the University of Melbourne studied 158 children (8–11 years) and compared the DEM test performance to quantified saccadic eye movements measured with eye movement spectacles containing an infrared tracker. The authors found no correlation between DEM test results and symptoms or any of the objective saccadic parameters measured (accuracy, speed or initiation). The study instead found a correlation between the DEM test, reading performance and visual processing speed whereby tasks that require higher levels of cognitive processing resulted in slower saccadic speeds. This suggests that while the DEM test is a useful test to determine reading speeds in children known to have reading difficulties, it does not have diagnostic value in assessing saccadic eye movements with reading (Ayton et al., 2009). Multiple other studies have also confirmed slower reading speeds in children with reading difficulties, as could be expected (W. Dusek et al., 2010; Medland et al., 2010; Moiroud et al., 2018; Palomo-Alvarez & Puell, 2009; Quaid & Simpson, 2013; Vagge et al., 2015), but saccadic speed and accuracy were noted to be normal (Bucci et al., 2009; Vagge et al., 2015).

Similarly, Webber et al. from the Queensland University of Technology found that the DEM test was not an accurate measure for assessing saccadic eye movements but of reading speed and that the most significant correlation to reading achievement was the duration of fixation, suggestive that it is the time taken to process the text that controls the reading speed (Webber et al., 2011). This supports the premise that the cognitive aspects of reading, being the decoding of words and comprehension, control the reading rate rather than eye movements.

A study by Orlansky of 181 children (6–12 years) found poor repeatability of the DEM test on repeat testing and that results generally improved with time, without any intervention of VT, implying a learning curve. They questioned the usefulness of the test in the diagnosis of saccadic dysfunction and subsequently monitoring the progress of patients receiving vision therapy (Orlansky et al., 2011).

Importantly, Medland et al. used the DEM test to show that eye movements were slower in subjects when reading from right to left, rather than the conventional English reading from left to right (Medland et al., 2010). This should not be the case if defective saccades or poor "tracking" are the cause of reading problems as a defect in both directions would be expected.

Researchers have commented on the lack of scientific merit in behavioural VT, specifically for eye movement dysfunction (S. Handler & Fierson, 2011; Metzger & Werner, 1984; Quercia et al., 2013) and the fact that there is "no biological plausibility for vision therapy interventions directed at 'ocular tracking' to improve reading" (Rucker & Phillips, 2018, p. 233). Other authors have reported no benefit from the intervention of VT to improve the reading rate in children who were low academic achievers or those with learning difficulties (Hussaindeen et al., 2018; Sampson, 2004; Sampson et al., 2005).

Several studies of children from kindergarten to grade 3, who were invited to participate (without classification of reading ability), showed that saccadic training with a computer program based on rapid autonomic naming with numbers improved oral reading speed and accuracy more in the treated group (Dodick et al., 2017; Leong et al., 2014). However, these studies contained flaws. In the earlier study (Leong et al., 2014), comprehension was not assessed. In addition, a "high needs" (unspecified) subgroup who had lower reading scores initially showed the greatest change. The authors hypothesised that the improvements were due to the "repetitive practice of reading-related eye movements, shifting visuospatial attention, and visual processing" (Dodick et al., 2017, p. 104). Reading fluency of the kindergarten group, however, was tested with numbers, which is not a valid test of reading ability as words were not used. It also remains unclear how increasing the speed of eye movements results in improved comprehension. It is also likely that improvement in reading fluency and comprehension may be obtained by merely increasing the subjects' reading experience with time and practice, as opposed to a more formal eye movement program using only numbers. This would have the added benefit of increasing vocabulary through improved word recognition and knowledge.

Importantly, children with known congenital neurological or other diagnoses which result in abnormal eye movements do not have an increased rate of reading difficulties in view of normal intelligence and normal language development (Gilchrist et al., 1997; Hodgetts et al., 1998; Kutzbach et al., 2008). Furthermore, it has also been noted that individuals who develop acquired eye movement disorders do not develop dyslexia (Rucker & Phillips, 2018).

In view of the above, eye movement exercises, with the subsequent costs in terms of time and money, to improve "tracking" or saccadic function in children with reading disability is unnecessary.

3.2. Reading, refractive error and low plus lenses

There is almost universal agreement that significant refractive error (optical error caused by the eye being too long, too short, or irregularly shaped) in children with reading difficulties should be corrected with glasses. Hyperopia, or long-sightedness, is commonly caused by the eyeball being too short in length and is a normal finding in children. The Sydney Myopia Study recorded a hyperopia in 93.7% of 6-year-old children ($n = 1724$) and 70.1% of 12-year-old children ($n = 2340$) (Ip et al., 2008). Children readily overcome low levels of hyperopia via accommodation, which is the adjustment of focusing within the eye to allow objects to be seen clearly.

The benefits of correcting higher degrees of hyperopia was demonstrated in 2016 by The Vision in Preschoolers (VIP) Study Group (USA) which found that some children with uncorrected hyperopia of ≥4 Dioptres (D, the unit of measurement used when discussing the degree of refractive error) or uncorrected hyperopia of 3-6D in conjunction with reduced near vision or depth perception, scored significantly worse on one aspect of early literacy testing (print knowledge) (Kulp et al., 2016).

However, various authors have linked lower degrees of hyperopia with academic underachievement (Quaid & Simpson, 2013; Rosner & Rosner, 1997). A 1997 study by Rosner and Rosner (Rosner & Rosner, 1997) claimed a "robust" link between hyperopia, defined as >1.25D and academic underachievement in a group of randomly selected school-aged children from first to fifth grade ($n = 782$). This conclusion was based on the finding that only 13% of the hyperopes (long-sighted children) were found to be high academic achievers compared to 33% of the myopes (short-sighted children). However, there were actually more emmetropes (children with no refractive error) in the lower range of academic scores than hyperopes (16% compared to 14%), and the majority of the hyperopes (73%) were in the average score range. Therefore, analysis should have concluded that myopia is associated with higher academic achievement, rather than asserting that hyperopia was associated with lower academic achievement. Other authors have also correlated myopia (short-sightedness) with higher academic achievement (S. Handler & Fierson, 2011; Thurston, 2014) while other studies have found no differences in refraction between dyslexic children and those who were typically developing readers (W. Dusek et al., 2010; Raghuram et al., 2018; Wahlberg-Ramsay et al., 2012). In his critical review, Thurston noted a "lack of evidence of causation between refractive errors and poor reading" and called for a robust randomised controlled trial to determine if any causation exists (Thurston, 2014, p. 162).

Together with the behavioural theory that focusing at near can result in symptoms of eye strain or "near point stress" and may therefore interfere with reading development (Barrett, 2009; Hurst, 2013; Jennings, 2000), behavioural optometry practitioners continue to advocate for the correction of *any* degree of hyperopia via the use of plus lenses, even if vision and accommodative ability are normal. This has resulted in many children, especially those with reading difficulties, being prescribed low plus lenses which provide some minor magnification but which are in reality very close to plain glass. The glasses can often include a bifocal or multifocal reading add to provide additional magnification for nearby tasks, which is unnecessary where there is normal accommodative ability.

In summary, there is little evidence to support the view that the correction of inconsequential hyperopia creates visual conditions more conducive to reading or that the correction of such confers any real-world benefit to struggling readers (Barrett, 2009; S. Handler & Fierson, 2011; Jennings, 2000). The use of such glasses represents a waste of resources and distracts from the underlying causes of reading problems.

3.3. Reading, accommodation and convergence

Functions such as accommodation (the ability to change focus at varying distances to see an object clearly) and vergence (the ability to move the eyes inward or outward in a co-ordinated way so that both eyes are fixed on the same target) are necessary for efficient viewing and are known as "binocular functions'', as both eyes are synchronised when performing these tasks.

Some studies have reported an association with vergence disorders, such as convergence weakness (reduced ability to move the eyes inwards together), and/or accommodative dysfunction in children with reading difficulties/dyslexia (W. Dusek et al., 2010; Grisham et al., 2007; Hussaindeen et al., 2018; Kapoula et al., 2007; Palomo-Alvarez & Puell, 2008; Raghuram et al., 2018), while other studies found little or no association (Ganivet et al., 2014; Hall & Wick, 1991; Kiely et al., 2001; Moiroud et al., 2018; Wahlberg-Ramsay et al., 2012). This is likely due to the study design and variations in normative values.

Grisham et al. found an 80% incidence of "inadequate" visual skills in a group of 461 high-school students deemed as poor readers (Grisham et al., 2007). However, refraction (and the subsequent need for glasses) was not assessed, despite over 40% of the students having reduced vision, but only 8% of the students in the study who needed corrective lenses wearing them. Hence, many of the "inadequate" visual skills may be related to significant uncorrected refractive errors which required glasses.

Wahlberg-Ramsay et al. found no differences in binocular vision between dyslexic children ($n = 63$) compared to controls ($n = 60$) apart from a slightly reduced accommodative amplitude (focusing range) in the dyslexic group which was not thought by the authors to be significant enough to contribute to any reading difficulties (Wahlberg-Ramsay et al., 2012).

No statistically significant differences were noted in a study of Victorian school children ($n = 284$, mean age 9.9 yrs) by Kiely et al. in binocular parameters, including accommodation and convergence, between normal readers and groups of dyslexic children and those with learning difficulties (Kiely et al., 2001).

Dusek et al. did not define accommodative insufficiency (AI) or convergence insufficiency (CI) in their retrospective study of school-aged children (6–14 years) but reported an incidence of 0.6% and 5.2% for AI and CI, respectively, in the control group ($n = 328$), and 4.4% and 18.2%, respectively, in children ($n = 825$) who were referred for reported reading and writing difficulties despite normal intelligence and no specific learning disability (W. Dusek et al., 2010).

A follow-up non-randomised study by Dusek et al. (W. A. Dusek et al., 2011) was unable to prove that the treatment of convergence insufficiency improves the reading ability of children with reading difficulties and documented CI. Children could choose between the treatment options of either a) prism reading glasses, with no bifocal, b) home-based computerised vision therapy, or c) no treatment. At the follow-up assessment 4 weeks later, all three groups improved in reading speed, with fewer reading errors. The authors reported greater improvements in reading time and accuracy and other parameters in both the a and b groups, with more improvement with the prism glasses, than in the untreated group. The prism glasses, however, were not worn at the follow-up visit, so it was not demonstrated how the glasses contributed to improvement in function at the subsequent assessment. In addition, the study's non-randomised design, with subjects choosing their own treatment, lends some insight to the level of participant motivation. There was no true placebo group (the control group being those who refused treatment, did not receive a placebo treatment) and the study was not masked. The primary aim of the study was to treat CI in a group of children with reading difficulties, however the additional data supplied revealed that the majority of children (83 of 134) had no demonstrable improvement of their convergence near point (the main criterion for CI) despite treatment for convergence insufficiency (W. A. Dusek et al., 2011).

A prospective randomised clinical trial in the US of 310 children (9–14 years), the Convergence Insufficiency Treatment Trial-Attention and Reading Trial (CITT-ART), in 2019 found that after 4 months of treatment in-office vergence/accommodative therapy for symptomatic convergence insufficiency was no better at improving reading fluency or comprehension than placebo (CITT-ART Investigator Group, 2019a) nor was there any significant difference between the two groups in symptom improvement (CITT-ART Investigator Group, 2019b). The authors concluded that objective testing was critical for assessing CI and response to treatment rather than relying on self-reported symptoms (CITT-ART Investigator Group, 2019b), confirming Morad et al. (2002) study that found no correlation between reading comprehension tests and convergence measurements (Morad et al., 2002).

A secondary measure of children with symptomatic CI enrolled in the CITT was the reporting of parents' perception of the frequency of adverse academic behaviours in their children as measured by the Academic Behaviour Survey (ABS) (Borsting et al., 2012). Only 19% of the children from the four groups were reported as successfully treated (composite measures of the CI symptom survey and clinical signs) following 12 weeks of CI treatment and 28% had improved, but the majority (53%) were "non-responders". The authors found a greater decrease in the ABS scores as perceived by parental observation in those children who were reported as successful/improved following treatment. This, however, did not correlate with improvements in clinical signs, and hence, any improvement in academic behaviour could be interpreted as subjective. Furthermore, the CITT-ART also showed that vergence/accommodative therapy was no more effective in improving attention than placebo therapy (CITT-ART Investigator Group, 2021).

In their study of children with learning difficulties, Hussaindeen et al. found accommodation and vergence anomalies in 46 of 94 children (Hussaindeen et al., 2018). The group with binocular vision anomalies was then randomly divided into an intervention group given VT ($n = 24$) and a control, non-intervention group ($n = 22$). Following 10 sessions of VT there was a statistically significant improvement in accommodation and vergence measurements in the intervention group. However, improvements in the various binocular vision parameters following VT could be perceived as reflecting a learning effect in performing the test as there was no difference in the reading rate, DEM scores or the vision-related quality-of-life scores between the intervention group post-treatment and non-intervention group. This would call into question the relevance of VT with regard to any functional impact for reading in children. The fact that the sample size was small, the examiners were not masked and the non-intervention group did not receive any placebo treatment were additional limitations to the study.

In 2018, Raghuram et al. published an inconclusive study to investigate the frequency of visual deficits in children (7–11 years) with developmental dyslexia (Raghuram et al., 2018). The reported increase in accommodative deficits, vergence anomalies and impaired ocular motor tracking in children with DD as compared with those who were typically developing readers (TD) was questionable. This prospective, observational and non-randomised study was criticised for its study design and methodology (Elder & Gole, 2019; Larson, 2018) and described as both controlled and uncontrolled in the text. Subject selection was by invitation, and the sample size was small, with only 29 children with DD (males 66%) and 33 with TD (males 36%). The groups were not well matched for age, sex, IQ or ethnicity (52% of the TD group were Asian, whereas none of the DD groups were). Eleven of the 27 children classified in the DD group who underwent eye movement recordings were reading at Grade level. In addition, the examiners were un-masked and the eye movement recordings were interpreted "in the absence of criteria in the literature" (Raghuram et al., 2018, p. 1090). Larson has noted that children with developmental dyslexia have more trouble with visual attention and cognitive reading skills and therefore testing of basic visual functions such as accommodation or convergence is likely to accentuate a child's weakness (Larson, 2018). Hence, it remains undetermined how much of the problem is due to reduced accommodation/convergence versus inattention and difficulties with higher-order cognitive function.

The above findings are consistent with the theory that dyslexia is caused by phonological defects rather than binocular vision defects. Remediation should therefore be appropriately directed to suitable language-based programs.

3.4. Reading and coloured filters (tinted lenses and overlays)

Coloured lenses and overlays (Irlen lenses, Precision Tinted Lenses) have been promoted by Irlen practitioners and others, including behavioural optometrists (Leslie, 2016) to relieve symptoms termed "pattern glare" or "visual stress" (Wilkins et al. 2004), or Irlen syndrome (H. Irlen, 1991, 2010) which remains an unproven entity.

Irlen proposed that many individuals, and especially those with reading difficulties, have an increased sensitivity to certain wavelengths of light which create visual distortions with print and backgrounds that interfere with reading. By filtering out these wavelengths with coloured/tinted filters, the visual distortions are purportedly reduced, allowing individuals to improve their reading fluency, comfort, comprehension, and attention with an expected immediate effect (H. Irlen, 1991, 2010; H. Irlen & Lass, 1989).

Irlen described the condition as the "scotopic sensitivity syndrome" (SSS) with the implication of excessive retinal sensitivity to specific/certain wavelengths of light (H. Irlen & Lass, 1989). The term "scotopic" implies involvement of specific photoreceptors (rods) in the retina which function best in dim conditions. Reading, however, is performed with the cone photoreceptors in light conditions (Fitzgerald, 1989; Helveston, 1990; Solan, 1990). Studies assessing retinal function with electrophysiology (which objectively measures the electrical responses of the retinal photoreceptors) have not detected any changes in either rod or cone responses in subjects with reading discomfort or dyslexia (Hannell et al., 1989; Ridder et al., 2008).

The existence of Irlen syndrome has been questioned (Helveston, 1990; Hoyt, 1990), as the diagnosis relies solely on the self-reporting symptoms of individuals, and their subjective response to treatment, making this a diagnosis of exclusion. Despite the condition being reported since the early 1980s, there remains no corresponding physiological or biological correlation to identify individuals with Irlen syndrome nor have any objective quantitative tests shown changes in visual function (Hannell et al., 1989; Ridder et al., 2008).

Subsequently, a perceptual dysfunction affecting visual processing of information was proposed whereby individuals have a heightened sensitivity to certain environmental stimuli, such as fluorescent lights, whiteboards, textbooks and computer screens (H. Irlen, 1991, 2010), which also remains unproven on a biological level.

Independent researchers have consistently failed to identify any demonstrable visual benefit of using tinted lenses in the reading ability of children (Albon et al., 2008; Evans & Drasdo, 1991; Galuschka et al., 2014; S. Handler & Fierson, 2011; Iovino et al., 1998; Malins, 2009; Menacker et al., 1993; Ritchie et al., 2011; Suttle et al., 2018). Criticisms have included the lack of a plausible basis for the hypothesis and a lack of randomised controlled trials. Reports that have shown the benefit of the lenses are often anecdotal and are generally reported by those who have a vested interest in promoting the lenses (H. Irlen, 1991, 2010; Wilkins et al., 2004). Studies which show the effect have been limited by small sample sizes, selection bias, lack of a control group to rule out a placebo effect, no statistical analysis, and lack of a comprehensive eye exam to exclude other eye conditions that may be present with similar symptoms (Evans & Drasdo, 1991; Fitzgerald, 1989; Gole et al., 1989; H. L. Irlen & Scheiman, 1994). In addition, there is significant variability in the selection method for the colour of the tints, with poor test–retest repeatability for colour choice (S. Handler & Fierson, 2011; Suttle et al., 2017; Woerz & Maples, 1997). A stereotypic gender-based preference in the choice of colours has also been reported (Conway et al., 2016).

In 2018, the Royal Australian and New Zealand College of Ophthalmologists released a policy statement on Irlen syndrome noting the critical lack of scientific evidence supporting the efficacy of coloured filters/overlays in the improvement of reading and hence could not endorse the treatment (RANZCO, 2018). This is in keeping with the Joint Technical Report on Learning Disabilities, Dyslexia and Vision by the American Academy of Ophthalmology, the American Academy of Pediatrics, the American Association for Pediatric Ophthalmology and Strabismus and the American Association of Certified Orthoptists (AAO, AAPOS, AACO Joint Statement, 2014).

Thus, there remains no credible body of research that supports the existence of Irlen syndrome or the efficacy of coloured lenses and filters in the improvement of reading, including in children with reading difficulties.

3.5. Reading and visual information processing/visual perception training

Visual information Processing (VIP) is a higher-order cognitive function that has been defined as the process of selecting, organising and integrating information acquired through vision (Sampson, 2004), and includes visual perception and visual-motor integration. Tests of Visual Perceptual Skills include visual discrimination (recognising differences and similarities between objects), visual memory (spatial and sequential), visual form constancy (recognising an object despite changes in size or orientation), visual figure ground (ability to see a specific object in a busy background), visual spatial relations (i.e. laterality and directionality) and visual closure (ability to recognise a visual form when incomplete) (Sampson, 2004).

Reversal of letters (and mirror writing), regarded by some as a sign of poor visual perception or visual spatial confusion, has been noted to be a normal developmental finding in young children and reported with no greater frequency among reading impaired children than in normal readers (Boden & Giaschi, 2007; Goswami, 2015; Granet, 2011; Metzger & Werner, 1984; Olitsky & Nelson, 2003; S. E. Shaywitz, 1996; Vellutino, 1987). Previous studies have also shown that poor readers are able to perform copying tasks similar to those of typically developing readers, indicating normal visual spatial skills, but have poorer responses in naming of objects, suggestive that the difficulty lies on the verbal/linguistic side, rather than any visual processing defect (Metzger & Werner, 1984; Vellutino, 1987; Vellutino et al., 2004).

In their study, Goldstand et al. did not find any significant difference in the visual information processing scores, including visual perception, between proficient and non-proficient readers (Goldstand et al., 2005). Similarly, in a series of experiments designed to resemble single-word reading, but without a phonological component, Shovman & Ahissar found no differences between dyslexics and a control group, concluding that dyslexia is not caused by a visual processing deficit (Shovman & Ahissar, 2006).

Behavioural optometrists propose that VT promotes a visual system optimal for learning by improving VIP skills (https://www.acbo.org.au/). However, both early (Kavale & Mattson, 1983; B. K. Keogh, 1974; B. Keogh & Pelland, 1985; Metzger & Werner, 1984; Vellutino, 1987) and later reviews (Fletcher & Currie, 2011; Handler et al., 2014) of the ophthalmic, optometric and psychological literature found little evidence to support the view that visual perception difficulties are the cause of reading failure in children nor any evidence to suggest that visual training was effective in improving reading ability. While Kavale et al. found a correlation between visual perceptual skills and reading in a meta-analysis study (Kavale, 1982), a follow-up meta-analysis of 180 studies (all with control groups) assessing the efficacy of perceptual-motor training in children showed that the effects of these treatments were negligible for improving academic, cognitive or perceptual motor skills and were in fact-negative interventions for reading achievement (Kavale & Mattson, 1983). They commented that such programs waste valuable time and money, providing the child with a placebo therapy rather than an appropriate remedial program which would address the child's underlying learning difficulties (Kavale & Mattson, 1983). Hence, it could be argued that practising VIP skills with VT activities may do no more than improve the ability to perform the test, rather than confer any improvement in academic performance (Fletcher & Currie, 2011).

A randomised controlled trial of 96 Grade 1 and 2 school children in Australia identified as being low academic achievers with poor VIP skills assessed the efficacy of treatment for VIP dysfunction and its effect on educational performance (Sampson, 2004; Sampson et al., 2005). The experimental group underwent a visual therapy program designed to be typical of intervention programs commonly used in contemporary paediatric optometric clinical practice. The control group received a placebo program providing similar amounts of time and individual attention as the experimental group but no VT. Results of the 69 children who successfully completed the program showed both groups demonstrated significant benefits in educational and VIP parameters beyond what was anticipated for the effects of maturation and continued educational instruction, suggesting that the placebo effect was responsible for much of the improvement. Sampson concluded that "there is no evidence to support the efficacy of the investigated VT program in improving reading capability above the level achieved by a control group" (Sampson, 2004, p. 223). This is consistent with the previously conducted study by Brodney et al. which also found no significant differences in visual perceptual skills or visual motor integration skills in children with reading difficulties between those who had received vision therapy and those who had not (Brodney et al., 2001).

Furthermore, the assessment of learning difficulties and of visual perception should be carried out by appropriately qualified professionals such as educators, neuropsychologists and speech pathologists and interpreted in the broader context of intelligence and academic ability, expressive and receptive language skills, adaptive behavioural functions and social and emotional developments (Auspeld, 2021).

3.6. Attention-deficit/hyperactivity disorder (ADHD), autism

A significant proportion of children who have dyslexia shares a comorbidity with ADHD and/or autism (American Psychiatric Association, 2013; Anketell et al., 2018; Bellocchi et al., 2013; Dawidowsky et al., 2019; S. M. Handler & Fierson, 2017; Hussaindeen et al., 2018; S. E. Shaywitz, 1998; Vellutino et al., 2004). Neurobehavioural disorders such as these are known to aggravate the symptoms and difficulties in children with learning disabilities (Bellocchi et al., 2013). ADHD or autism may masquerade as either a specific learning difficulty or a visual problem in that poor academic performance may reflect inattention and difficulties in performing the test, rather than any true deficiency in these areas (American Psychiatric Association, 2013).

An increase in convergence insufficiency and/or accommodative dysfunction has been reported in children with ADHD/ADHD behaviours and autism (Anketell et al., 2018; Borsting et al., 2005; CITT-ART Investigator Group, 2021; Dawidowsky et al., 2019; Granet et al., 2005; Lee et al., 2014; Rouse et al., 2009). Confounding factors, however, in assessing visual function in children with ADHD include difficulties with concentration, following instructions and sustaining attention long enough to be tested adequately (Larson, 2018). In addition, many children with ADHD/autism are on behaviour modifying medications which may influence accommodative responses and convergence (Bingöl-Kızıltunç et al., 2022; CITT-ART Investigator Group, 2021; Farrar et al., 2001).

To date, there are no studies which show children with ADHD/autism have an aversion or avoidance for near visual activities such as looking at or playing on handheld devices, which should be the case if difficulties with convergence or accommodation were symptomatic. On the contrary, studies have shown that many children with ADHD/autism enjoy prolonged use of their devices (Dong et al., 2021; Kim et al., 2019; Yang et al., 2022).

4. Conclusion

There is no scientific basis to the view that "tracking" problems cause reading difficulties nor any plausible evidence that VT exercises to improve "tracking" will confer improvement in reading ability. There is no compelling evidence that minor accommodation or convergence weakness or mild refractive errors contribute to reading difficulties, or that treatment of such is beneficial. Treatment of symptomatic convergence insufficiency has not been shown to improve reading function. There is no credible evidence to support the theory that training visual perceptual skills will transfer to improved reading ability. Treatments such as VT, coloured filters/lenses or movement-based exercises do not have sufficient evidence to be considered effective in enabling children to be more responsive to educational instruction, and therefore should not be recommended. Publications that promote the utilisation of such techniques are limited and/or flawed.

Reported claims of improvement are often through testimonials and self-promotional internet advertising rather than by rigorous evidence. At the time of submission, much of the research that the ACBO provides on their website with regard to the efficacy of VT on reading difficulties is written by a small number of proponents and constitutes summaries of questionable publications, many of which have been critiqued here. Other evidence cited on the ACBO website is irrelevant, such as the publication of adjustable sutures, a technique used in surgery to restraighten misaligned eyes. Therefore, the lack of evidence to support VT techniques which has been raised by other authors continues to remain unaddressed.

Ineffective treatments waste valuable time and resources and may cause a delay in seeking evidence-based treatments. As Evans and Allen point out "it is important for practitioners to appreciate that any interventions carry a cost to the patient and family in terms of expense, time, and raised expectations. For interventions where the evidence is weak (e.g. coloured filters, small refractive errors, vision therapy) then the practitioner should be particularly careful not to overstate the case for intervening" (Evans & Allen, 2016, p. 216).

Given that the primary defect in dyslexia is linguistic, early intervention with intensive, explicit instruction in the language areas, including phonics and phonemic awareness, remains the best recommended primary intervention. As Fletcher and Currie point out "if the goal is improved reading or math, teach reading and math" (Fletcher & Currie, 2011, p. 5).

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References

Albon, E., Adi, Y., & Hyde, C. (2008). Structural neuroimaging in psychosis: A systematic review and economic evaluation. *Health Technology Assessment (Winchester, England)*, *12*(18), iii-iv, ix–163. https://doi.org/10.3310/hta12180

American Academy of Ophthalmology, American Association for Pediatric Ophthalmology and Strabismus, American Association of Certified Orthoptists. (2014). *Joint statement: Learning disabilities, dyslexia, and vision - reaffirmed 2014*. https://www.aao.org/clinical-statement/joint-statement-learning-disabilities-dyslexia-vis

American National Institute of Child Health and Human Development. (2000). *Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction*. https://www.nichd.nih.gov/sites/default/files/publications/pubs/nrp/Documents/report.pdf

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596.dsm05

Anketell, P. M., Saunders, K. J., Gallagher, S. M., Bailey, C., & Little, J. A. (2018). Accommodative function in individuals with autism spectrum disorder. *Optometry and Vision Science*, *95*(3), 193–201. https://doi.org/10.1097/OPX.0000000000001190

Auspeld. (2021). *Understanding learning difficulties a practical guide* (Revised ed.). D. L. Services.

The Australasian College of Behavioural Optometrists. (2011). *Vision therapy explained*. https://www.acbo.org.au/ACBO_Vision_Therapy_Explained_Final.pdf

Aylward, E. H., Richards, T. L., Berninger, V. W., Nagy, W. E., Field, K. M., Grimme, A. C., Richards, A. L., Thomson, J. B., & Cramer, S. C. (2003). Instructional treatment associated with changes in brain activation in children with dyslexia. *Neurology*, *61*(2), 212–219. https://doi.org/10.1212/01.wnl.0000068363.05974.64

Ayton, L. N., Abel, L. A., Fricke, T. R., & McBrien, N. A. (2009). Developmental eye movement test: What is it really measuring? *Optometry and Vision Science*, *86*(6), 722–730. https://doi.org/10.1097/OPX.0b013e3181a6a4b3

Barrett, B. T. (2009). A critical evaluation of the evidence supporting the practice of behavioural vision therapy. *Ophthalmic & Physiological Optics*, *29*(1), 4–25. https://doi.org/10.1111/j.1475-1313.2008.00607.x

Bellocchi, S., Muneaux, M., Bastien-Toniazzo, M., & Ducrot, S. (2013). I can read it in your eyes: What eye movements tell us about visuo-attentional processes in developmental dyslexia. *Research in Developmental Disabilities*, *34*(1), 452–460. https://doi.org/10.1016/j.ridd.2012.09.002

Bingöl-Kızıltunç, P., Yürümez, E., & Atilla, H. (2022). Does methylphenidate treatment affect functional and structural ocular parameters in patients with attention deficit hyperactivity disorder? - a prospective, one year follow-up study. *Indian Journal of Ophthalmology*, *70*(5), 1664–1668. https://doi.org/10.4103/ijo.IJO_2966_21

Blythe, H. I., Kirkby, J. A., & Liversedge, S. P. (2018). Comments on: what is developmental dyslexia? Brain Sci. 2018, 8, 26. The relationship between eye movements and reading difficulties. *Brain Sciences*, *8*(6), 100. https://doi.org/10.3390/brainsci8060100

Boden, C. & Giaschi, D. (2007). M-stream deficits and reading-related visual processes in developmental dyslexia. *Psychological Bulletin*, *133*(2), 346–366. https://doi.org/10.1037/0033-2909.133.2.346

Borsting, E., Mitchell, G. L., Kulp, M. T., Scheiman, M., Amster, D. M., Cotter, S., Coulter, R. A., Fech, G., Gallaway, M. F., Granet, D., Hertle, R., Rodena, J., Yamada, T., & CITT Study Group. (2012). Improvement in academic behaviors after successful treatment of convergence insufficiency. *Optometry and Vision Science*, *89*(1), 12–18. https://doi.org/10.1097/OPX.0b013e318238ffc3

Borsting, E., Rouse, M., & Chu, R. (2005). Measuring ADHD behaviors in children with symptomatic accommodative dysfunction or convergence insufficiency: A preliminary study. *Optometry - Journal of the American Optometric Association*, *76*(10), 588–592. https://doi.org/10.1016/j.optm.2005.07.007

Brodney, A. C., Pozil, R., Mallinson, K., & Kehoe, P. (2001). Vision therapy in a school setting. *J Behav Optom*, *12*(4), 99–103.

Bucci, M. P., Vernet, M., Gerard, C. L., & Kapoula, Z. (2009). Normal speed and accuracy of saccade and vergence eye movements in dyslexic reader children. *Journal of Ophthalmology*, *2009*, 1–8. https://doi.org/10.1155/2009/325214

CITT-ART Investigator Group. (2019a). Effect of Vergence/Accommodative therapy on reading in children with convergence insufficiency: A randomized clinical trial. *Optometry and Vision Science*, *96*(11), 836–849. https://doi.org/10.1097/OPX.0000000000001442

CITT-ART Investigator Group. (2019b). Treatment of symptomatic convergence insufficiency in children enrolled in the convergence insufficiency treatment trial–attention & reading trial: A randomized clinical trial. *Optometry and Vision Science*, *96*(11), 825–835. https://doi.org/10.1097/OPX.0000000000001443

CITT-ART Investigator Group. (2021). Effect of Vergence/Accommodative therapy on attention in children with convergence insufficiency: A randomized clinical trial. *Optometry and Vision Science*, *98*(3), 222–233. https://doi.org/10.1097/OPX.0000000000001659

Cockburn, D. (1992). Hold it right there! *Clinical & Experimental Optometry*, *75*(4), 128–129. https://doi.org/10.1111/j.1444-0938.1992.tb00622.x

Collins, M. E., Mudie, L. I., Inns, A. J., & Repka, M. X. (2017). Pediatric ophthalmology and childhood reading difficulties: Overview of reading development and assessments for the pediatric ophthalmologist. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, *21*(6), 433–436. e431. https://doi.org/10.1016/j.jaapos.2017.06.017

Conway, M. L., Evans, B. J. W., Evans, J. C., Suttle, C. M., & Allen, P. (2016). Does gender influence colour choice in the treatment of visual stress? *PLoS One*, *11*(9), e0163326. https://doi.org/10.1371/journal.pone.0163326

Creavin, A. L., Lingam, R., Steer, C., & Williams, C. (2015). Ophthalmic abnormalities and reading impairment. *Pediatrics*, *135*(6), 1057–1065. https://doi.org/10.1542/peds.2014-3622

Dawidowsky, B., Cerovski, B., Klobučar, A., & Dawidowsky, K. (2019). Do orthoptic exercises have any influence on children and adolescents diagnosed with convergence insufficiency and attention deficit/hyperactivity disorder? *Acta Clinica Croatica*, *58*(4), 662–671. https://doi.org/10.20471/acc.2019.58.04.14

Demonet, J. F., Taylor, M. J., & Chaix, Y. (2004). Developmental dyslexia. *Lancet*, *363*(9419), 1451–1460. https://doi.org/10.1016/S0140-6736(04)16106-0

Dodick, D., Starling, A. J., Wethe, J., Pang, Y., Messner, L. V., Smith, C., Master, C. L., Halker-Singh, R. B., Vargas, B. B., Bogle, J. M., Mandrekar, J., Talaber, A., & Leong, D. (2017). The effect of In-school saccadic training on reading fluency and comprehension in first and second grade students. *Journal of Child Neurology*, *32*(1), 104–111. https://doi.org/10.1177/0883073816668704

Dong, H.-Y., Wang, B., Li, H.-H., Yue, X.-J., & Jia, F.-Y. (2021). Correlation between screen time and autistic symptoms as well as development quotients in children with autism spectrum disorder. *Frontiers in Psychiatry*, *12*. https://doi.org/10.3389/fpsyt.2021.619994

Dusek, W. A., Pierscionek, B. K., & McClelland, J. F. (2011). An evaluation of clinical treatment of convergence insufficiency for children with reading difficulties. *BMC Ophthalmology*, *11*(1), 21. https://doi.org/10.1186/1471-2415-11-21

Dusek, W., Pierscionek, B. K., & McClelland, J. F. (2010). A survey of visual function in an Austrian population of school-age children with reading and writing difficulties. *BMC Ophthalmology*, *10*(1), 16. https://doi.org/10.1186/1471-2415-10-16

Eckert, M. A., Vaden, K. I., Jr., Maxwell, A. B., Cute, S. L., Gebregziabher, M., Berninger, V. W., Dyslexia Data, C. V., Castellanos, X., Chiarello, C., Conway, T., Cutting, L., Dehaene-Lambertz, G., Eden, G., Frye, R., Giaschi, D., Gilger, J., Hoeft, F., Kibby, M., . . . Talcott, J. (2017). Common brain structure findings across children with varied reading disability profiles. *Scientific Reports*, *7*(1), 6009. https://doi.org/10.1038/s41598-017-05691-5

Elder, J. E. & Gole, G. A. (2019). Accurately assessing visual deficits in children with developmental dyslexia. *JAMA Ophthalmology*, *137*(8), 955–955. https://doi.org/10.1001/jamaophthalmol.2019.1709

Evans, B. J. W. & Allen, P. M. (2016). A systematic review of controlled trials on visual stress using intuitive overlays or the intuitive colorimeter. *Journal of Optometry*, *9*(4), 205–218. https://doi.org/10.1016/j.optom.2016.04.002

Evans, B. J. W. & Drasdo, N. (1991). Tinted lenses and related therapies for learning disabilities–a review. *Ophthalmic & Physiological Optics*, *11*(3), 206–217. https://doi.org/10.1111/j.1475-1313.1991.tb00535.x

Farrar, R., Call, M., & Maples, W. C. (2001). A comparison of the visual symptoms between ADD/ADHD and normal children. *Optometry*, *72*(7), 441–451.

Fitzgerald, A. (1989). Tinted lenses and dyslexia: A review of the literature. *Australian Orthoptic Journal*, *25*(1), 1–6. https://www.aojournal.com.au/archive/1989/volume-25/tinted-lenses-and-dyslexia-a-review-of-the-literature

Fitzroy North Eye Centre. (2024) https://fitzroynortheyecentre.com.au/eyecare/behavioural-optometry/vision-therapy/

Fletcher, J. M. & Currie, D. (2011). The international dyslexia association. Vision efficiency interventions and reading disability. *Perspective on Language and Literacy*, *37*, 21–24. http://www.onlinedigeditions.com/publication/?i=59673&article_id=625330&view=articleBrowser&ver=html5

Gabrieli, J. (2009). Dyslexia: A new synergy between education and cognitive neuroscience. *Science (New York, NY)*, *325*(5938), 280–283. https://doi.org/10.1126/science.1171999

Galaburda, A. M., Sherman, G. F., Rosen, G. D., Aboitiz, F., & Geschwind, N. (1985). Developmental dyslexia: Four consecutive patients with cortical anomalies. *Annals of Neurology*, *18*(2), 222–233. https://doi.org/10.1002/ana.410180210

Galuschka, K., Ise, E., Krick, K., Schulte-Körne, G., & Lidzba, K. (2014). Effectiveness of treatment approaches for children and adolescents with reading disabilities: A meta-analysis of randomized controlled trials. *PLOS ONE*, *9*(2), e89900. https://doi.org/10.1371/journal.pone.0089900

Ganivet, A., Denault, I., Superstein, R., & Fallaha, N. (2014). Diverses modalités de traitement des troubles d'apprentissage scolaire par thérapies visuelles: quelles sont les évidences scientifiques? *Canadian Journal of Optometry*, *76*(2), 15–22. https://doi.org/10.15353/cjo.76.526

Garzia, R. P., Richman, J. E., Nicholson, S. B., & Gaines, C. S. (1990). A new visual-verbal saccade test: The development eye movement test (DEM). *Journal of the American Optometric Association*, *61*(2), 124–135. https://www.ncbi.nlm.nih.gov/pubmed/2313029

Gilchrist, I. D., Brown, V., & Findlay, J. M. (1997). Saccades without eye movements. *Nature*, *390*(6656), 130–131. https://doi.org/10.1038/36478

Goldstand, S., Koslowe, K. C., & Parush, S. (2005). Vision, visual-information processing, and academic performance among seventh-grade schoolchildren: A more significant relationship than we thought? *The American Journal of Occupational Therapy*, *59*(4), 377–389. https://doi.org/10.5014/ajot.59.4.377

Gole, G., Dibden, A., Pearson, S. N., C, C., Pidgeon, K. J., Mann, J. W., Rice, D., Rooney, K. F., Hannell, G., Fitzgerald, B. A., & Kortman, J. Y. (1989). Tinted lenses and dyslexics—a controlled study. *Australian and New Zealand Journal of Ophthalmology*, *17*(2), 137–141. https://www.ncbi.nlm.nih.gov/pubmed/2757828

Goswami, U. (2015). Sensory theories of developmental dyslexia: Three challenges for research. *Nature Reviews: Neuroscience*, *16*(1), 43–54. https://doi.org/10.1038/nrn3836

Granet, D. B. (2011). Learning disabilities, dyslexia, and vision: The role of the pediatric ophthalmologist. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, *15*(2), 119–120. https://doi.org/10.1016/j.jaapos.2011.03.003

Granet, D. B., Gomi, C. F., Ventura, R., & Miller-Scholte, A. (2005). The relationship between convergence insufficiency and ADHD. *Strabismus*, *13*(4), 163–168. https://doi.org/10.1080/09273970500455436

Grisham, D., Powers, M., & Riles, P. (2007). Visual skills of poor readers in high school. *Optometry - Journal of the American Optometric Association*, *78*(10), 542–549. https://doi.org/10.1016/j.optm.2007.02.017

Hall, P. S. & Wick, B. C. (1991). The relationship between ocular functions and reading achievement. *Journal of Pediatric Ophthalmology & Strabismus*, *28*(1), 17–19. http://europepmc.org/abstract/MED/2019952

Handler, S. & Fierson, W. (2011). Joint technical report. Learning disabilities, dyslexia, and vision. *Pediatrics*, *127*(3), e818–856. https://doi.org/10.1542/peds.2010-3670

Handler, S. M. & Fierson, W. M. (2017). Reading difficulties and the pediatric ophthalmologist. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, *21*(6), 436–442. https://doi.org/10.1016/j.jaapos.2017.09.001

Hannell, G., Gole, G. A., & D, S. N. (1989). Reading improvement with tinted lenses: A report of two cases. *Clinical & Experimental Optometry*, *72*(5), 170–176. https://doi.org/10.1111/j.1444-0938.1989.tb03080.x

Helveston, E. M. (1990). Scotopic sensitivity syndrome. *Archives of Ophthalmology*, *108*(9), 1232–1233. https://www.ncbi.nlm.nih.gov/pubmed/2400343

Helveston, E. M. (2005). Visual training: Current status in ophthalmology. *American Journal of Ophthalmology*, *140*(5), 903–910. https://doi.org/10.1016/j.ajo.2005.06.003

Hodgetts, D. J., Simon, J. W., Sibila, T. A., Scanlon, D. M., & Vellutino, F. R. (1998). Normal reading despite limited eye movements. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, *2*(3), 182–183. https://www.ncbi.nlm.nih.gov/pubmed/10532756

Hoyt, C. S., III. (1990). Irlen lenses and reading difficulties. *Journal of Learning Disabilities*, *23*(10), 624–626. https://doi.org/10.1177/002221949002301010

Hoyt, C. S. (1999). Visual training and reading. *The American Orthoptic Journal*, *49*(1), 23–25. https://doi.org/10.1080/0065955X.1999.11982187

Hurst, C. (2013). Behavioural optometry: Learning difficulties and the visual process. *International Journal of Ophthalmic Practice*, *4*(3), 127–135. https://doi.org/10.12968/ijop.2013.4.3.127

Hussaindeen, J. R., Shah, P., Ramani, K. K., & Ramanujan, L. (2018). Efficacy of vision therapy in children with learning disability and associated binocular vision anomalies. *Journal of Optometry*, *11*(1), 40–48. https://doi.org/10.1016/j.optom.2017.02.002

Hutzler, F., Kronbichler, M., Jacobs, A. M., & Wimmer, H. (2006). Perhaps correlational but not causal: No effect of dyslexic readers' magnocellular system on their eye movements during reading. *Neuropsychologia*, *44*(4), 637–648. https://doi.org/10.1016/j.neuropsychologia.2005.06.006

Iovino, I., Fletcher, J. M., Breitmeyer, B. G., & Foorman, B. R. (1998). Colored overlays for visual perceptual deficits in children with reading disability and attention Deficit/Hyperactivity disorder: Are they differentially effective? *Journal of Clinical and Experimental Neuropsychology*, *20*(6), 791–806. https://doi.org/10.1076/jcen.20.6.791.1113

Ip, J. M., Robaei, D., Kifley, A., Wang, J. J., Rose, K. A., & Mitchell, P. (2008). Prevalence of hyperopia and associations with eye findings in 6- and 12-year-olds. *Ocular Diagnoses at Enrollment: Ophthalmology*, *115*(4), 678–685. e671. https://doi.org/10.1016/j.ophtha.2007.04.061

Irlen, H. (1991). *Reading by the colors: Overcoming dyslexia and other reading disabilities through the irlen method*. Avery Publishing Group. https://books.google.com.au/books?id=ma6PQgAACAAJ

Irlen, H. (2010). *The irlen revolution*. Square One Publishers.

Irlen, H. & Lass, M. J. (1989). Improving reading problems due to symptoms of scotopic sensitivity syndrome using irlen lenses and overlays. *Education*, *109*(4), 413–417.

Irlen, H. L. & Scheiman, M. (1994). Viewpoints: Scotopic sensitivity syndrome, irlen filters and reading disability. *J Behav Optom*, *5*(3), 62–66.

Jennings, J. A. M. (2000). Behavioural optometry – a critical review. *Optometry in Practice*, *1*(1), 67–78.

Kapoula, Z., Bucci, M. P., Jurion, F., Ayoun, J., Afkhami, F., & Bremond-Gignac, D. (2007). Evidence for frequent divergence impairment in French dyslexic children: Deficit of convergence relaxation or of divergence per se? *Graefe's Archive for Clinical and Experimental Ophthalmology*, *245*(7), 931–936. https://doi.org/10.1007/s00417-006-0490-4

Kavale, K. (1982). Meta-analysis of the relationship between visual perceptual skills and reading achievement. *Journal of Learning Disabilities*, *15*(1), 42–51. https://doi.org/10.1177/002221948201500110

Kavale, K. & Mattson, P. D. (1983). "One jumped off the balance beam": Meta-analysis of perceptual-motor training. *Journal of Learning Disabilities*, *16*(3), 165–173. https://doi.org/10.1177/002221948301600307

Keogh, B. K. (1974). Optometric vision training programs for children with learning disabilities: Review of issues and research. *Journal of Learning Disabilities*, *7*(4), 219–231. https://doi.org/10.1177/002221947400700407

Keogh, B. & Pelland, M. (1985). Vision training revisited. *Journal of Learning Disabilities*, *18*(4), 228–236. https://doi.org/10.1177/002221948501800410

Kiely, P. M., Crewther, S. G., & Crewther, D. P. (2001). Is there an association between functional vision and learning to read? *Clinical & Experimental Optometry*, *84*(6), 346–353. https://doi.org/10.1111/j.1444-0938.2001.tb06606.x

Kim, S. G., Park, J., Kim, H. T., Pan, Z., Lee, Y., & McIntyre, R. S. (2019). The relationship between smartphone addiction and symptoms of depression, anxiety, and attention-deficit/hyperactivity in South Korean adolescents. *Annals of General Psychiatry*, *18*(1), 1. https://doi.org/10.1186/s12991-019-0224-8

Kirkby, J. A., Blythe, H. I., Drieghe, D., Liversedge, S. P., & Castles, A. (2011). Reading text increases binocular disparity in dyslexic children. *PLOS ONE*, *6*(11), e27105. https://doi.org/10.1371/journal.pone.0027105

Klingberg, T., Hedehus, M., Temple, E., Salz, T., Gabrieli, J. D. E., Moseley, M. E., & Poldrack, R. A. (2000). Microstructure of temporo-parietal white matter as a basis for reading ability: Evidence from diffusion tensor magnetic resonance imaging. *Neuron*, *25*(2), 493–500. https://doi.org/10.1016/S0896-6273(00)80911-3

Kulp, M. T., Ciner, E., Maguire, M., Moore, B., Pentimonti, J., Pistilli, M., Cyert, L., Candy, T. R., Quinn, G., Ying, G.-S., & Writing Committee for The VIP-HIP Study Group. (2016). Uncorrected hyperopia and preschool early literacy: Results of the vision in Preschoolers-hyperopia in Preschoolers (VIP-HIP) study. *Ocular Diagnoses at Enrollment: Ophthalmology*, *123*(4), 681–689. https://doi.org/10.1016/j.ophtha.2015.11.023

Kutzbach, B. R., Summers, C. G., Holleschau, A. M., & MacDonald, J. T. (2008). Neurodevelopment in children with albinism. *Ocular Diagnoses at Enrollment: Ophthalmology*, *115*(10), 1805–1808. https://doi.org/10.1016/j.ophtha.2008.03.006

Larson, S. A. (2018). Is oculomotor testing important in developmental dyslexia? *JAMA Ophthalmology*, *136*(10), 1096–1097. https://doi.org/10.1001/jamaophthalmol.2018.2805

Lee, S. H., Moon, B. Y., & Cho, H. G. (2014). Improvement of vergence movements by vision therapy decreases K-ARS scores of symptomatic ADHD children. *Journal of Physical Therapy Science*, *26*(2), 223–227. https://doi.org/10.1589/jpts.26.223

Leong, D. F., Master, C. L., Messner, L. V., Pang, Y., Smith, C., & Starling, A. J. (2014). The effect of saccadic training on early reading fluency. *Clinical Pediatrics*, *53*(9), 858–864. https://doi.org/10.1177/0009922814532520

Leslie, S. (2016). *Pattern glare, photosensitivity and tinted lenses*. Australian College of Behavioural Optometrists. https://www.acbo.org.au/images/News_Views_FAQs/Evidence_landing_page/Leslie_-_Pattern_Glare_Photosensitivity_and_Tinted_lenses.pdf

Malins, C. (2009). The use of coloured filters and lenses in the management of children with reading difficulties. Aliterature review commissioned for the Irlen Screening Research Project. *New Zealand Ministry of Health Manatū Hauora* (Vol. 1, no. 1). Ministry of Health | Manatū Hauora. http://www.health.govt.nz/system/files/documents/publications/use-of-coloured-filters-and-lenses-children-learning-difficulties-nov2010.doc .

Medland, C., Walter, H., & Woodhouse, J. M. (2010). Eye movements and poor reading: Does the developmental eye movement test measure cause or effect? *Ophthalmic & Physiological Optics*, *30*(6), 740–747. https://doi.org/10.1111/j.1475-1313.2010.00779.x

Menacker, S. J., Breton, M. E., Breton, M. L., Radcliffe, J., & Gole, G. A. (1993). Do tinted lenses improve the reading performance of dyslexic children?: A cohort study. *JAMA Ophthalmology*, *111*(2), 213–218. https://doi.org/10.1001/archopht.1993.01090020067025

Metzger, R. L. & Werner, D. B. (1984). Use of visual training for reading disabilities: A review. *Pediatrics*, *73*(6), 824–829. https://doi.org/10.1542/peds.73.6.824

Moiroud, L., Gerard, C. L., Peyre, H., Bucci, M. P., & Weng, X. (2018). Developmental eye movement test and dyslexic children: A pilot study with eye movement recordings. *PLOS ONE*, *13*(9), e0200907. https://doi.org/10.1371/journal.pone.0200907

Morad, Y., Lederman, R., Avni, I., Atzmon, D., Azoulay, E., & Segal, O. (2002). Correlation between reading skills and different measurements of convergence amplitude. *Current Eye Research*, *25*(2), 117–121. https://doi.org/10.1076/ceyr.25.2.117.10155

Olitsky, S. E. & Nelson, L. B. (2003). Reading disorders in children. *Pediatric Clinics of North America*, *50*(1), 213–224. https://doi.org/10.1016/s0031-3955(02)00104-9

Olulade, O., Napoliello, E., & Eden, G. (2013). Abnormal visual motion processing is not a cause of dyslexia. *Neuron*, *79*(1), 180–190. https://doi.org/10.1016/j.neuron.2013.05.002

Orlansky, G., Hopkins, K. B., Mitchell, G. L., Huang, K., Frazier, M., Heyman, C., & Scheiman, M. (2011). Reliability of the developmental eye movement test. *Optometry and Vision Science*, *88*(12), 1507–1519. https://doi.org/10.1097/OPX.0b013e318230f03a

Palomo-Alvarez, C. & Puell, M. C. (2008). Accommodative function in school children with reading difficulties. *Graefe's Archive for Clinical and Experimental Ophthalmology*, *246*(12), 1769–1774. https://doi.org/10.1007/s00417-008-0921-5

Palomo-Alvarez, C. & Puell, M. C. (2009). Relationship between oculomotor scanning determined by the DEM test and a contextual reading test in schoolchildren with reading difficulties. *Graefe's Archive for Clinical and Experimental Ophthalmology*, *247*(9), 1243–1249. https://doi.org/10.1007/s00417-009-1076-8

Panoptic Vision Therapy. (2024) https://www.panopticvision.com.au/vision-therapy
Peterson, R. L. & Pennington, B. F. (2012). Developmental dyslexia. *Lancet*, *379*(9830), 1997–2007. https://doi.org/10.1016/S0140-6736(12)60198-6
Pezzimenti Nixon Optometrists. 2024. https://www.pezzimentinixon.com.au/vision-and-learning/dyslexia/
Quaid, P. & Simpson, T. (2013). Association between reading speed, cycloplegic refractive error, and oculomotor function in reading disabled children versus controls. *Graefe's Archive for Clinical and Experimental Ophthalmology*, *251*(1), 169–187. https://doi.org/10.1007/s00417-012-2135-0
Quercia, P., Feiss, L., & Michel, C. (2013). Developmental dyslexia and vision. *Clinical Ophthalmology*, *7*, 869–881. https://doi.org/10.2147/OPTH.S41607
Raghuram, A., Gowrisankaran, S., Swanson, E., Zurakowski, D., Hunter, D. G., & Waber, D. P. (2018). Frequency of visual deficits in children with developmental dyslexia. *JAMA Ophthalmology*, *136*(10), 1089–1095. https://doi.org/10.1001/jamaophthalmol.2018.2797
Ramus, F. (2003). Developmental dyslexia: Specific phonological deficit or general sensorimotor dysfunction? *Current Opinion in Neurobiology*, *13*(2), 212–218. https://doi.org/10.1016/s0959-4388(03)00035-7
Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., & Frith, U. (2003). Theories of developmental dyslexia: Insights from a multiple case study of dyslexic adults. *Brain A Journal of Neurology*, *126*(4), 841–865. https://doi.org/10.1093/brain/awg076
Rawstron, J. A., Burley, C. D., & Elder, M. J. (2005). A systematic review of the applicability and efficacy of eye exercises. *Journal of Pediatric Ophthalmology & Strabismus*, *42*(2), 82–88. https://www.ncbi.nlm.nih.gov/pubmed/15825744
Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, *124*(3), 372–422. https://doi.org/10.1037/0033-2909.124.3.372
Ridder, W. H., Borsting, E., Tosha, C., Tong, A., Dougherty, R., & Chase, C. (2008). ERGs and psychophysical thresholds in students with reading discomfort. *Optometry and Vision Science*, *85*(3), 180–186. https://doi.org/10.1097/OPX.0b013e3181643e81
Ritchie, S. J., Sala, S. D., & McIntosh, R. D. (2011). Irlen colored overlays do not alleviate reading difficulties. *Pediatrics*, *128*(4), e932–e938. https://doi.org/10.1542/peds.2011-0314
Rose, J. (2006). *Independent review of the teaching of early reading: Final report*. Department for Education and Skills London.
Rosner, J. & Rosner, J. (1997). The relationship between moderate hyperopia and academic achievement: How much plus is enough? *Journal of the American Optometric Association*, *68*(10), 648–650. https://www.unboundmedicine.com/medline/citation/9354056/The_relationship_between_moderate_hyperopia_and_academic_achievement:_how_much_plus_is_enough
Rouse, M., Borsting, E., Mitchell, G. L., Kulp, M. T., Scheiman, M., Amster, D., Coulter, R., Gregory, F., & Gallaway, M. (2009). Academic behaviors in children with convergence insufficiency with and without parent-reported ADHD. *Optometry and Vision Science*, *86*(10), 1169–1177. https://doi.org/10.1097/OPX.0b013e3181baad13
Rowe, K. (2005). *Teaching reading: Report and recommendations. The final report of the national inquiry into the teaching of literacy*. Australian Government, Department of Education, Science and Training.
The Royal Australian and New Zealand College of Ophthalmologists. (2014). https://ranzco.edu/policies_and_guideli/learning-disabilities-dyslexia-and-vision/
The Royal Australian and New Zealand College of Ophthalmologists. (2018). *Position statement: Irlen syndrome*. https://ranzco.edu/wp-content/uploads/2018/11/Irlen-Syndrome-Position-Statement-May-2018-1.pdf
Rucker, J. C. & Phillips, P. H. (2018). Efferent vision therapy. *Journal of Neuro-Ophthalmology*, *38*(2), 230–236. https://doi.org/10.1097/WNO.0000000000000480
Sampson, G. (2004). *Efficacy of treatment for visual information processing dysfunction and its effect on educational performance* [Doctoral dissertation, The University of Melbourne.].
Sampson, G., Fricke, T., Metha, A., & McBrien, N. A. (2005). Efficacy of treatment for visual information processing dysfunction and its effect on educational performance. *Investigative Ophthalmology & Visual Science*, *46*(13), E–Abstract 679.

Shaywitz, B. A., Shaywitz, S. E., Blachman, B. A., Pugh, K. R., Fulbright, R. K., Skudlarski, P., Mencl, W. E., Constable, R. T., Holahan, J. M., Marchione, K. E., Fletcher, J. M., Lyon, G. R., & Gore, J. C. (2004). Development of left occipitotemporal systems for skilled reading in children after a phonologically- based intervention. *Biological Psychiatry*, *55*(9), 926–933. https://doi.org/10.1016/j.biopsych.2003.12.019

Shaywitz, B. A. & Waxman, S. G. (1987). Dyslexia. *New England Journal of Medicine*, *316*(20), 1268–1270. https://doi.org/10.1056/NEJM198705143162008

Shaywitz, S. E. (1996). Dyslexia. *Scientific American*, *275*(5), 98–104. https://doi.org/10.1038/scientificamerican1196-98

Shaywitz, S. E. (1998). Dyslexia. *New England Journal of Medicine*, *338*(5), 307–312. https://doi.org/10.1056/NEJM199801293380507

Shovman, M. M. & Ahissar, M. (2006). Isolating the impact of visual perception on dyslexics' reading ability. *Vision Research*, *46*(20), 3514–3525. https://doi.org/10.1016/j.visres.2006.05.011

Simos, P. G., Fletcher, J. M., Bergman, E., Breier, J. I., Foorman, B. R., Castillo, E. M., Davis, R. N., Fitzgerald, M., & Papanicolaou, A. C. (2002). Dyslexia-specific brain activation profile becomes normal following successful remedial training. *Neurology*, *58*(8), 1203–1213. https://doi.org/10.1212/wnl.58.8.1203

Snowling, M. J. (2001). From language to reading and dyslexia. *Dyslexia*, *7*(1), 37–46. https://doi.org/10.1002/dys.185

Solan, H. A. (1990). An appraisal of the irlen technique of correcting reading disorders using tinted overlays and tinted lenses. *Journal of Learning Disabilities*, *23*(10), 621–623, 626. https://doi.org/10.1177/002221949002301009

Stephen Daly Optometrist. (2024). https://www.stephendaly.com.au/services/behavioural-optometry/

Stephenson, J. & Wheldall, K. (2008). Miracles take a little longer: Science, commercialisation, cures and the dore program. *Australasian Journal of Special Education*, *32*(1), 67–82. https://doi.org/10.1017/S1030011200025768

Stephenson, J. & Wheldall, K. (2012). *MUSEC briefings: Behavioural optometry*. Macquarie University.

Suttle, C. M., Barbur, J., & Conway, M. L. (2017). Coloured overlays and precision-tinted lenses: Poor repeatability in a sample of adults and children diagnosed with visual stress. *Ophthalmic & Physiological Optics*, *37*(4), 542–548. https://doi.org/10.1111/opo.12389

Suttle, C. M., Lawrenson, J. G., & Conway, M. L. (2018). Efficacy of coloured overlays and lenses for treating reading difficulty: An overview of systematic reviews. *Clinical & Experimental Optometry*, *101*(4), 514–520. https://doi.org/10.1111/cxo.12676

Temple, E., Deutsch, G. K., Poldrack, R. A., Miller, S. L., Tallal, P., Merzenich, M. M., & Gabrieli, J. D. (2003). Neural deficits in children with dyslexia ameliorated by behavioral remediation: Evidence from functional MRI. *Proceedings of the National Academy of Sciences*, *100*(5), 2860–2865. https://doi.org/10.1073/pnas.0030098100

Thurston, A. (2014). The potential impact of undiagnosed vision impairment on reading development in the early years of school. *International Journal of Disability, Development and Education*, *61*(2), 152–164. https://doi.org/10.1080/1034912X.2014.905060

Vagge, A., Cavanna, M., Traverso, C. E., & Iester, M. (2015). Evaluation of ocular movements in patients with dyslexia. *Annals of Dyslexia*, *65*(1), 24–32. https://doi.org/10.1007/s11881-015-0098-7

Vellutino, F. R. (1987). Dyslexia. *Scientific American*, *256*(3), 34–41. https://doi.org/10.1038/scientificamerican0387-34

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry*, *45*(1), 2–40. https://www.ncbi.nlm.nih.gov/pubmed/14959801

Wahlberg-Ramsay, M., Nordstrom, M., Salkic, J., & Brautaset, R. (2012). Evaluation of aspects of binocular vision in children with dyslexia. *Strabismus*, *20*(4), 139–144. https://doi.org/10.3109/09273972.2012.735335

Webber, A., Wood, J., Gole, G., & Brown, B. (2011). DEM test, visagraph eye movement recordings, and reading ability in children. *Optometry and Vision Science*, *88*(2), 295–302. https://doi.org/10.1097/OPX.0b013e31820846c0

Wilkins, A., Huang, J., & Cao, Y. (2004). Visual stress theory and its application to reading and reading tests. *Journal of Research in Reading*, *27*(2), 152–162. https://doi.org/10.1111/j.1467-9817.2004.00223.x

Woerz, M. & Maples, W. C. (1997). Test-retest reliability of colored filter testing. *Journal of Learning Disabilities*, *30*(2), 214–221. https://doi.org/10.1177/002221949703000209

Yang, A., Rolls, E. T., Dong, G., Du, J., Li, Y., Feng, J. & Zhao, X. M. (2022). Longer screen time utilization is associated with the polygenic risk for attention-deficit/hyperactivity disorder with mediation by brain white matter microstructure. *E Bio Medicine*, *80*, 104039. https://doi.org/10.1016/j.ebiom.2022.104039