Identifying and supporting children with evidence of cerebral visual impairment as part of an in-school eyecare service in special schools

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I confirm that the word count of this thesis is less than 100,000 words

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Acknowledgments

“I can do all things through Christ who gives me strength.”

Philippians 4:13

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Summary

Background

Cerebral visual impairment (CVI) is the leading cause of childhood visual impairment in the developed world. It arises due to damage to, or underdevelopment of the brain. Children attending special schools are likely to have a high prevalence of CVI due to the aetiologies surrounding the condition.

Aim

The current project aimed to determine whether evidence of CVI could be elicited during a comprehensive in-school vision assessment for children in special schools.

Methods

Children (n=200) attending the largest special school in Northern Ireland received a comprehensive vision assessment on the school premises. Systematic review of the literature facilitated decision-making when selecting which assessments to employ to probe for evidence of CVI. These included, in addition to a full eye examination, parental questioning using the Visual Skills Inventory (VSI) and Strengths and Difficulties Questionnaire (SDQ), direct observation of visual behaviour, tests of visual perception and evaluation of crowding ratios. Following the assessment, parents and teachers were provided with jargon-free Vision Reports detailing the findings and highlighting action points to address vision needs. Evaluation of the in-school assessment and Vision Reports was conducted through feedback from parents and teachers.

Results

The key findings from the present study are summarised as follows;

- There is a lack of consensus in the reported literature regarding which assessments are used to investigate and diagnose childhood CVI.
- The VSI was useful at identifying evidence of CVI and facilitated provision of management strategies to parents and teachers to account for CVI-related difficulties; almost 40% of the study population exhibited evidence of CVI.
- Key features which differentiated between participants with and without evidence of CVI were; i) a medical history of deficits affecting neurological function/development, ii) impaired distance visual acuity and iii) parent-reported difficulties on the SDQ.
- Observation of visual behaviour, crowding ratios and tests of visual perception were not useful at distinguishing between participants with and without evidence of CVI.
- Parents and teachers value and utilise written Vision Reports of visual and CVI status, however they require additional support to implement suggested actions.

Conclusion

This study has shown that eliciting evidence of CVI during an in-school vision assessment is possible and warranted. It is crucial that in-school eyecare models incorporate investigation of CVI to ensure associated vision difficulties do not remain unrecognised which could ultimately hinder a child's personal and educational development.

Abbreviations

ADHD	Attention Deficit Hyperactivity Disorder
ANCOVA	Analysis of covariance
ASD	Autism Spectrum Disorder
BCVA	Best corrected visual acuity
COTAN	Committee of Test Affairs in Netherlands
CP	Cerebral Palsy
CR	Crowding ratio
CSBQ	Children's Social Behaviour Questionnaire
CT	Computed tomography
CVI	Cerebral visual impairment
CVIT 3-6	Child Visual Impairment Test for 3- to 6-year-olds
DS	Down Syndrome
DTVP	Developmental Test of Visual Perception
EEG	Electroencephalography
ERG	Electroretinography
GA	Gestational age
GDD	Global Developmental Delay
HIE	Hypoxic-ischaemic encephalopathy
IEP	Individual Education Plan
IQR	Interquartile range
KBIT	Kaufman Brief Intelligence Test
LGN	Lateral geniculate nucleus
MAR	Minimum angle of resolution
Mdn	Median
MLD	Moderate learning difficulties
MRI	Magnetic resonance imaging
OKN	Optokinetic nystagmus
PedsQL	Pediatric Quality of Life Inventory
PMLD	Profound and multiple learning difficulties
PVD	Perceptual visual dysfunction
QTVI	Qualified Teacher of the Visually Impaired
SD	Standard deviation
SDQ	Strengths and Difficulties Questionnaire
SEN	Special Educational Needs
SER	Spherical equivalent refractive error
SLD	Severe learning difficulties
sMRI	Structural magnetic resonance imaging
StEN	Statement of Educational Need
TD	Typically developing
TVPS-R	Test of Visual Perceptual Skills-Revised
UVR	Ulster Vision Resources
VEP	Visual Evoked Potential
VMI	Beery Visual-Motor Integration test
VSI	Visual Skills Inventory
WHO	World Health Organisation
WISC	Wechsler Intelligence Scale for Children
WPPSI	Wechsler Preschool and Primary Scale of Intelligence

Access to contents

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Chapter 1

Introduction, background and thesis rationale

1.0. Chapter overview

This chapter provides an overview of cerebral visual impairment in children including prevalence, aetiology, associated ocular conditions and management. The aims and rationale for this doctoral thesis are outlined at the end of this chapter.

1.1. What is Cerebral Visual Impairment?

Cerebral visual impairment (CVI) is an umbrella term used to describe atypical visual function which arises due to abnormal development of, or damage to the brain which affects the retro-chiasmic visual pathway and disrupts normal visual processing (Khetpal & Donahue, 2007; Philip & Dutton, 2014; Lueck et al., 2019). Damage affecting the visual pathway can disrupt how visual information is perceived and interpreted by an individual, which can lead to characteristic visual difficulties experienced by the affected individual, discussed later in this chapter. Children with CVI may have a normal or near normal eye examination, yet how they interpret and interact with the visual world results in a very different visual experience (Ravenscroft, 2017).

1.1.1. Defining Cerebral Visual Impairment

For many years there has been deliberation over the correct terminology with which to define CVI. Variations in terminology have been noted geographically (Sakki et al., 2018; Kran et al., 2019); ‘cortical visual impairment’ is more

commonly reported by North American populations, however, use of the word ‘cortical’ is considered less favourable among European populations, as visual dysfunctions arising due to CVI may not be strictly cortical in origin. As such, the term ‘cerebral visual impairment’ is in common usage in Europe as it implies a less localised deficit, encompassing visual impairments arising due to disruption anywhere along the posterior visual pathway (Frebel, 2006; Bennett et al., 2020). In recent years, Ravenscroft (2017) has advocated the need to have a unified, global definition of CVI and proposes that broadening the definition to encompass ‘cerebral visual disorders’ may be more appropriate. Ravenscroft argues that such an umbrella term could encompass the range of severities with which CVI presents. Another term which has emerged in scientific publications in recent years is ‘perceptual visual disorders/dysfunction’ (PVD) which, similar to ‘cerebral visual disorders’, encompasses the broad range of dysfunctions which may arise as a result of neurological insult or impairment (Mitry et al., 2016; Duke et al., 2019).

In an attempt to reconcile the difficulties associated with defining CVI and to initiate consistency in terminology used, Sakki et al. (2018) carried out a systematic review to identify and evaluate the terminologies in current use in the scientific literature to define childhood CVI. Sakki et al. conducted a thematic analysis of definitions used by articles identified through systematic literature searching to produce a definition of childhood CVI: *‘a verifiable visual dysfunction which cannot be attributed to disorders of the anterior visual pathway or any potentially co-occurring ocular impairment.’*

1.1.2. Prevalence of CVI

CVI is now, and has been for many years, recognised as the leading cause of childhood visual impairment in developed countries (Rogers, 1996; Rahi & Cable, 2003; Ravenscroft et al., 2008; Boonstra et al., 2012; Kong et al., 2012; Solebo et al., 2017). It is thought that this is likely due to an increase in survival rates among premature neonates and/or children born with complications at birth due to advances in medical care in developed countries (Good et al., 2001; Boonstra et al., 2012; Lueck et al., 2019). Despite the increase in prevalence, and promising signs of increased awareness of the condition among health care professionals and educators, CVI continues to be under-diagnosed.

1.1.3. The importance of receiving a diagnosis

Regardless of what definition is agreed upon, it is key that children who exhibit evidence of CVI receive a timely diagnosis and/or support to alleviate the impact of CVI on the child's daily living. At the heart of many parents' frustrations is that without a diagnosis, children may not be entitled to the extra support they require at home and in school, simply because they do not meet the criteria to qualify for additional support services either through third-sector organisations or government funding (Guide Dogs NI, 2017, personal communication; Kran et al., 2019). At present, to qualify for support from a Qualified Teacher of the Visually Impaired (QTVI), a child is required to have a 'registerable' visual impairment (i.e. sight impaired or severely sight impaired). The criteria for registration as visually impaired are largely dependent on a person's level of visual acuity and/or extent of peripheral visual

field (Department of Health, 2017; Kran et al., 2019). With regard to CVI, Lueck et al. (2019) suggests that children with CVI can be categorised into three subgroups; 1) those with profound visual impairment due to CVI, 2) those with CVI who have functionally useful vision and 3) those with CVI who have functionally useful vision and who work at or near the expected academic level for their age group (Lueck et al., 2019). Applying the criteria for registration as visually impaired, it is unlikely that children in subgroup 2 or 3 would qualify, and may, therefore, be denied access to vision support services, yet the difficulties they are likely to face in education are significant. As such, it is imperative that CVI is recognised as a tangible visual impairment to ensure that affected children are not disadvantaged due to their visual processing difficulties, regardless of which 'subgroup' they are classified into. Furthermore, providing parents with a diagnosis ignites the process of deepening a parents' understanding of their child's visual dysfunctions and ultimately empowers them to advocate for necessary support for their child (McDowell, 2020; Dutton & Bauer, 2019).

1.2. CVI aetiology and associated systemic conditions

CVI can arise from any condition which disrupts the normal function of the visual pathway. It often co-occurs with systemic conditions which cause damage to the brain or affect typical brain development. Many such conditions occur perinatally or in early infancy. Table 1.1 summaries the most common aetiologies of childhood CVI reported in the literature. Presented articles included a large sample size and explicitly report CVI aetiologies of their included cohort. Hypoxic-ischaemic encephalopathy (HIE) is reported as the

most common cause of childhood CVI (Philip & Dutton, 2014). HIE occurs as a result of loss of blood flow and oxygen deprivation resulting in necrosis of brain tissue. Other commonly reported causes of CVI include central nervous system infections (e.g. meningitis, encephalitis, cytomegalovirus, rubella), traumatic brain injury, metabolic disorders (e.g. neonatal hypoglycaemia, mitochondrial and lysosomal disorders), maternal substance abuse, and seizures or epilepsy (Soul & Matsuba, 2010; Philip & Dutton, 2014). CVI may occur in conjunction with any other neurological abnormality which disrupts the normal processing of visual information (e.g. brain tumours and cysts, hydrocephalus). Children born prematurely are also at a greater risk of CVI as they are often affected by periventricular cerebral white matter damage, particularly if born between 24 and 34 weeks gestation (Soul & Matsuba, 2010).

1.2.1. Associated systemic conditions and syndromes

Cerebral palsy (CP) often occurs following a hypoxic-ischaemic event in the brain (Jacobson & Dutton, 2000). As hypoxic ischaemia is the most common cause of CVI in children, it is unsurprising that the prevalence of CVI is high among children with CP, with literature reporting prevalence been 60 and 90% (Schenk-Rootlieb et al., 1994).

Children with CVI are also frequently reported as having intellectual/learning disabilities. In their sample of 121 children with CVI, Fazzi et al. (2007) reported that 74.4% had an intellectual disability ranging from mild to profound. Matsuba and Jan (2006) similarly report a high prevalence of intellectual

disability, with 87% of their study population (n=423 in total) of children with CVI reported as having moderate mental delay. Further, 96% of children with CVI included in a study by Bosch et al. (2014) were reported as having intellectual disability.

Features consistent with a diagnosis of autism spectrum disorder (ASD), such as poor eye contact, social difficulties or difficulty understanding the meaning of facial expressions, have been reported in children with CVI (Dutton, 2013). In a preliminary study, Fazzi et al. (2019) report that children with CVI exhibit greater autistic-like features compared with the general population and propose this is due to neurological damage which disrupts brain network organisation. Philip and Dutton (2014) argue that CVI may act as a contributor to autistic behavioural traits, or could be considered as a differential diagnosis, however the relationship between ASD and CVI warrants further investigation as at present there is a paucity of information available in the scientific literature investigating the association and/or overlap between the two conditions.

1.3. Ocular conditions associated with CVI in children

There is wide variation in the presentation and clinical visual profile of children with CVI which is dependent on the extent and location of damage to the brain. Co-existing ophthalmologic deficits affecting the anterior visual pathway are frequently observed. Such impaired functions include oculomotor deficits, significant refractive errors, reduced visual acuity, visual field defects and optic nerve and retinal disorders (Dutton, 2013). Table 1.2 summarises co-existing

ocular conditions commonly reported in the scientific literature. Presented articles included a large sample size and explicitly report ocular conditions that co-occur with CVI. Reduction in visual acuity is most often reported, however the number of children presenting with a visual acuity impairment varies greatly across studies ranging from 12 to 100%. Strabismus, nystagmus and optic nerve abnormalities are all frequently reported to co-exist in children with CVI (Table 1.2).

	Sample size (n)	Hypoxic-ischaemic encephalopathy	Structural abnormalities (e.g. cysts, tumours)	Seizures/epilepsy	Hydrocephalus	CNS infections	Prematurity	Traumatic brain injury	Metabolic disorders	Acquired hypoxia	Maternal substance abuse	Hypoglycaemia	Cerebral vascular incident (e.g. stroke)	Unknown	Other
Matsuba & Jan (2006)	423	36%	12%	1%	17%	12%	-	0.2%	10%	-	-	-	-	-	10%
Bosch et al. (2014)	309	11%	-	-	6%	6%	32%	2%	-	-	-	-	10%	40%	33%
Fazzi et al. (2019)	214	62%	5%	-	-	3%	46%	-	2%	-	1%	-	-	13%	14%
Huo et al. (1999)	170	23%	11%	4%	9%	12%	8%	4%	-	10%	2%	-	14%	9%	6%
Pehere et al. (2018)	124	40%	2%	32%	2%	2%	32%	-	4%	-	-	3%	3%	32%	3%
Fazzi et al. (2007)	121	67%	14%	2%	3%	3%	-	-	9%	-	-	-	-	-	3%
Cavascan et al. (2014)	115	8%	7%	16%	4%	-	24%	-	-	6%	-	-	-	-	16%
Khetpal & Donahue (2007)	98	36%	11%	61%	19%	15%	30%	4%	-	-	2%	1%	-	7%	12%

Table 1.1: Summary of Childhood CVI aetiologies identified from key studies investigating CVI in children. No data (–) indicates the study did not report any cases of the conditions listed. More than one aetiology may have been attributed to an individual child in the study populations.

	Sample size (n)	Strabismus (Esotropia / exotropia)	Ocular movement abnormalities	Nystagmus	Optic nerve abnormalities	Significant refractive error	Retinal disease	Reduced vision	Abnormal OKN response	Visual field deficit	Reduced contrast sensitivity
Matsuba & Jan (2006)	423	-	21%	17%	18%	-	5%	97%	-	-	-
Bosch et al. (2014)	309	77%	35%	42%	44%	25%	-	20%	-	60%	-
Huo et al. (1999)	170	37% (19/18%)	15%	11%	17%	8%	3%	100%	-	-	-
Pehere et al. (2018)	124	49% (18/31%)	-	7%	32%	50%	-	77%	-	11%	-
Fazzi et al. (2007)	121	73% (42/31%)	36%	19%	44%	79%	-	87%	73%	9%	60%
Khetpal & Donahue (2007)	98	60% (19/41%)	-	21%	42%	20%	4%	100%	-	-	-
Cioni et al. (1997)	48	56% (50/6%)	31%	-	-	-	-	21%	31%	23%	-
Lanzi et al. (1998)	38	63%	11%	29%	49%	17%	-	66%	-	-	-
Geldof et al. (2015)	25	24%	4%	4%	-	-	-	12%	-	12%	-

Table 1.2: Co-occurring ophthalmologic deficits reported in children with CVI identified from key studies investigating CVI in children. No data (–) indicates the study did not report any cases of the conditions listed. Study participants may have had more than one ophthalmologic deficit.

1.4. Visual difficulties experienced by children with CVI

1.4.1. Normal process of vision

Before we can understand the visual difficulties a child with CVI may experience, it is first important to understand the normal process of how we see and interpret the visual world around us. In brief, light passes through the anterior structures of the eye (cornea, pupil, lens) before reaching the retina on the posterior surface of the eye. The retina is comprised of millions of photoreceptor cells which receive stimulation from light entering the eye. From here, visual information is conducted along a complex cell structure network within the retina (for more information see Snowden et al., 2006), concluding with the retinal ganglion cells. Axons of the retinal ganglion cells then traverse down the optic nerve, before crossing the optic chiasm, forming the optic tract and terminating in the lateral geniculate nucleus (LGN) located in the thalamus of the brain. The LGN is a highly organised structure comprised of six layers which receive input from individual cell types located in the retinal ganglion cell layer of the retina (midget cells, parasol cells and bistratified cells). The LGN projects neurons via the optic radiations prior to terminating in the primary visual cortex (also known as Area V1) located in the occipital lobe of the brain. It is here that contrast, acuity, colour, movement and light are first processed (Dutton & Bauer, 2019).

1.4.2. Higher visual processing

From the primary visual cortex, visual information is translated to a vast number of extra-striate areas where higher processing of visual information occurs (Goodale, 2010). Examples of such areas include V4 and V8

responsible for colour perception, area V5 responsible for perception of motion and area V3, responsible for form perception (Snowden et al., 2006). In an attempt to categorise the complex process of higher visual processing functions, Goodale and Milner (1992) described two post-cortical higher visual pathways; the dorsal stream and the ventral stream. The dorsal stream, often referred to as the 'where' pathway, connects the occipital lobe to the posterior parietal and frontal lobe of the brain, and is responsible for visually guided movement (parietal lobe), perception of movement (parietal lobe), interpreting complex visual scenes (parietal lobe) and orienting the head and eyes to attend to an object of interest (frontal lobe) (Goodale & Milner, 1992; Dutton & Jacobson, 2002; Dutton, 2009). The ventral stream, often referred to as the 'what' pathway, connects the occipital lobe to the infero-temporal lobe and is responsible for object and person recognition, visual memory and orientation (Dutton, 2009; Dutton & Jacobson, 2002). The ventral stream relies on an 'image library' located in the temporal lobe so that when an object in space is viewed, reference is made to this 'image library' to determine whether the object is recognisable to the subject or not (Dutton, 2009). Figure 1.1 illustrates the higher visual functions involved in the interpretation and interaction with visual information categorised according to the post-cortical ventral and dorsal stream.

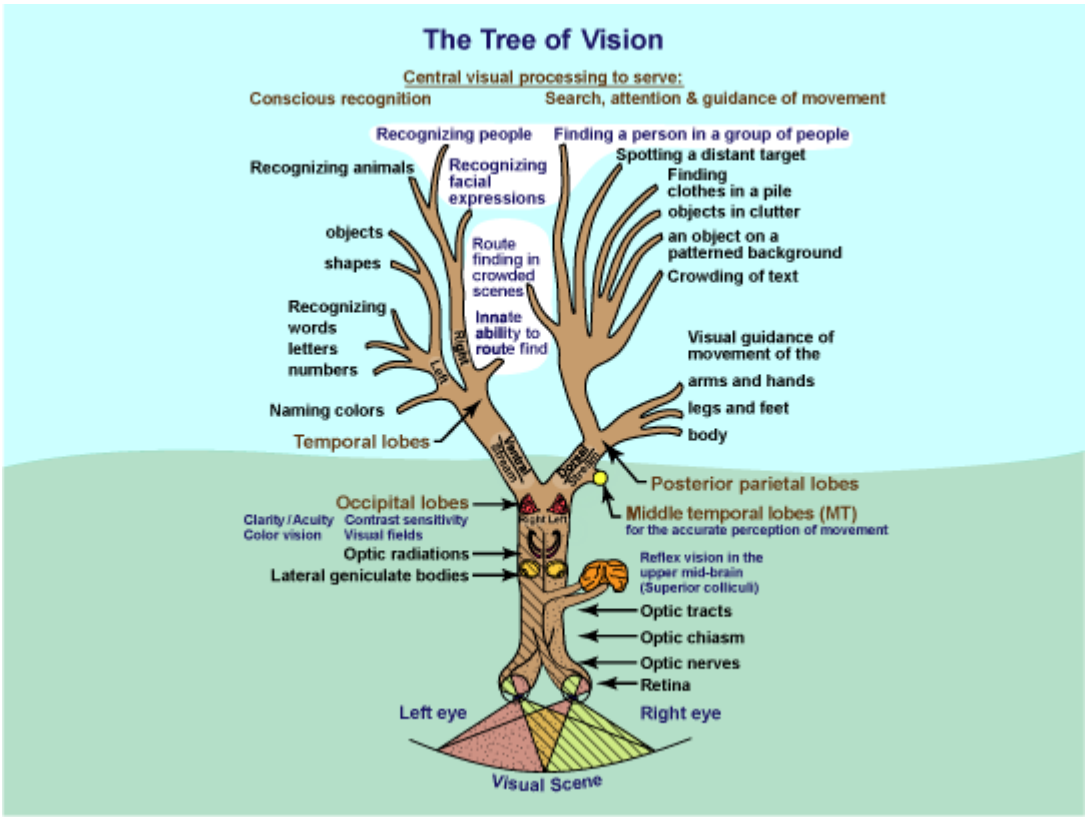


Figure 1.1: Tree of vision designed by Gordon N. Dutton to illustrate visual functions associated with the higher visual pathways. Originally printed in Lueck & Dutton (2015).

Other theories of higher-visual processing have emerged in recent years with Haak and Beckmann (2018) proposing a three-way structure which builds on the dual-pathway described by Goodale and Milner (1992). Haak and Beckmann (2018) describe an additional 'lateral pathway'. This lateral pathway extends from the occipital cortex to the temporal lobe and is reported to have similarities in function to the dorsal stream with the addition of language processing (Haak & Beckmann, 2018).

While the exact structure of the higher visual pathway remains open for debate, the dual-pathway hypothesis may be considered a suitable approach which adds clarity to the interpretation of difficulties faced by children with CVI.

Ultimately what is most important, regardless of which model of visual processing is considered, is that the child's difficulties are mapped to management strategies to alleviate the daily impact of their difficulties (as discussed further in Section 1.6).

1.4.3. Characteristic behaviours and difficulties experienced by children with CVI

Disruption of normal visual processing leads to characteristic behavioural difficulties seen in children with CVI, first described by Jan and colleagues (Jan et al., 1987). Such difficulties, which have since been described by Dutton et al. (2009; 2010a), can be summarised according to whether they indicate dorsal or ventral stream dysfunction (Table 1.3). The dorsal stream is more susceptible to damage than the ventral stream and as such impairments relating to dorsal stream dysfunction are reported more commonly than ventral stream dysfunctions (Dutton, 2009; Ortibus et al., 2011; Macintyre-Beon et al., 2012).

Difficulties associated with impaired dorsal stream function	
Difficulty	**Manifests as problems:**
Impaired visually guided movement	Interpreting differences in floor surface
	Reaching accurately for objects
	Avoiding obstacles on the floor/in a room e.g. door frames, coffee tables
	Navigating stairs, kerbs, escalators
	Walking on uneven floor surfaces
Impaired ability to interpret complex visual environments	Locating an object on a crowded shelf or cluttered room
	Locating objects on a patterned surface or in rooms with patterned wallpaper, bed spreads etc.
	Reading crowded text
	Identifying familiar people or objects in a group
	Seeing objects in the distance
	Navigating in crowded locations
	Locating an item of clothing in a drawer or pile of clothes
Impaired visual attention	Performing more than one visual task at once
	Walking and talking at the same time
Difficulties associated with impaired ventral stream function	
Difficulty	**Manifests as problems:**
Impaired recognition	Recognising family members in real life or from photographs
	Recognising familiar objects and shapes
	Understanding the meaning of facial expressions
Impaired orientation	Navigating familiar and unfamiliar places

Table 1.3: Characteristic difficulties experienced by children with impaired dorsal and ventral stream function as described by Dutton et al. (2009; 2010a).

Other characteristic difficulties have been described by Roman-Lantzy (2007a). Roman-Lantzy explains that these difficulties, outlined in Table 1.4, are typically observed in children with the most severe forms of CVI.

Characteristic behaviour	Description
Strong colour preference	Children with CVI present with a strong attraction to objects of a particular colour; red and yellow are most commonly reported.
Need for movement	Children with CVI are reported as being more visually attracted to moving rather than stationary objects.
Visual latency	Children with CVI may exhibit a delayed response when looking at an object which is presented into the child's field of vision.
Visual field preferences	Children with CVI may attend to objects presented in one area of the visual field and ignore other areas.
Difficulties with visual complexity	Children with CVI may have difficulty interpreting visual information in a complex sensory environment as their visual system becomes overwhelmed by too many visual stimuli.
Light-gazing and non-purposeful gaze	Light-gazing is described as when a child spends prolonged periods of time looking at light sources. Non-purposeful gaze is when a child appears to gaze blankly into space rather than fixating on an object of interest.
Difficulty with distance viewing	Children with CVI may appear to have difficulty viewing distant objects irrespective of their visual acuity or refractive error. The cause of this is thought to be due to the extra visual information to process between the child and object of interest.
Absent/atypical visual reflexes	Children with CVI may exhibit absence of visual blink reflex in response to an object presented close to the child's face.
Difficulty with visual novelty	Children with CVI prefer objects which are familiar to them and reject objects which are novel and unfamiliar.
Absence of visually-guided reach	When reaching for an object, children with CVI may first look at the object, then turn their gaze away from the object before grasping for it.

Table 1.4: Characteristic difficulties children with CVI may present with as described by Roman-Lantzy (2007a).

Various parental questionnaires have been developed to help identify the specific behaviours and difficulties outlined in this section with which children with CVI are likely to present. These questionnaires are discussed in greater detail in Chapter 2 and 3 of this thesis. One questionnaire which is commonly used is the Visual Skills Inventory (VSI) developed by Dutton and colleagues based on behaviours which were frequently observed or reported by parents of children with CVI (Dutton et al., 1996; Dutton et al., 2010b). Using the VSI, parents are asked to respond, using a Likert-scale, whether their child experiences the characteristic behaviours included in the inventory through structured history-taking. Responses can then be used to identify key-problematic areas for which management strategies can be provided to caregivers and educators in order to alleviate the impact of visual dysfunctions on the child's tasks of daily living (discussed in more detail in Section 1.6.).

1.5. Investigation and assessment of childhood CVI

Despite the increased prevalence and awareness of CVI, there remains much deliberation among professionals regarding which methods of assessment should be employed when forming a CVI diagnosis (Bennett et al., 2020). Systematic review of the literature has been conducted in Chapter 2 of this thesis in order to identify which methods of assessment are currently employed to investigate CVI in children, and to determine which assessments are applied when forming a diagnosis. In summary, it is apparent that, at present, there exists a lack of consensus regarding which assessments should be employed when investigating and diagnosing childhood CVI. Often diagnosis is achieved through consideration of multiple aspects of a child's

function and history, including medical history, results of vision assessment/ophthalmologic examination, structured history-taking using CVI questionnaires and results of neuroimaging. Input from a multidisciplinary team of medical and healthcare professionals is often employed during a CVI assessment.

1.6. Management and alleviation of difficulties associated with CVI

Often the characteristic behaviours with which children affected by CVI may present are misunderstood by parents and teachers or attributed to other diagnoses the child may have (Dutton, 2013). This diagnostic-overshadowing can cause frustration for parents and teachers as they fail to understand why a child is behaving in a certain manner. Furthermore, poor understanding of the child's behaviours can impede their personal and educational development. Recognition of a child's vision difficulties and provision of a CVI diagnosis can help explain the child's behaviours, and ultimately allow commencement of a habilitation plan. The impact of CVI on aspects of daily living and education can be alleviated by implementing simple and practical modifications and strategies in the child's home and educational environment. When forming a habilitation plan, it is important to acknowledge the heterogeneity of CVI and recognise that a 'one-size-fits-all' approach is inadequate. Rather, each child's visual needs should be addressed on an individual basis (Fazzi et al., 2007).

1.6.1. Management strategies to alleviate CVI-related difficulties

As discussed previously, identification of key-problematic areas can be elicited using structured history-taking questionnaires completed with the child's parent/carer. Responses can then be used to map the difficulties identified as most problematic to appropriate management strategies. Using over 20 years' clinical experience, Dutton and colleagues have devised simple strategies which can be easily adopted in the child's home or educational environment (McKillop & Dutton, 2008; Philip & Dutton, 2014). Table 1.5 describes examples of practical strategies which may be applied to alleviate the difficulties listed previously in Table 1.3. When providing management strategies, it is best to begin with a small number in the first instance. Once successfully implemented, more strategies can be incorporated into the child's daily living activities. This will ensure the parent, educator and child do not become overwhelmed with multiple changes at once.

Difficulties associated with impaired dorsal stream function		Examples of strategies to alleviate difficulties
Impaired visually guided movement	Interpreting differences in floor surface	- Ensure home is well illuminated - Wear white trainers which stand out from the floor surface
	Reaching accurately for objects	- Use tactile guidance with other hand - Provide verbal cues to guide child's movements
	Avoiding obstacles on the floor/in a room	- Provide verbal cues e.g. there is a table three steps in front of you - Highlight edges of coffee tables, door frames etc. with brightly coloured edges - Keep floor free from clutter
	Navigating stairs, kerbs, escalators	- Mark the edges of stairs with brightly coloured tape - Use a toy pram/scooter to help navigate kerbs
	Walking on uneven floor surfaces	- Use plain, unpatterned carpets to minimise distraction - Use a toy pram/scooter to provide tactile support when walking on uneven surfaces
Impaired ability to interpret complex visual environments and impaired visual attention	Locating an object on a crowded shelf or cluttered room	- Use storage boxes to segregate items - Remove clutter from environment - Store frequently accessed items in the same location
	Locating objects on a patterned surface or in room with patterned wallpaper, bed spreads etc.	- Use plain, unpatterned carpets, bed spreads and wallpaper to minimise distraction
	Reading crowded text	- Enlarge text with fewer words on a page - Use double-line spacing - Obscure surrounding text
	Identifying familiar people or objects in a group	- Wear easily-identifiable clothing - Use auditory or visual cues to make presence more obvious e.g. waving, speaking
	Seeing objects in the distance	- Encourage child to move closer to object - Minimise clutter/visual distractions between child and object of interest
	Navigating in crowded locations	- Train child to recall specific landmarks - Visit location during quieter times to invoke familiarity
	Locating an item of clothing in a drawer or pile of clothes	- Compartmentalise clothing using separate storage boxes

	Performing more than one visual task at once	- Complete one task at a time
	Walking and talking at the same time	- Limit conversation when walking
Difficulties associated with impaired ventral stream function		**Examples of strategies to alleviate difficulties**
Impaired recognition and orientation	Recognising family members in real life or from photographs	- Ask family and friends to introduce themselves to the child
	Recognising familiar objects and shapes	- Provide training in tactile recognition
	Understanding the meaning of facial expressions	- Use additional verbal information to explain mood - Train child in recognising facial expressions
	Navigating familiar and unfamiliar places	- Visit new locations during quiet, less busy times - Colour code doors at home - Create songs and poems for navigating familiar routes

Table 1.5: Examples of strategies to alleviate CVI-related difficulties associated with dorsal and ventral stream dysfunction derived from Dutton (2009) and McKillop and Dutton (2008).

Practical advice should not only be provided to alleviate the impact of characteristic CVI-related difficulties, but also to address more 'basic' visual dysfunctions the child may present with, such as reduced visual acuity. Resources are available to provide parents and teachers with advice on how they can alleviate the impact of these reduced functions (e.g. Optometry and Vision Science Research Group, 2020). Studies have shown that early intervention and implementation of alleviation strategies improves visual, social and educational outcomes (Merrill & Kewman, 1986; Sonksen et al., 1991; Huo et al., 1999; Roman-Lantzy, 2007b). Huo et al. (1999) reviewed clinical records of 170 children with CVI over a fifteen-year period, of these 96 returned for follow-up evaluation. Huo et al. report that children whose CVI was diagnosed before the age of three years exhibited greater levels of

improvement in visual function compared to children diagnosed after three years of age. Similarly, Sonksen et al. (1991) applied a developmentally based programme to promote the visual development of infants with severe visual impairment and showed a greater improvement in visual outcome when interventions were implemented at a younger age. These studies highlight the importance of ensuring children receive a timely diagnosis of CVI to allow prompt initiation of a habilitation plan and to encourage a better visual prognosis.

While these studies have shown improved visual outcomes in children, as yet there have been no studies which have evaluated the effectiveness of CVI management strategies on improving quality of life. In an attempt to provide this much needed evidence, Duke et al. (2019) are conducting a randomised control trial to determine whether implementation of specific strategies to address difficulties identified on the Visual Skills Inventory (also commonly referred to as the INSIGHT questionnaire) improve quality of life in children with cerebral palsy in a low-mid income country. This trial is currently underway, and results are eagerly anticipated as they may provide a means to advocate for vision support services for children with CVI.

1.6.2. Management of CVI in educational settings

As a means to determine whether CVI management strategies have a positive effect on alleviating a child's difficulties, Roman-Lantzy (2007c) developed a 'CVI Resolution Chart' which allows parents and/or teachers to document the progress a child is making in terms of their CVI-related visual dysfunctions.

Roman-Lantzy advocates that this resolution chart can be used when developing specific goals on a child's Individual Education Plan (IEP; Roman-Lantzy, 2007c). This is a document which specifically details the short-term learning objectives for children with special educational needs (SEN). Incorporation of specific advice, including adjustments to the child's environment and schoolwork, into an IEP is also supported by Lehman (2013). Lehman advocates for good communication of vision difficulties between stakeholders involved in a child's care to ensure they receive optimal support. However, Little and Saunders (2015) have shown that visual impairments, including CVI, are inadequately reported on a child's statutory educational documentation, indicating that teachers are unlikely to receive sufficient information to understand and ameliorate a child's visual dysfunctions in the classroom.

This raises the question of how to ensure visual difficulties are effectively communicated not only to parents, but also to teachers in order to ensure each child receives the necessary adaptations to permit maximal access to the curriculum. At the time of diagnosis, parents may be left without further advice on how to alleviate CVI-related difficulties in their child's daily routine. A survey conducted by Jackel et al. (2010) asked parents of children with CVI what support they received following the child's diagnosis. Ninety-five percent of parents (n=76) reported that they received very little to no information or practical support. Of those who reported receiving information, this was limited to signposting to published literature rather than active vision support and habilitation services (Jackel et al., 2010). McDowell (2020) reports similar findings; parents were surveyed on their experience surrounding their child's

CVI diagnosis. A third of parents who responded to the survey reported that they received no information on their child's diagnosis. Even where information was provided, many parents reported that the information was difficult to understand or was not relevant to the needs of their child (McDowell, 2020). If parents themselves are unsure of a management plan, they will be unable to communicate their child's difficulties to teachers, which ultimately hinders the child's access to learning (McLinden et al., 2016). It is therefore of great importance that improved and accessible methods of reporting of visual status and CVI-related difficulties are explored and implemented.

1.7. Thesis rationale and research questions

At present there is a lack of clarity regarding how CVI is identified, described and managed among parents, teachers and healthcare professionals, despite numerous epidemiological studies reporting CVI as the most common cause of visual impairment in developed countries (Rahi & Cable, 2003; Boonstra et al., 2012; Kong et al., 2012; Solebo et al., 2017). If left undiagnosed, children will be disadvantaged in terms of their personal and educational development. As discussed previously, studies have shown that CVI often co-exists with learning disabilities in children (Fazzi et al., 2007; Matsuba & Jan, 2006; Bosch et al., 2014). If left unrecognised and unmanaged, CVI is likely to further disadvantage children with learning disabilities who are likely to attend special schools.

The current thesis formed part of a larger project (the Special Education Eyecare (SEE) project) which applied a framework for the provision of

comprehensive eyecare in special schools to a population of children attending the largest special school in Northern Ireland. This Eyecare in Special Schools Framework, endorsed by eyecare professional bodies and charities in the United Kingdom, recognises that children in special schools present with a higher prevalence of vision problems which render traditional mainstream visual screening (assessment of monocular visual acuity using crowded logMAR charts) inadequate and inappropriate for this population (The Royal College of Ophthalmologists, 2016). The Framework also acknowledges that children with SEN may experience challenges in accessing traditional routes of vision care (e.g. community optometrists or hospital eye services), such as cooperation in an unfamiliar setting. As such, the Framework recommends that;

1) children in special schools receive a comprehensive visual assessment on the school premises,
2) spectacles are dispensed and fitted in-school where required,
3) parents, teachers and healthcare professionals involved in the child's care are provided with a jargon-free, written report detailing the results of the vision assessment, including practical advice to ameliorate the impact of a visual deficit in the child's home or educational environment.

The SEE project, of which this thesis formed part of, aimed to determine whether application of this sector-agreed Framework was effective at reducing unmet visual need among children and increasing classroom engagement and behaviour in special schools in Northern Ireland. As part of this provision of a comprehensive vision assessment, the author aimed to determine whether identification of CVI-related difficulties was possible within a special school

eyecare service. Where identified, practical advice and management strategies could then be provided to parents and teachers verbally and through written report in an attempt to increase awareness of, and alleviate the impact of CVI-related difficulties both in the child's home and educational environment.

In order to achieve this, the current thesis aimed to answer the following questions;

1) ***What methods of assessment are currently used in the investigation and diagnosis of CVI in children?***

   Prior to determining whether investigation of CVI is possible within a special school setting, it is first important to determine what methods of assessment are currently reported in the literature when assessing and diagnosing CVI in children. Systematic review of the literature was undertaken to address this question (Chapter 2). From this, it could then be determined which assessments may be most suitable to apply in an in-school setting.

2) ***Can assessment tools applied as part of a comprehensive vision assessment in a special school setting identify children with evidence of CVI?***

   Following selection of which assessments may be applicable to an in-school population with SEN, the author sought to determine whether application of the chosen assessments was feasible for children with SEN of varying severity, and whether the assessments were useful in identifying children who exhibited evidence of CVI (Chapter 3 to 7).

3) ***Do parents and teachers of children in special schools value comprehensive in-school eyecare and provision of written reports of visual and CVI status?***

To test the Eyecare in Special Schools Framework, written reports of visual and CVI status were provided to parents and teachers following the in-school vision assessment. Evaluation of whether these were understood, utilised and appreciated by parents and teachers was conducted to determine whether there was value in incorporating the provision of written reports into eyecare services for children in special schools (Chapter 8).

Chapter 2

What assessments are currently used to investigate and diagnose cerebral visual impairment (CVI) in children? A systematic review.

2.0. Chapter overview

This chapter presents results of systematic review of the scientific literature to determine which methods of assessment are currently used to investigate and diagnose CVI in children. A version of this review is prepared for submission to Ophthalmic and Physiologic Optics.

2.1. Introduction

The growing recognition of the existence and relevance of CVI has led to debate about how CVI is defined (Sakki et al., 2018), diagnostic criteria and who can and should diagnose CVI (Good et al., 2001). Uncertainties around diagnosis delay or prevent a child receiving the support they require at home and at school. As discussed previously in Chapter 1, whilst there is no ‘cure’, the impact of CVI on daily living activities can be alleviated by the adoption of practical strategies and modification of the child’s environment, targeting specific difficulties with which the child presents (Philip & Dutton, 2014; Dutton et al., 2012). Additionally, providing a diagnosis offers parents and carers an explanation for the child’s visual strengths, limitations and behaviours (Dutton, 2013).

One of the challenges in assessing and diagnosing CVI is that young children, and those with the learning and/or physical disabilities that commonly coexist with CVI, are often unable to undertake the plethora of tests that aid identification of CVI. Responding to this challenge, researchers across the globe have developed a range of accessible assessments to evidence and diagnose CVI in children. These include quantitative and qualitative assessments using behavioural, clinical and visual metrics. Diagnosis of CVI generally requires a range of assessments, applied by a multi-disciplinary team of professionals and collated to create a comprehensive picture of the child's difficulties, form a diagnosis and devise a habilitation plan (Lueck & Dutton, 2015). In order to determine which assessments may be useful components to form diagnostic guidelines, it is first valuable to appreciate which tools are currently utilised in the assessment and diagnosis of CVI.

The aim of this systematic review is to **identify and evaluate the assessments which are currently used to investigate and diagnose CVI in children,** as determined through examination of the peer-reviewed scientific literature. A secondary aim is to determine which professionals are most often involved in assessment and diagnosis of CVI.

2.2. Methods

2.2.1. Protocol and registration

The methods used in this review were designed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher et al., 2010). The review protocol was registered with the International Prospective

Register for Systematic Reviews online in November 2016 (registration number CRD42016051262).

2.2.2. Eligibility criteria

This review focused on methods and tools used to assess and diagnose CVI in children. Articles were included if they (i) were original research papers, conference abstracts or research protocols published in peer-reviewed scientific journals, or relevant textbooks, (ii) included a clinical investigation of CVI in children (0-18 years), (iii) provided an explanation or criteria to diagnose CVI, (iv) were specifically investigating cerebral/cortical visual impairment or perceptual visual dysfunction rather than visual perception or dorsal/ventral stream function. No restrictions were placed on date of publication, sample size, gender, race or study locations. Review articles and individual case studies were excluded but citation lists of these articles were searched for additional papers which met the inclusion criteria.

2.2.3. Search Strategy

Literature searches were carried out using the following databases: Medline, Embase, CINAHL, Scopus and the Cochrane library in January 2020 by one author (ELM) after development of a search strategy by all authors. An example of the search terms used in Medline is included in Appendix 1. Results from database searches were stored in RefWorks where duplicates were removed. Searches were limited to English language.

2.2.4. Study selection

Titles and abstracts were independently screened for suitability by two researchers (ELM and JAL). Disagreements between researchers were resolved through discussion and reference to study eligibility criteria. Full texts of articles which met the inclusion criteria following title and abstract screening were obtained and reviewed by ELM for eligibility. Ten percent of articles included/excluded by ELM were screened by second reviewer JAL to evaluate repeatability of decisions. Where a full text was unavailable, or there was insufficient detail included in a conference abstract, attempt was made to contact the author of the publication. Manual screening of textbooks and grey literature was also carried out to identify relevant literature and determine eligibility.

2.2.5. Data extraction

Data were extracted from articles which met inclusion criteria following full-text review. A data extraction tool was designed to gather study characteristics, participant details, information on the type of tests and methods used during the CVI assessment, CVI diagnostic criteria, professionals involved in the assessment process and study findings.

2.2.6. Data analysis

Initial analysis determined, for each article, which assessment tools were used to assess children with diagnosed or suspected CVI. Further analysis recorded, where available, the specific diagnostic criteria or description used

by the researchers to form a CVI diagnosis. The professionals and disciplines involved in assessment and diagnostic process were recorded.

2.2.7. Quality assessment

As this review aimed to identify and evaluate the tools used to investigate and diagnose CVI in children, the quality of articles was graded according to the detail provided on how a CVI diagnosis was achieved. Articulation of the professionals involved in the assessment was also considered, to address the secondary aim of the review. A quality assessment tool was developed for this purpose. Currently available tools were considered and deemed inappropriate for the present review as they are designed for use with randomised and non-randomised studies (Downs & Black, 1998; Wells et al., 2018). The assessment tool used a simple three-point grading system, similar to that used by a previous review (Sakki et al., 2018), and graded the quality of information as ‘Good’ (Grade A), ‘Moderate’ (Grade B) and ‘Poor’ (Grade C). To achieve a grade of ‘Good’, articles were required to include an explicit diagnostic criterion, for example “CVI was diagnosed…”, a description of the professionals involved in the assessment and a clear description of the tests used to assess CVI. ‘Moderate’ grades were attributed when there was a description of how the diagnosis was made, but no information on which professional(s) undertook the assessment, or if a description of how a diagnosis was made and the professionals involved were included, but the description of tests and assessments used was brief/ambiguous. An article was graded ‘Poor’ if CVI diagnosis was mentioned, but the method for reaching a diagnosis was unclear or unavailable, or little detail was provided

on the assessments used to form the diagnosis. An article graded ‘Poor’ also failed to document the professionals involved in the assessment.

2.2.8. Scoring of assessments

In addition to assigning a quality grade to each article as described above, an additional numerical score was attributed to each article based on which tests were used by the authors in their assessment. The purpose of this score was to quantify the overall scope and depth of the CVI assessment. Scores were attributed based on information available in the literature evidencing the validity of tests and assessments used. A score of 0, 1 or 2 for each assessment was possible, with a higher score equating to a more robust/well-established assessment method. The rationale for assigning scores is discussed at the end of each assessment category. For all, a score of ‘0’ was assigned if an assessment was not undertaken. A total score of 20 was possible.

2.3. Results

Figure 2.1 shows the PRISMA diagram of the article screening and review process. Cohen’s kappa was carried out to determine the level of agreement between articles double-screened for eligibility which indicated good agreement between reviewers ($k=0.80$, $p=0.005$; Altman, 1991). Forty-five articles and one textbook were identified which met the inclusion criteria outlined above. Attempt was made to contact authors of three articles for additional information. One author did not respond, contact details could not be obtained for one and data were unavailable for one article. Using the quality

assessment described above, 12 articles were graded ‘Good’, 14 ‘Moderate’ and 20 were graded ‘Poor’.

This review is structured such that assessments used to examine children with, or suspected of having, CVI are discussed first, followed by a description of the tests specifically reported as being used to diagnose CVI, and finally discussion on which professionals were involved in the assessment process.

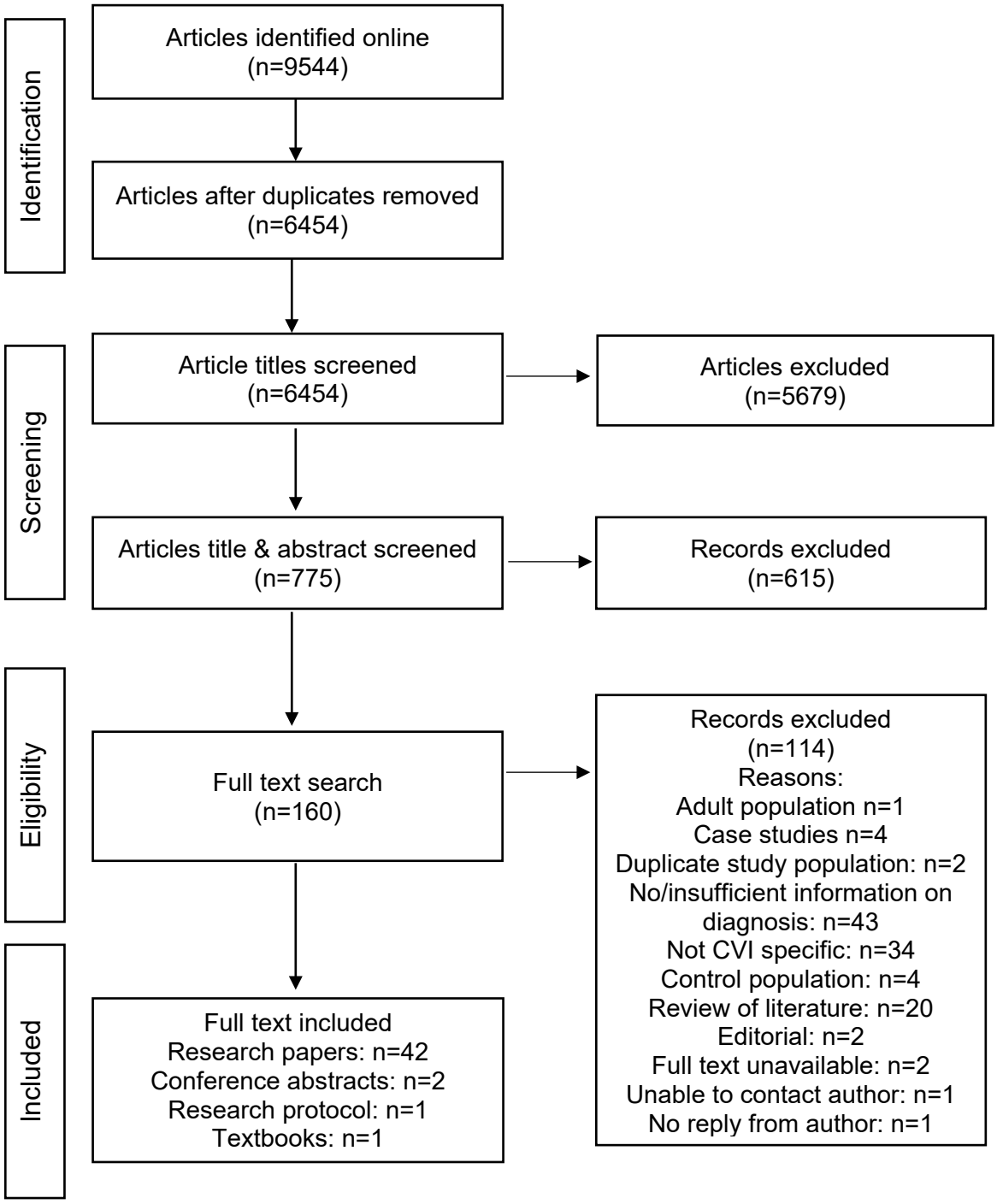


Figure 2.1. PRISMA diagram of selection process for articles included in review.

2.3.1. Tests used in assessment of participants

All articles were reviewed and methods of assessment recorded and scrutinised. These were grouped into ten 'categories of assessment'; (1) Medical history, (2) Vision assessment/ophthalmologic examination, (3) Neuroimaging, (4) Visual behaviour and direct observation, (5) Structured history-taking, (6) Visual perception tests, (7) Ocular movement and posture assessment, (8) Intelligence/IQ assessment, (9) Electrophysiology, and (10) Neurodevelopmental test(s). Table 2.1 summarises and quantifies the number of categories of assessment reported in the included studies.

1. Medical History

CVI is associated with conditions which may cause damage to, or abnormal development of the brain. Such conditions include cerebral haemorrhage, hydrocephalus, neonatal hypoglycaemia, central nervous system infections, traumatic brain injury, metabolic disorders, cerebral palsy, and hypoxic-ischaemic encephalopathy. The latter is the most common cause of CVI (Philip & Dutton, 2014; Khetpal & Donahue, 2007; Fazzi et al., 2007; Good, 2001; Boot et al., 2010). Consideration of the child's medical history and diagnoses in the assessment and diagnostic process adds value in helping to identify children who are most 'at-risk' of CVI (Roman-Lantzy, 2007d).

In the present review, details of the child's medical history or diagnoses were documented in 43 articles (93.5%; Table 2.1). Studies which clearly documented the children's medical history and diagnoses with sufficient detail were assigned a score of 2. Articles which reported more general information on the study sample's medical history (for example, the study was carried out

in a population of children with cerebral palsy but no further information on the study sample was provided), or reported that medical history was accessed through medical notes but did not provide further detail on this scored 1. Articles which did report on the children's medical history scored 0 (Table 2.2).

2. Vision assessment/ophthalmologic examination

Assessment of visual function is vital when examining children with suspected CVI. Visual deficits must be identified and managed to rule out ocular causes of visual impairment which may account for the child's visual difficulties, such as refractive or accommodative deficits. Vision assessment, including visual acuity measurement as a minimum, was reported in 43 articles (93.5%; Table 2.1). Of three articles who did not include information on vision assessments, one was a conference abstract, and although it is likely that vision tests were carried out as part of the study this information was not reported in the published abstract (Franki et al., 2017). Another was a textbook which detailed an approach to CVI assessment which included having a 'normal or near normal eye examination that cannot explain the child's impaired vision', however a description of the tests used to determine the normality (or otherwise) identified by the eye examination were not documented (Roman-Lantzy, 2007a). The remaining article was a short report discussing validation of the visual skills inventory questionnaire (Macintyre-Beon et al., 2012). All remaining articles reported a visual acuity measurement, 20 (43.5%) reported measuring the participants' refractive status (Huo et al., 1999; van Genderen et al., 2012; Eken et al., 1996; Chen et al., 1992; Khetpal & Donahue, 2007; Hård et al., 2004; Ferziger et al., 2011; Lanzi et al., 1998; Fazzi et al., 2007;

Salati et al., 2003; Andersson et al., 2006; Houliston et al., 1999; Macintyre-Beon et al., 2013; Geldof et al., 2015; Mitry et al., 2016; Pehere et al., 2018; Jasper & Philip, 2018; Duke et al., 2019; Handa et al., 2018; Bosch et al., 2014) and 26 articles (56.5%) documented that a visual field assessment was conducted (Matsuba & Jan, 2006; Huo et al., 1999; van Genderen et al., 2012; Cioni et al., 1997; Hård et al., 2004; Ferziger et al., 2011; Whiting et al., 1985; Ortibus et al., 2009; Fazzi et al., 2007; Weinstein et al., 2012; Philip, 2017; Ortibus et al., 2011; Andersson et al., 2006; Cioni et al., 1996; Houliston et al., 1999; Macintyre-Beon et al., 2013; Salavati et al., 2017; Dutton et al., 1996; Salavati et al., 2015; Geldof et al., 2015; Kooiker et al., 2015; Pehere et al., 2018; Jasper & Philip, 2018; Duke et al., 2019; Bosch et al., 2014; Vancleef et al., 2020a). Twenty-six (56.5%) reported assessment of ocular health (Matsuba & Jan, 2006; Huo et al., 1999; van Genderen et al., 2012; Eken et al., 1996; Chen et al., 1992; Khetpal & Donahue, 2007; Hård et al., 2004; Ferziger et al., 2011; Salati et al., 2001; Whiting et al., 1985; Lanzi et al., 1998; Fazzi et al., 2007; Salati et al., 2003; Weinstein et al., 2012; Andersson et al., 2006; Cioni et al., 1996; Brodsky et al., 2002; Houliston et al., 1999; Skoczenski & Good, 2004; Philip et al., 2016; Pehere et al., 2018; Duke et al., 2019; Jasper & Philip, 2018; Handa et al., 2018; Good, 2001; Bosch et al., 2014). Five (10.9%) studies documented assessment of contrast sensitivity (Fazzi et al., 2007; Macintyre-Beon et al., 2013; Geldof et al., 2015; Suner et al., 2016; Duke et al., 2019), seven (15.2%) reported measuring stereopsis (Fazzi et al., 2007; Weinstein et al., 2012; Philip, 2017; Andersson et al., 2006; Macintyre-Beon et al., 2013; Geldof et al., 2015; Duke et al., 2019) and four (8.7%) articles reported measuring focussing (accommodative) accuracy (Ferziger et al., 2011; Philip, 2017; Pehere et al., 2018; Duke et al., 2019).

For vision assessment/ophthalmological examination, a score of 2 was assigned if an article reported assessment of refractive error, ocular health and visual acuity using a validated and/or well-established test. A score of 1 was assigned if an article reported assessment of at least one aspect of visual assessment, i.e. refractive error, ocular health or visual acuity (using any method to assess visual acuity). Remaining articles who did not report any form of vision assessment were scored 0 (Table 2.2).

3. Neuroimaging

Neuroimaging is a central tool used in the detection and diagnosis of pathology in the brain (Thukral, 2015). Three techniques are commonly used to image the infant brain; ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI). Thukral (2015) reviewed the problems and preferences in paediatric brain imaging and reported that ultrasound is the preferred technique for screening, MRI is best used for investigating brain tissue and anatomy, and that CT is reserved for trauma evaluation. Blankenberg et al. (2000) further support the use of MRI or CT rather than ultrasound to aid the diagnosis of paediatric neurological problems.

Neuroimaging was reported in 29 (63.0%; Table 2.1) articles. The most commonly reported imaging technique was MRI (n=22; van Genderen et al., 2012; Eken et al., 1996; Chen et al., 1992; Khetpal & Donahue, 2007; Cioni et al., 1997; Hård et al., 2004; Ferziger et al., 2011; Salati et al., 2001; Lanzi et al., 1998; Ortibus et al., 2009; Fazzi et al., 2007; Salati et al., 2003; Weinstein et al., 2012; Ortibus et al., 2011; Franki et al., 2017; Cioni et al., 1996; Weiss

et al., 2001; Brodsky et al., 2002; Vancleef et al., 2020a; Ben Itzhak et al., 2019; Jasper & Philip, 2018; Bosch et al., 2014).

Ten studies reported use of CT scans (Eken et al., 1996; Chen et al., 1992; Khetpal & Donahue; 2007; Hård et al., 2004; Whiting et al., 1985; Fazzi et al., 2007; Andersson et al., 2006; Cioni et al., 1996; Weiss et al., 2001; Brodsky et al., 2002), and five reported use of ultrasound (Eken et al., 1996; Cioni et al., 1997; Hård et al., 2004; Weinstein et al., 2012; Cioni et al., 1996). Ten studies reported use of more than one neuroimaging modality (Eken et al., 1996; Chen et al., 1992; Khetpal & Donahue, 2007; Cioni et al., 1997; Hård et al., 2004; Fazzi et al., 2007; Weinstein et al., 2012; Cioni et al., 1996; Weiss et al., 2001; Brodsky et al., 2002).

For the majority of articles (n=23, 79.3%), neuroimaging results were obtained retrospectively from the child's medical records. Four of the remaining six articles reported use of MRI at the time of assessment (Ortibus et al., 2009; Fazzi et al., 2007; Salati et al., 2003; Salati et al., 2001); one reported use of a mixture of all three neuroimaging modalities (Eken et al., 1996) and one did not specify the type of neuroimaging technique employed (Duke et al., 2019). This resulted in a considerable amount of missing neuroimaging data and a lack of consistency in the type of neuroimaging assessment undertaken i.e. some participants may have had a CT scan, while others had a MRI scan. Five studies did not report which neuroimaging technique had been used, but simply stated that neurological assessments were performed or results were available from medical notes (Huo et al., 1999; Good et al., 2012; Philip, 2017; Kooiker et al., 2014; Duke et al., 2019).

For neuroimaging, a score of 2 was assigned if neuroimaging was carried out contemporaneously at the time of assessment and a score of 1 was assigned if results were obtained retrospectively from medical records. Studies which did not report use of neuroimaging were scored 0 (Table 2.2).

4. Visual behaviour and direct observations

An assessment of visual behaviour through direct observation can provide valuable information regarding how a child perceives and interprets the visual world around them (Dutton & Bauer, 2019). Such observations can help identify a child's key challenges and allow targeted interventions to be introduced in order to assist the child's daily living (Steendam, 2015).

Nineteen articles (41.3%) reported observation of the child's visual behaviour as part of the CVI assessment (Table 2.1). Included in the evaluation of visual behaviour was observation of blink reflex (n=1; Eken et al., 1996), visual threat response (n=2; Eken et al., 1996; Cioni et al., 1997), interaction with objects (n=1; Salati et al., 2001), visual environmental exploration (n=3; Salati et al., 2001; Salati et al., 2003; Duke et al., 2019), photophobia (n=1; Khetpal & Donahue, 2007), visual fixation (n=2; Duke et al., 2019; Bosch et al., 2014), visual attention (n=4; Ortibus et al., 2011; Macintyre-Beon et al., 2013; Geldof et al., 2015; Duke et al., 2019) and light perception (n=2; Ferziger et al., 2011; Salati et al., 2001). Three articles reported observation of the child's spontaneous visual behaviour (Fazzi et al., 2007; Philip, 2017; Cioni et al., 1996), while another reported ophthalmological observation of the child (Philip et al., 2016). One article reported clinical observation in accordance with Huo's

criteria (Huo et al., 1999; Good, 2001), and two articles reported children underwent ‘clinical observation’ but did not detail what this entailed (Jasper & Philip, 2018; Salavati et al., 2015). Roman-Lantzy advocates for observing a child’s visual behaviour in a range of settings, in addition to presenting the child with different visual stimuli during the clinical assessment in order to assess how the child responds or interacts with these stimuli (Roman-Lantzy, 2007e).

If an article reported specific detail on which behaviours were observed, and observed a minimum of two behaviours, a score of 2 was assigned. Where an article stated observations of visual behaviour were carried out, but provided no information on which behaviours were observed, or reported on one behaviour only, a score of 1 was assigned. Studies which did not report any assessment of visual behaviour scored 0 (Table 2.2).

5. Structured history-taking

Opinions of parents and carers involved in a child’s care on a daily basis allows unique insight into the child’s habitual visual and behavioural strengths and limitations (Roman-Lantzy, 2007f; McDowell, 2020). By contrast, clinicians are only able to observe the child for a short time in an unfamiliar environment. While the in-clinic assessment provides valuable information, it is unlikely to reveal the true extent of the child’s difficulties. As such, parental interview and questioning affords valuable, additional insight into the child’s visual function.

Seventeen articles (37.0%) reported the use of structured history-taking to explore the child's visual behaviours as a way of assessing functional vision (Table 2.1). History-taking was primarily conducted using a clinician-administered questionnaire directed at the parent or carer at the time of assessment. This method allows clarification and further exploration of any reported vision difficulties.

Thirteen articles reported use of a version of the Visual Skills Inventory (VSI) which was developed based on difficulties observed and reported by Dutton and colleagues in 1996 (Dutton et al., 1996; van Genderen et al., 2012; Hård et al., 2004; Philip, 2017; Andersson et al., 2006; Houliston et al., 1999; Philip et al., 2016; Macintyre-Beon et al., 2013; Geldof et al., 2015; Mitry et al., 2016; Macintyre-Beon et al., 2012; Jasper & Philip, 2018; Duke et al., 2019). The first iteration of this questionnaire contained 22 questions (Houliston et al., 1999). Various adaptations have been made to the VSI following its initial development. Macintyre-Beon et al. (2013) used the questionnaire to explore CVI behaviours in a population of prematurely-born children, using an extended 48-question version of the original questionnaire. A further two articles reported use of a 52-item version, referred to as the INSIGHT questionnaire (Mitry et al., 2016; Duke et al., 2019).

Roman-Lantzy advocates for parent/carer input into the assessment and diagnosis of CVI, and suggests using parent, carer or educator interview to elicit evidence of characteristic behaviours associated with CVI. In her book, she uses a 25-item questionnaire which parents complete during a face-to-face interview with the clinician (Roman-Lantzy, 2007f).

Two studies included in the present review reported use of the Flemish CVI questionnaire developed by Ortibus and colleagues (Ortibus et al., 2011; Ben Itzhak et al., 2019). This questionnaire was designed as a screening tool to seek evidence of behaviours associated with CVI and contains 46 items (Ortibus et al., 2011). Furthermore, Ferziger et al. (2011) developed a 26-item functional vision questionnaire for completion by the child's primary education designed to assess children's daily visual performance.

Other questionnaires used in the present review to explore the child's behaviour include the Strengths and Difficulties Questionnaire (SDQ; Geldof et al., 2015; Duke et al., 2019), Children's Social Behaviour Questionnaire (CSBQ; Geldof et al., 2015) and the Pediatric Quality of Life Inventory (PedsQL; Mitry et al., 2016; Duke et al., 2019).

Articles which reported use of well-established or validated questionnaires which were CVI- or vison-specific were assigned a score of 2. Questionnaires which were not validated or were not CVI/vision-specific scored 1. Studies which did not report any structured history-taking were scored 0 (Table 2.2).

6. Visual Perception tests

Children with CVI often present with visual perceptual difficulties. A wide range of tests are available to examine aspects of visual perception, e.g. tests of visual memory and attention (Ortibus et al., 2011; Mitry et al., 2016; Fazzi et al., 2009; Williams et al., 2015; Kovacs et al., 2000). Use of tests to measure various aspects of visual perception was reported in 12 articles (26.1%) in the

present review (Table 2.1). The L94 visual perception battery (Ortibus et al., 2009) was the most frequently reported (n=4; Ortibus et al., 2009; Ortibus et al., 2011; Franki et al., 2017; Vancleef et al., 2020a). Use of the Test of Visual Perceptual Skills-Revised (TVPS-R) was reported in two articles (Hård et al., 2004; Ortibus et al., 2011), as was the Developmental Test of Visual Perception (DTVP; Fazzi et al., 2007; Macintyre-Beon et al., 2013). The Stirling Face Processing test (Macintyre-Beon et al., 2013), LEA 3D puzzle (Duke et al., 2019) and Heidi expression facial recognition test (Duke et al., 2019) were each reported in one article. Use of the Beery Visual-Motor Integration test (VMI; Ortibus et al., 2011; Vancleef et al., 2020a), LEA mailbox (Mitry et al., 2016; Duke et al., 2019) and LEA rectangles (Mitry et al., 2016; Duke et al., 2019) were each reported in two articles. A child was required to pick objects up from a patterned and plain background in two studies (Mitry et al., 2016; Duke et al., 2019). Assessment of visual coherence (in both static and motion form) was reported in two articles (Macintyre-Beon et al., 2013; Geldof et al., 2015). The Child Visual Impairment Test for 3- to 6-year-olds (CVIT 3-6) was employed in one study (Vancleef et al., 2020a). Two studies did not report which tests were used; one of these reported that a neuropsychological test battery was used to assess visual perception but a description of the test was not provided (van Genderen et al., 2012). One study reported that information regarding visual perceptual ability was extracted from the child's medical records, however no information on how the ability had been measured was reported (Kooiker et al., 2015).

The L94 battery comprises eight tasks which collectively assess ability to identify everyday objects, visuo-constructional ability and form discrimination

(Stiers et al., 2002). The TVPS-R consists of seven subscales which measure visual discrimination, visual memory, visual spatial relationships, visual form constancy, visual sequential memory, visual figure ground and visual closure (Brown & Roger, 2009). The DTVP has five subscales which are designed to measure motor-enhanced visual perception and motor reduced visual perception, in addition to an overall general visual perception index (Brown, 2016). The VMI consists of three tasks; one core and two supplementary. The core task assesses the integration of visual perception and motor skills, while the supplementary tasks assess visual ability without the integration of fine motor skills and fine motor skills when not integrated with visual perceptual ability (McCrimmon et al., 2012). The Stirling Face Processing test measures a child's ability to identify and match faces (Bruce et al., 2000). The LEA Mailbox and LEA rectangles tests assess the perception of line direction and the length of lines respectively (Buultjens et al., 2010). The LEA 3D puzzle task assesses visual guidance of movement and visual memory, and the Heidi expression test assesses a child’s ability to interpret facial expressions (Duke et al., 2019). The CVIT-3-6 is a recently developed tool designed for assessing the broad range of visual perception impairments which are commonly reported in children with CVI (Vancleef et al., 2020b).

Each of these tests assess different aspects of visual perception. Whilst acknowledging that studies included in the present review did not consistently assess the same facets of visual perception, a score of 2 was assigned if the study described the visual perceptual measure employed. Where authors did not provide this information a score of 1 was assigned. A score of 0 was

assigned if an article did not report carrying out an assessment of visual perception (Table 2.2).

7. Ocular movements and posture

Children with CVI often present with oculomotor deficits (Philip & Dutton, 2014; Khetpal & Donahue, 2007) including nystagmus (Khetpal & Donahue, 2007; Fazzi et al., 2007), strabismus (Khetpal & Donahue, 2007; Phillips et al., 2005), and abnormal saccadic and smooth pursuit eye movements (Philip & Dutton, 2014; Fazzi et al., 2007). Thirty-two articles (69.6%) reported carrying out an ocular movement assessment (Matsuba & Jan, 2006; Huo et al., 1999; Eken et al., 1996; Chen et al., 1992; Khetpal & Donahue, 2007; Cioni et al., 1997; Hård et al., 2004; Ferziger et al., 2011; Salati et al., 2001; Whiting et al., 1985; Lanzi et al., 1998; Fazzi et al., 2007; Salati et al., 2003; Weinstein et al., 2012; Philip, 2017; Ortibus et al., 2011; Andersson et al., 2006; Cioni et al., 1996; Weiss et al., 2001; Kooiker et al., 2014; Brodsky et al., 2002; Houliston et al., 1999; Skoczenski & Good, 2004; Philip et al., 2016; Macintyre-Beon et al., 2013; Geldof et al., 2015; Kooiker et al., 2015; Pehere et al., 2018; Duke et al., 2019; Jasper & Philip, 2018; Handa et al., 2018; Bosch et al., 2014).

Twenty-six reported (56.5%) assessment of ocular posture/alignment (Huo et al., 1999; Eken et al., 1996; Chen et al., 1992; Khetpal & Donahue, 2007; Cioni et al., 1997; Hård et al., 2004; Ferziger et al., 2011; Lanzi et al., 1998; Fazzi et al., 2007; Salati et al., 2003; Weinstein et al., 2012; Philip, 2017; Ortibus et al., 2011; Andersson et al., 2006; Brodsky et al., 2002; Houliston et al., 1999; Skoczenski & Good, 2004; Macintyre-Beon et al., 2013; Geldof et al., 2015;

Kooiker et al., 2015; Pehere et al., 2018; Duke et al., 2019; Jasper & Philip, 2018; Handa et al., 2018; Bosch et al., 2014; Ben Itzhak et al., 2019). Of those who detailed specific details of the ocular movement assessment, six included saccadic eye movement assessment (Fazzi et al., 2007; Salati et al., 2003; Philip, 2017; Weiss et al., 2001; Houliston et al., 1999; Duke et al., 2019), four smooth pursuits (Salati et al., 2001; Fazzi et al., 2007; Weiss et al., 2001; Duke et al., 2019), nine assessed the optokinetic nystagmus response (OKN; Cioni et al., 1997; Ferziger et al., 2011; Salati et al., 2001; Whiting et al., 1985; Fazzi et al., 2007; Philip, 2017; Cioni et al., 1996; Weiss et al., 2001; Jasper & Philip, 2018), eight assessed the child's ability to fix and follow (Eken et al., 1996; Ferziger et al., 2011; Salati et al., 2001; Fazzi et al., 2007; Salati et al., 2003; Philip, 2017; Ortibus et al., 2011; Bosch et al., 2014), and two assessed convergence (Duke et al., 2019; Geldof et al., 2015). Twenty-three articles commented on whether the child presented with nystagmus eye movements (Matsuba & Jan, 2006; Huo et al., 1999; van Genderen et al., 2012; Eken et al., 1996; Chen et al., 1992; Khetpal & Donahue, 2007; Hård et al., 2004; Ferziger et al., 2011; Lanzi et al., 1998; Fazzi et al., 2007; Salati et al., 2003; Ortibus et al., 2011; Andersson et al., 2006; Kooiker et al., 2014; Brodsky et al., 2002; Houliston et al., 1999; Skoczenski & Good, 2004; Geldof et al., 2015; Kooiker et al., 2015; Pehere et al., 2018; Duke et al., 2019; Bosch et al., 2014; Ben Itzhak et al., 2019) .

If an article detailed the method of assessing and/or results of an ocular movement and posture assessment a score of 2 was assigned. Articles which detailed ocular movement or posture assessment or OKN only scored 1.

Articles which did not report assessment of ocular movements, or reported only whether the child had nystagmus or not, scored 0 (Table 2.2).

8. Intelligence/cognitive (IQ) assessment

Intelligence tests are often used to provide an overall assessment of general cognitive functioning (Climie & Rostad, 2011). Two commonly used intelligence tests are the Wechsler Intelligence Scale for Children (WISC), designed for use in children aged six years and over, and the Wechsler Preschool and Primary Scale of Intelligence (WPPSI), used for children aged 2.6 to 7.7 years. The WISC tests a child's verbal comprehension, perceptual reasoning, working memory and processing speed (Weiss et al., 2013). The WPPSI measures full scale intelligence quotient (IQ), verbal comprehension, working memory, visual spatial index, fluid reasoning and processing speed (Wechsler, 2012).

An alternative intelligence test is the Snijders-Oomen Nonverbal Intelligence test which can be used with very young children and those with poor communication and language development (Tellegen & Laros, 1993a). The Snijders-Oomen has four different test types; abstract reasoning, concrete reasoning, spatial and perceptual tests (Tellegen & Laros, 1993b).

The Kaufman Brief Intelligence Test (KBIT) is another readily available IQ test that includes both verbal and non-verbal scales which collectively assess expressive vocabulary, verbal knowledge and matrices. The non-verbal matrices subtest aims to measure fluid reasoning and visual processing

(Kaufman & Kaufman, 2004; Bain & Jaspers, 2010). The developers of the test suggest it should be used for screening rather than diagnostic purposes.

In this review, 16 articles (34.8%) reported results from IQ assessment (Table 2.1). Seven recorded that this information was extracted from medical notes (Philip, 2017; Kooiker et al., 2014; Salavati et al., 2017; Salavati et al., 2015; Kooiker et al., 2015; Vancleef et al., 2020a; Ben Itzhak et al., 2019), or if not available, testing was conducted during the assessment (Vancleef et al., 2020a). Three articles which extracted results of IQ assessment from medical notes did not list which tests were used to ascertain intelligence. The most common intelligence test employed by included studies was the Wechsler Intelligence Scale (n=8; van Genderen et al., 2012; Ortibus et al., 2009; Fazzi et al., 2007; Salati et al., 2003; Ortibus et al., 2011; Andersson et al., 2006; Geldof et al., 2015; Ben Itzhak et al., 2019). Two articles classified intelligence according to the Committee of Test Affairs in Netherlands (COTAN) criteria for IQ scores, however the authors did not state which tests were used to obtain the scores (Salavati et al., 2017; Kooiker et al., 2015). Four articles reported use of the Snijders-Oomen non-verbal intelligence scale (Ortibus et al., 2009; Ortibus et al., 2011; Ben Itzhak et al., 2019; Vancleef et al., 2020a) and one study used the KBIT (Macintyre-Beon et al., 2013). The remaining three articles did not state which tests were carried out (Whiting et al., 1985; Philip, 2017; Salavati et al., 2015).

Considering this information, articles which documented use of a well-established, recognised test scored 2 and those who did not list which tests

were used in their assessment scored 1. If IQ assessment was not carried out, an article scored 0 in this section (Table 2.2.).

9. Electrophysiology

Electrophysiology is used to measure the function of living tissue using electrical and chemical signals (Carter & Shieh, 2015). Fifteen articles (32.6%) reported use of at least one electrophysiology method to measure brain or visual function in response to visual stimuli. Eleven of these reported use of visual evoked potentials (VEPs; Eken et al., 1996; Salati et al., 2001; Whiting et al., 1985; Lanzi et al., 1998; Good et al., 2012; Fazzi et al., 2007; Weinstein et al., 2012; Cioni et al., 1996; Weiss et al., 2001; Good, 2001; Skoczenski & Good, 2004), five studies used electroretinography (ERG; Salati et al., 2001; Whiting et al., 1985; Fazzi et al., 2007; Handa et al., 2018; Bosch et al., 2014) and seven used electroencephalography (EEG; Whiting et al., 1985; Lanzi et al., 1998; Fazzi et al., 2007; Salati et al., 2003; Cioni et al., 1996; Good, 2001; Jasper & Philip, 2018). Each of these electrophysiology techniques measure different functions; ERG measures the function of retinal photoreceptors in response to light stimuli (Perlman, 1995), VEP is used to determine the subjects' visual potential by measuring neural activity at the primary visual cortex in response to light and/or spatial information (Rabbetts, 2007), and EEG is used to measure brain function, diagnose neurological disease and monitor brain activity by using electrodes which attach to the scalp and record brain activity (Kulkarni & Bairagi, 2018).

A score of 2 was assigned to articles which reported use of VEP as this provides relevant information on the function of the primary visual pathway.

EEG and ERG were both assigned a score of 1 as these measures provide less specific information in terms of a child's visual function. Articles which did not report use of electrophysiology testing were scored 0 for this section (Table 2.2).

10. Neurodevelopmental assessment

It is recommended that children who are at risk of developmental delay, for example children who are born preterm or have suffered hypoxic insult at birth, undergo developmental testing to assess mental and psychomotor development (Cirelli et al., 2015). Many of these children at risk of developmental delay are also at risk of CVI due to the associated aetiologies. In this review, eight articles (17.4%) reported use of a neurodevelopment test as part of their assessment (Table 2.1). Of these, four reported use of the Griffiths developmental scales only (Huntley, 1996; Lanzi et al., 1998; Fazzi et al., 2007; Salati et al., 2003; Andersson et al., 2006), one study employed both the Dubowitz protocol (Dubowitz & Dubowitz, 1981) and the Griffiths developmental scales (Eken et al., 1996), and one used Bayley Scales of Infant and Toddler Development (Bayley, 2006; Weiss et al., 2001). Two studies did not state which neurodevelopmental test was used (Chen et al., 1992; Pehere et al., 2018).

The Griffiths (Huntley, 1996) and Bayley scales (Bayley, 2006) are two commonly used instruments to measure development in infants. Several studies have compared the two scales. Cirelli et al. (2015) conclude that while the scores between the two instruments are not interchangeable, the meaning

of the results from each test are the same indicating the validity of both tests for the use in neurodevelopmental assessment. In addition, Ramsay and Fitzhardinge (1977) contend that the Griffiths test lacks scoring precision compared with the Bayley scales. Cirelli et al. (2015) suggest that the Bayley test is more often used in research, whereas the Griffiths may be more suited to clinical use.

Taking this information into consideration, tests which were well-established or validated were scored 2 and articles which did not state which test was used, or employed tests which were less well-established scored 1. Articles which did not administer a neuro-developmental test scored 0 (Table 2.2).

In summary, it is apparent that the methods used to assess children with suspected CVI are manifold. Even within each category of assessment, there is little consistency in the tests applied across articles.

2.3.1.1. Assigned assessment utility scores

Using the scoring system outlined above, the highest possible total score assigned, based on the scope and depth of assessment methods used by the article, was 20. None of the included articles applied tests covering all assessment categories and thus none scored 20. Total utility scores assigned to each article are shown in Table 2.2. Fazzi et al. (2007) were awarded the highest score having covered nine categories of assessment and achieving the highest possible score within each assessment category, with the exception of the ‘visual behaviours and direct observation’ category. This was

closely followed by Salati et al. (2003) with a score of 15. Salati et al. (2003) covered eight categories of assessment; achieving the highest possible score within each category with the exception of the ‘intelligence/cognitive assessment’ category. Both of the highest scoring articles, however, were assigned a moderate grading (B) in the overall quality assessment grading.

Considering those who achieved the highest quality grading of ‘good’, along with the assessment utility score, Duke et al. (2019) and Geldof et al. (2015) scored highest with 13. Ortibus et al. (2011) scored third highest with a score of 12. None of these articles included a neurodevelopmental test or electrophysiology techniques in their assessment. In addition, Duke et al. (2019) did not report use of IQ assessment and Geldof et al. (2015) did not utilise neuroimaging. All other categories of assessment were included in these articles. Across all included categories of assessment, Duke et al. (2019) obtained the maximum possible score in all categories of assessment except medical history, indicating use of well-established tests and explicit detail provided on each assessment. Geldof et al. (2015) also achieved the maximum possible score across all included categories of assessment with the exclusion of visual assessment/ophthalmologic examination as assessment of ocular health was not reported (Table 2.2).

Article	Quality assessment	Participant details		Sample size		Medical history	Vision assessment/ Ophthalmologic examination	Neuroimaging	Visual behaviour and direction observation	Structured history - taking	Visual perceptual tests	Ocular movements and posture	Intelligence test	Electrophysiology	Neuro developmental assessment	Number of assessment methods used
		Mean age (yrs)	Age range (yrs)	No. of CVI	No. of controls											
Philip (2017)	A			1478		X	X	X	X	X	-	X	X	-	-	**7**
Duke et al. (2019)	A		4-16	370		X	X	X	X	X	X	X	-	-	-	**7**
Bosch et al. (2014)	A	(Mdn 3)		309		X	X	X	X	-	-	X	-	X	-	**6**
Andersson et al. (2006)	A	(Mdn 9.3)		75	140	X	X	X	-	X	-	X	X	-	X	**7**
Handa et al. (2018)	A	1.53	0.24-6.37	53		X	X	-	-	-	-	X	-	X	-	**4**
Whiting et al. (1985)	A		0.5-19	50		X	X	X	-	-	-	X	X	X	-	**6**
Ortibus et al. (2011)	A	6.83	3.42-17	45	46	X	X	X	X	X	X	X	X	-	-	**8**
van Genderen et al. (2012)	A	8	5-16	30	23	X	X	X	-	X	X	-	X	-	-	**6**
Ortibus et al. (2009)	A	0.5	4-20	29	70	X	X	X	-	-	X	-	X	-	-	**5**
Ferziger et al. (2011)	A	8.25	3-20	26	51	X	X	X	X	X	-	X	-	-	-	**6**
Geldof et al. (2015)	A	5.5		25	62	X	X	-	X	X	X	X	X	-	-	**7**
Roman-Lantzy (2007)	A					X	-	-	X	X	-	-	-	-	-	**3**
Matsuba & Jan (2006)	B			423		X	X	-	-	-	-	X	-	-	-	**3**

Ben Itzhak et al. (2019)	B	(Mdn 6.42)	3-20	179	166	X	X	X	-	X	-	X	X	-	-	**6**
Jasper & Philip (2018)	B	4 definite CVI group, 2 probable CVI group	0.25-17	167 definite 109 probable	65	X	X	X	X	X	-	X	-	X	-	**7**
Fazzi et al. (2007)	B	4.5	0.25-15	121		X	X	X	X	-	X	X	X	X	X	**9**
Brodsky et al. (2002)	B			100		X	X	X	-	-	-	X	-	-	-	**4**
Khetpal et al. (2007)	B	3.1	0.2-19	98		X	X	X	X	-	-	X	-	-	-	**5**
Mitry et al. (2016)	B		4-15	90		X	X	-	-	X	X	-	-	-	-	**4**
Salati et al. (2003)	B	7.1	2-16	56		X	X	X	X	-	-	X	X	X	X	**8**
Kooiker et al. (2015)	B	8.5	1.08-12.9	48	56	X	X	-	-	-	X	X	X	-	-	**5**
Macintyre-Beon et al. (2013)	B		5.5-12.3	46	130	X	X	-	X	X	X	X	X	-	-	**7**
Skoczenski & Good (2004)	B	3.5	0.33-16	35		X	X	-	-	-	-	X	-	X	-	**4**
Weinstein et al. (2012)	B	6.75	5-16	19	81	X	X	X	-	-	-	X	-	X	-	**5**
Vancleef et al. (2020a)	B	6.83	4-9.08	12	25	X	X	X	-	-	X	-	X	-	-	**5**
Salati et al. (2001)	B	5	1-9	11		X	X	X	X	-	-	X	-	X	-	**6**
Philip et al. (2016)	C	3.8	0-17	342		X	X	-	X	X	-	X	-	-	-	**5**
Pehere et al. (2018)	C	5.24		124		X	X	-	-	-	-	X	-	-	X	**4**
Huo et al. (1999)	C	3		170		X	X	X	-	-	-	X	-	-	-	**4**
Hård et al. (2004)	C	(Mdn 6.7)		91		X	X	X	-	X	X	X	-	-	-	**6**

Dutton et al. (1996)	C			90		X	X	-	-	X	-	-	-	-	-	**3**
Salavati et al. (2015)	C	9.5	4.17-12	77		X	X	-	X	-	-	-	X	-	-	**4**
Houliston et al. (1999)	C			52	200	X	X	-	-	X	-	X	-	-	-	**4**
Cioni et al. (1997)	C	11.8		48	18	X	X	X	X	-	-	X	-	-	-	**5**
Cioni et al. (1996)	C	(Mdn 2.21)		48	32	X	X	X	X	-	-	X	-	X	-	**6**
Kooiker et al. (2014)	C	7.3	1.1-12.9	42	127	X	X	X	-	-	-	X	X	-	-	**5**
Good (2001)	C		0.5-16	41		X	X	-	X	-	-	-	-	X	-	**4**
Salavati et al. (2017)	C	9.4	4.5-12	37		X	X	-	-	-	-	-	X	-	-	**3**
Macintyre-Beon et al. (2012)	C	10.8	5-16.5	36	156	-	-	-	-	X	-	-	-	-	-	**1**
Good et al. (2012)	C	1.94	0.42-5	34	16	X	X	X	-	-	-	-	-	X	-	**4**
Chen et al. (1992)	C			30		X	X	X	-	-	-	X	-	-	X	**5**
Lanzi et al. (1998)	C	3.5	1.67-5.5	23	12	X	X	X	-	-	-	X	-	X	X	**6**
Franki et al. (2017)	C	4.25		23	51	-	-	X	-	-	X	-	-	-	-	**2**
Weiss et al. (2001)	C	0.51	0.083-1.083	17	31	X	X	X	-	-	-	X	-	X	X	**6**
Eken et al. (1996)	C		0.77-1.5	9		X	X	X	X	-	-	X	-	X	X	**7**
Suner et al. (2016)	C					-	X	-	-	-	-	-	-	-	-	**1**
Total number of articles						**43 (93.5%)**	**43 (93.5%)**	**29 (63%)**	**19 (41%)**	**17 (37%)**	**12 (26%)**	**33 (72%)**	**16 (35%)**	**15 (33%)**	**8 (17%)**	

Table 2.1: Categories of assessment reported in included articles, where X = use reported by article and - = use not reported by article for each assessment category. Quality assessment: A=Good, B=Moderate, C=Poor used to order articles, followed by number of participants with CVI included in article. Mdn = median.

Article	QA	MH	VA	NI	DO	SH	VP	OM	IQ	EP	ND	Total
Duke et al. (2019)	**A**	1	2	2	2	2	2	2	0	0	0	**13**
Geldof et al. (2015)	**A**	2	1	0	2	2	2	2	2	0	0	**13**
Ortibus et al. (2011)	**A**	2	1	1	1	1	2	2	2	0	0	**12**
Andersson et al. (2006)	**A**	1	2	1	0	2	0	1	2	0	2	**11**
Philip (2017)	**A**	2	1	1	1	2	0	2	1	0	0	**10**
van Genderen et al. (2012)	**A**	2	2	1	0	2	1	0	2	0	0	**10**
Bosch et al. (2014)	**A**	2	2	1	2	0	0	2	0	1	0	**10**
Ortibus et al. (2009)	**A**	2	1	2	0	0	2	0	2	0	0	**9**
Ferziger et al. (2011)	**A**	2	2	1	1	1	0	2	0	0	0	**9**
Whiting et al. (1985)	**A**	2	1	1	0	0	0	1	1	2	0	**8**
Handa et al. (2018)	**A**	2	2	0	0	0	0	2	0	1	0	**7**
Roman-Lantzy (2007)	**A**	1	0	0	2	2	0	0	0	0	0	**5**
Fazzi et al. (2007)	**B**	2	2	2	1	0	2	2	2	2	2	**17**
Salati et al. (2003)	**B**	2	2	2	2	0	0	2	2	1	2	**15**
Macintyre-Beon et al. (2013)	**B**	1	1	0	1	2	2	2	2	0	0	**11**
Jasper & Philip (2018)	**B**	2	2	1	1	2	0	2	0	1	0	**11**
Salati et al. (2001)	**B**	2	1	2	2	0	0	1	0	2	0	**10**
Ben Itzhak et al. (2019)	**B**	2	1	1	0	1	0	1	2	0	0	**8**
Weinstein et al. (2012)	**B**	2	1	1	0	0	0	2	0	2	0	**8**
Vancleef et al. (2020a)	**B**	1	1	1	0	0	2	0	2	0	0	**7**
Kooiker et al. (2015)	**B**	2	1	0	0	0	1	2	1	0	0	**7**

Khetpal et al (2007)	**B**	2	1	1	1	0	0	1	0	0	0	**6**
Skoczenski & Good (2004)	**B**	2	1	0	0	0	0	1	0	2	0	**6**
Brodsky et al. (2002)	**B**	2	1	1	0	0	0	2	0	0	0	**6**
Mitry et al. (2016)	**B**	1	1	0	0	2	2	0	0	0	0	**6**
Matsuba & Jan (2006)	**B**	2	1	0	0	0	0	1	0	0	0	**4**
Eken et al. (1996)	**C**	2	2	2	2	0	0	2	0	2	2	**14**
Lanzi et al. (1998)	**C**	2	2	1	0	0	0	2	0	2	2	**11**
Hård et al. (2004)	**C**	1	2	1	0	2	2	2	0	0	0	**10**
Weiss et al. (2001)	**C**	1	1	1	0	0	0	1	0	2	2	**8**
Cioni et al. (1996)	**C**	2	1	1	1	0	0	1	0	2	0	**8**
Philip et al. (2016)	**C**	2	1	0	1	2	0	1	0	0	0	**7**
Pehere et al. (2018)	**C**	2	2	0	0	0	0	2	0	0	1	**7**
Good (2001)	**C**	2	1	0	2	0	0	0	0	2	0	**7**
Houliston et al. (1999)	**C**	1	1	0	0	2	0	2	0	0	0	**6**
Good et al. (2012)	**C**	2	1	1	0	0	0	0	0	2	0	**6**
Chen et al. (1992)	**C**	2	1	1	0	0	0	1	0	0	1	**6**
Huo et al. (1999)	**C**	2	1	1	0	0	0	2	0	0	0	**6**
Cioni et al. (1997)	**C**	1	1	1	1	0	0	2	0	0	0	**6**
Kooiker et al. (2014)	**C**	2	1	1	0	0	0	1	1	0	0	**6**
Dutton et al. (1996)	**C**	2	1	0	0	2	0	0	0	0	0	**5**
Salavati et al. (2015)	**C**	2	1	0	1	0	0	0	1	0	0	**5**
Salavati et al. (2017)	**C**	2	1	0	0	0	0	0	1	0	0	**4**
Franki et al. (2017)	**C**	0	0	1	0	0	2	0	0	0	0	**3**
Macintyre-Beon et al. (2012)	**C**	0	0	0	0	2	0	0	0	0	0	**2**

Suner et al. (2016)	**C**	0	1	0	0	0	0	0	0	0	0	**1**

Table 2.2: Assessment Utility scores assigned, by category of assessment, to articles.

QA=quality assessment score, MH=medical history, VA=vision assessment/ophthalmological examination, NI=neuroimaging, DO=direct observation and visual behaviours, SH=structured history, VP=visual perception assessment, OM=ocular movement assessment, IQ=intelligence assessment, EP=electrophysiology, ND=neurodevelopmental assessment.

2.3.2. Diagnostic methods for CVI

The first section of this review has discussed the assessments used to investigate CVI. The following section reviews more specifically how each article reports the means by which a CVI diagnosis was formed.

Table 2.3 shows how each article assigned a CVI diagnosis. Articles often provided a written description to inform the reader how a diagnosis was made, rather than detailing results of specific assessment procedures. The most commonly reported diagnostic description utilised results from the vision assessment, articulating that the presence of CVI was determined where there existed ‘visual dysfunction which could not be accounted for based on ocular examination findings/anterior pathway abnormalities’ (n=22, 47.8%; Matsuba & Jan, 2006; Huo et al., 1999; Eken et al., 1996; Chen et al., 1992; Khetpal & Donahue, 2007; Ferziger et al., 2011; Lanzi et al., 1998; Good, 2012; Fazzi et al., 2017; Salati et al., 2003; Weinstein et al., 2012; Cioni et al., 1996; Weiss et al., 2001; Brodsky et al., 2002; Good, 2001; Skoczenski & Good, 2004; Salavati et al., 2017; Salavati et al., 2015; Pehere et al., 2018; Jasper & Philip, 2018; Handa et al., 2018; Bosch et al., 2014). An additional six articles also reported that results from the vision assessment/ophthalmologic examination were used to form a diagnosis (n=28 in total, 60.9%; van Genderen et al.,

2012; Philip, 2017; Ortibus et al., 2011; Geldof et al., 2015; Suner et al., 2016; Vancleef et al., 2020a). Of these, a crowding ratio derived from visual acuity measures was considered by one article (van Genderen et al., 2012), and a novel method for assessing visual function and diagnosing CVI using a computer-based system relying on the child's eye movements was reported as the only method to detect and quantify CVI by one article (Suner et al., 2016).

The next most common method for forming a diagnosis was based on findings from neurological examination (n=13; Matsuba & Jan, 2006; Salati et al., 2001; Good et al., 2012; Fazzi et al., 2007; Salati et al., 2003; Weinstein et al., 2012; Philip, 2017; Ortibus et al., 2011; Brodsky et al., 2002; Salavati et al., 2017; Pehere et al., 2018; Vancleef et al., 2020a; Ben Itzhak et al., 2019). Eleven of these articles reported use of additional methods of assessment alongside neurological findings to reach a diagnosis (Table 2.3).

Consideration of the child's medical history to determine whether conditions known to be associated with CVI were present was reported as diagnostic in 12 articles; all used medical history in conjunction with other metrics to form a diagnosis (Table 2.3; Matsuba & Jan, 2006; van Genderen et al., 2012; Good et al., 2012; Philip, 2017; Ortibus et al., 2011; Kooiker et al., 2014; Skoczenski et al., 2004; Salavati et al., 2017; Salavati et al., 2015; Kooiker et al., 2015; Ben Itzhak et al., 2019; Jasper & Philip, 2018). Structured history-taking was reported as diagnostic by eight articles (Philip, 2017; Andersson et al., 2006; Houliston et al., 1999; Macintyre-Beon et al., 2013; Mitry et al., 2016;

Macintyre-Beon et al., 2012; Duke et al., 2019; Jasper & Philip, 2018), with six reporting this as the only assessment used to form a diagnosis (Table 2.3).

IQ assessment was reported as diagnostic in five articles (Philip, 2017; Kooiker et al., 2014; Kooiker et al., 2015; Ben Itzhak et al., 2018; Vancleef et al., 2020a) and direct observation of visual behaviours was also reported as diagnostic in five articles (Matsuba & Jan, 2006; Philip, 2017; Salavati et al., 2017; Salavati et al., 2015; Bosch et al., 2014); results of IQ assessment and direct observation of visual behaviours were used in conjunction with other methods of assessment (Table 2.3).

Results from electrophysiology testing were reported as diagnostic in three articles (Matsuba & Jan, 2006; Whiting et al., 1985; Fazzi et al., 2007) and one article reported that results of a 'visuomotor assessment' were used to form a diagnosis, however no information on what this entailed was provided (Ben Itzhak et al., 2019); these assessments were used in conjunction with other methods to form a diagnosis (Table 2.3).

The L94 visual perception battery was reported as the only diagnostic method used in two articles (Ortibus et al., 2009; Franki et al., 2017). Other tests of visual perception were used by three articles (Ortibus et al., 2011; Geldof et al., 2015; Vancleef et al., 2020a), all in conjunction with additional metrics to form a diagnosis (Table 2.3). Diagnostic criteria were unclear or not well documented in four articles (Cioni et al., 1997; Hård et al., 2004; Philip et al., 2016; Dutton et al., 1996).

Twenty-one articles (45.7%) reported using a single method to diagnose CVI (Table 2.3). The most common of these was on the basis that visual deficits could not be accounted for based on vision assessment/ophthalmological examination findings (n=11) and the second most frequent single method reported was structured history-taking (n=6). Eleven articles reported using two measures to form a diagnosis, five used results from three assessments, three used four assessments and one study each used combinations of five or six methods to diagnose CVI (Table 2.3).

Articles that were graded as good quality were considered separately in an attempt to refine which tests may be best applied when forming a diagnosis of CVI. Twelve articles were awarded the highest quality grading; of these, six reported use of a single diagnostic description/method to form a CVI diagnosis (Table 2.3), four reported use of two methods and one study each used results from four and six assessment methods to form a diagnosis. Methods of assessment most commonly utilised were results from: 1. vision assessment/ophthalmologic examination (n=7), 2. structured history-taking (n=4), 3. medical history (n=3), 4. visual perception tests (n=3) and 5. results of visual behaviour/direct observation assessment (n=3). Neurological examination was reported by two articles when making a diagnosis, and electrophysiology and IQ assessment were each reported by one article.

Article	Vision measures/ ophthalmologic exam	Neurological findings	Medical history	Structured history-taking	Visual perception tests	Observation of characteristic behaviours associated with CVI	Intelligence (IQ) assessment	Electrophysiological results	Not clear	Number of methods used to diagnose	Number of assessment methods used (taken from Table 2.1)	Assessment utility score (taken from Table 2.2)	Quality assessment
Duke et al. (2019)	-	-	-	X	-	-	-	-	-	**1**	7	13	A
Geldof et al. (2015)	X	-	-	-	X	-	-	-	-	**2**	7	13	A
Ortibus et al. (2011)	X	X	X	-	X	-	-	-	-	**4**	8	12	A
Andersson et al. (2006)	-	-	-	X	-	-	-	-	-	**1**	7	11	A
Philip (2017)	X	X	X	X	-	X	X	-	-	**6**	7	10	A
van Genderen et al. (2012)	X	-	X	-	-	-	-	-	-	**2**	6	10	A
Bosch et al. (2014)	X	-	-	-	-	X	-	-	-	**2**	6	10	A
Ortibus et al. (2009)	-	-	-	-	X	-	-	-	-	**1**	5	9	A
Ferziger et al. (2011)	X	-	-	-	-	-	-	-	-	**1**	6	9	A
Whiting et al. (1985)	-	-	-	-	-	-	-	X	-	**1**	6	8	A
Handa et al. (2018)	X	-	-	-	-	-	-	-	-	**1**	4	7	A
Roman-Lantzy (2007)	-	-	-	X	-	X	-	-	-	**2**	3	5	A
Fazzi et al. (2007)	X	X	-	-	-	-	-	X	-	**3**	9	17	B

Salati et al. (2003)	X	X	-	-	-	-	-	-	-	**2**	8	15	B
Macintyre-Beon et al. (2013)	-	-	-	X	-	-	-	-	-	**1**	7	11	B
Jasper & Philip (2018)	X	-	X	X	-	-	-	-	-	**3**	7	11	B
Salati et al. (2001)	-	X	-	-	-	-	-	-	-	**1**	6	10	B
Ben Itzhak et al. (2019)	-	X	X	-	X	-	X	-	-	**4**	6	8	B
Weinstein et al. (2012)	X	X	-	-	-	-	-	-	-	**2**	5	8	B
Vancleef et al. (2020a)	X	X	-	-	X	-	X	-	-	**4**	5	7	B
Kooiker et al. (2015)	-	-	X	-	-	-	X	-	-	**2**	5	7	B
Khetpal et al. (2007)	X	-	-	-	-	-	-	-	-	**1**	5	6	B
Skoczenski & Good (2004)	X	-	X	-	-	-	-	-	-	**2**	4	6	B
Mitry et al. (2016)	-	-	-	X	-	-	-	-	-	**1**	4	6	B
Brodsky et al. (2002)	X	X	-	-	-	-	-	-	-	**2**	4	6	B
Matsuba & Jan (2006)	X	X	X	-	-	X	-	X	-	**5**	3	5	B
Eken et al. (1996)	X	-	-	-	-	-	-	-	-	**1**	7	14	C
Hård et al. (2004)	-	-	-	-	-	-	-	-	X		6	10	C
Lanzi et al. (1998)	X	-	-	-	-	-	-	-	-	**1**	5	11	C
Weiss et al. (2001)	X	-	-	-	-	-	-	-	-	**1**	6	8	C
Philip et al. (2016)	-	-	-	-	-	-	-	-	X		5	7	C

Pehere et al. (2018)	X	X	-	-	-	-	-	-	-	**2**	4	7	C
Good (2001)	X	-	-	-	-	-	-	-	-	**1**	4	7	C
Houliston et al. (1999)	-	-	-	X	-	-	-	-	-	**1**	4	6	C
Cioni et al. (1996)	X	-	-	-	-	-	-	-	-	**1**	6	6	C
Good et al. (2012)	X	X	X	-	-	-	-	-	-	**3**	4	6	C
Chen et al. (1992)	X	-	-	-	-	-	-	-	-	**1**	5	6	C
Cioni et al. (1997)	-	-	-	-	-	-	-	-	X		5	6	C
Huo et al. (1999)	X	-	-	-	-	-	-	-	-	**1**	4	6	C
Kooiker et al. (2014)	-	-	X	-	-	-	X	-	-	**2**	5	6	C
Dutton et al. (1996)	-	-	-	-	-	-	-	-	X		3	5	C
Salavati et al. (2015)	X	-	X	-	-	X	-	-	-	**3**	3	5	C
Salavati et al. (2017)	X	X	X	-	-	X	-	-	-	**3**	3	4	C
Franki et al. (2017)	-	-	-	-	X	-	-	-	-	**1**	2	3	C
Macintyre-Beon et al. (2012)	-	-	-	X	-	-	-	-	-	**1**	1	2	C
Suner et al. (2016)	X	-	-	-	-	-	-	-	-	**1**	1	1	C
Total number of articles using diagnostic method	***28***	***13***	***12***	***9***	***6***	***6***	***5***	***3***	***4***				

Table 2.3: Diagnostic tests and descriptions described by included articles, where X = use reported by article, - = use not reported by article for each diagnostic category. Quality assessment: A=Good, B=Moderate, C=Poor.

2.3.3. Professionals involved in assessment

If an article specifically mentioned which professionals were involved in the assessment of CVI, this was recorded. Of the 46 articles which were included in the present analysis, 18 (39.1%) did not state who was involved in the CVI assessment and diagnostic process. Use of multidisciplinary input was documented in 18 cases (39.1%). Multidisciplinary input was recorded where input from two or more of the following disciplines was reported: medicine (non-vision) (which includes (neuro) paediatrician, neuroradiologist, neurologist), vision (ophthalmologist, optometrist, orthoptist), therapy (physiotherapist, speech therapist, occupational therapist, developmental coach, therapists), psychology (neuro-psychiatrist, neuro-psychologist, psychiatrist, psychologist) and trained researchers. The authors acknowledge that the professions listed could be included in more than one category, but for the purposes of this review professionals have been grouped into one category only as described. Multidisciplinary input was also indicated where the article stated the involvement of a multidisciplinary team, even if specific disciplines were not explicitly described (n=3).

The list of professionals involved in the CVI assessment, along with the number of articles which report involvement of these professionals, are detailed in Appendix 2. Vision professionals (ophthalmologist, optometrist, orthoptist) were most frequently involved in the assessment of CVI (n=21), with ophthalmologists the most common (n=19). Neurospecialists were also frequently involved (n=15). These specialists comprised neuropsychologists (n=2), neuropsychiatrists (n=2), neuroradiologists (n=4) and neurologists

(n=6) and neuropaediatrician (n=1). In addition to professional input, parents/carers were frequently involved in the assessment process by reporting the child's visual difficulties through structured history-taking or questionnaire completion (n=18). Educator input was reported in three articles. Eleven articles (23.9%) reported input from only one discipline. These included vision (n=7), medical (n=3) and psychology (n=1) using the groupings described previously.

2.4. Discussion

The prevalence and awareness of CVI is increasing and, as such, there is an increased need to develop tools to aid the evaluation and diagnosis of this condition in children. This review aimed to establish what methods of assessment are currently used to investigate and diagnose CVI.

Review of the literature highlights that the most commonly documented presentation used to form a CVI diagnosis is based on a child presenting with visual difficulties which are unexplained by results of vision assessment/ophthalmological examination. This 'diagnosis of exclusion' ensures that children receive a thorough examination of visual function and provides an overall profile of the child's visual function, facilitating management of co-existing ocular deficits in addition to addressing visual processing difficulties. This approach is also beneficial in that it utilises equipment and assessments readily available within an ophthalmological clinical or hospital setting, making assessment of CVI accessible and easily implemented. A downside to this 'diagnosis of exclusion' approach is that it

may allow for diagnostic-overshadowing; visual deficits recorded may be attributed to co-existing neurological impairments affecting speech, behaviour, cognition or movement rather than CVI.

Neurological assessment was the second most commonly reported method used to diagnose CVI in children. In most cases (n=10) this was in conjunction with visual difficulties which could not be explained by results of vision assessment/ophthalmological examination. Often, neuroimaging was not carried out contemporaneously, but drawn from clinical records. A drawback in using this approach is the variable and often lengthy time interval between the neuroimaging assessment and subsequent clinical testing, making associations between clinical test outcomes and neuroimaging results difficult to interpret (Daneman et al., 2006). Lowery et al. (2006) report that it is critical to have a high-quality MRI scan and careful medical history to establish a diagnosis of CVI. This claim is in conflict with other authors' findings. Ortibus et al. (2009) found that 14% of children with CVI in their study population presented with a normal MRI. Similarly, Franki et al. (2017) sought to compare the extent and location of brain lesions using structural MRI (sMRI) in children with and without a diagnosis of CVI. They concluded that sMRI was not effective at differentiating between both groups and reported normal MRI findings in 17.4% of the population of children with CVI. Whiting et al. (1985) state that while neuroimaging was useful in determining the extent and cause of brain damage in their study population, neuroimaging results did not correlate well with the degree of visual loss in patients with CVI. This contrasts with findings from Lanzi et al. (1998) who report that lesions present on MRI

scans affecting the visual pathway in their study population of children with periventricular leukomalacia correlated well with visual function. In Lanzi's study cohort, children with severe damage to the optic radiations, as determined by neuroimaging, were three times more likely to have CVI compared to children with less neurological damage (Lanzi et al., 1998). The different findings may be attributed to the variety of neuroimaging techniques employed across studies and also how the samples have been selected in terms of CVI diagnosis. In their study, Cioni et al. (1996) suggest that MRI scans play an important role in the early detection of visual deficits affecting the visual cortex and optic radiations in neonates with encephalopathy, as otherwise these deficits may continue unrecognised until children are old enough to undertake more subjective clinical measures.

Nine studies reported using structured clinical history-taking to diagnose CVI. In six of these, this was the only assessment reported to form a diagnosis. Applying structured history-taking tools has value in identifying key problems with which children may present. Results from these tools can be used to develop habilitation plans for children which address highlighted problems and implement simple and practical management strategies to alleviate the impact of identified problems in daily life (Dutton, 2013). Duke et al. (2019) have designed a randomized control trial, which is currently underway, to determine the impact of such strategies on quality of life of children with cerebral palsy and CVI in a low to middle income country. However, van Genderen et al. (2012) urge caution in the use of CVI questionnaires/inventories as a screening tool (especially in isolation), and contend these tools create an

unacceptable number of false positives. Results from structured history-taking and CVI inventories can be augmented by clinical examination or direct observation of the child (Ortibus et al., 2011). Roman-Lantzy recommends that a child's behaviour is observed in a variety of environments and conditions, including during quiet and noisy times, with moving and stationary objects and in cluttered and uncluttered environments (Roman-Lantzy, 2007e). Coupling this approach with parental input can help gather a comprehensive overview of the child's visual strengths and weaknesses in order to highlight areas which require habilitation. Another drawback in the use of currently available inventories to elicit difficulties associated with CVI is that they are likely to be inappropriate for infants and young children as many items rely on the child having met developmental milestones, for example walking or grasping. This is also problematic where children have co-morbidities which seriously restrict their physical or cognitive ability and for whom many of the questions applied by the inventories are not appropriate. As such, if relying solely on inventories for a diagnosis, very young or very physically or cognitively impaired children with CVI may remain undiagnosed.

Van Genderen et al. (2012) sought to determine which commonly available investigative tools were effective at identifying children with CVI in a population of children with good visual acuity in a general ophthalmic clinic. They concluded that known causes of CVI in the child's medical history was the most important consideration. To further support a diagnosis, they proposed incorporation of whether the child presented with additional symptoms of cerebral damage, for example visual field defects, nystagmus and partial optic

atrophy. Consensus for this approach is evident from the present review, in which twelve studies considered the child's medical history to form a diagnosis in combination with other assessments.

Results of visual perception testing were reported as diagnostic in six articles. Individual tests of visual perception often examine very specific aspects of visual processing. Due to the heterogeneous nature of CVI, if visual perception tests were used in isolation, they risk underdiagnosing children with CVI if the particular aspect of visual perception assessed is not defective. For example, the LEA mailbox task assesses visually guided motion and perception of line direction. Even if a child performs this task without difficulty, they may exhibit other deficits in visual perception which are not assessed using the LEA mailbox. Macintyre-Beon et al. (2013) report that results on tests of visual perception do not correlate well with problems identified using the visual skills inventory and propose that this is not a failure of the inventory, but rather the tests of visual perception as they are not developed to specifically identify problems associated with CVI. The recently developed CVIT 3-6 offers a promising alternative to previously available tests of visual perception. This test was designed specifically to identify problems associated with CVI and has shown encouraging results in stratifying children with and without a diagnosis of CVI (Vancleef et al., 2020a).

For the majority of included articles, a combination of assessment methods was used to form a diagnosis of CVI. This approach considers multiple aspects of a child's visual function and provides a comprehensive picture of the child's

visual profile. Including a range of assessments also allows flexibility in which tests are applied to each child. Affected children are likely to present with co-existing physical and mental impairments and some children may be unable to perform all tests required of them in the clinic. Implementation of a multi-assessment approach increases the likelihood of a child being able to complete some aspects of the assessment process and therefore still provides the clinician with valuable information regarding a child's visual processing ability. While a multi-assessment approach is beneficial, it may be important to prioritise those tests which are most useful when forming a diagnosis, rather than expecting a child to complete every possible assessment method discussed in this review (and beyond). Considering articles which were rated 'good' quality in the present review, the most commonly reported components employed in the diagnostic process were results from vision assessment/ophthalmologic examination, consideration of the child's medical history, structured history-taking of visual processing difficulties and tests of visual perception. Prioritising these assessments may be appropriate when seeking a diagnosis of CVI.

Given that a multi-assessment approach is beneficial and often employed when diagnosing children with CVI, it is not surprising that a team of professionals is often required to apply testing. Using a team draws on multi-disciplinary expertise when assessing and interpreting results in order to ensure a consensus when providing a diagnosis (Lueck & Dutton, 2015; Philip, 2017). In the present review, eye care professionals (specifically ophthalmologists) most commonly led the assessment process, however this

was often coupled with input from other medical and allied health professionals.

It is important that a timely CVI diagnosis can be applied, as evidence has shown that early intervention in these children improves their visual, social and educational outcomes (Sonksen et al., 1991; Merril & Kewman, 1986). Following diagnosis, necessary support and habilitation can be implemented in the child's home and educational environment to minimise the compounding impact CVI can have on the child's daily living. To provide an early diagnosis it is therefore important that assessments and tests which are developed and utilised are applicable to young paediatric patients. In addition, Philip (2017) reports the importance of providing an assessment report to teachers and therapists involved in the child's care so that they can take account of the child's processing difficulties and ensure optimal access to education. The importance of communicating results from assessments is also echoed by Lehman (2013) and Hyvärinen et al. (2012) who recommend documenting accommodations that are medically necessary so that carers and educators can make suitable adjustments to the child's activities of daily living.

2.5. Conclusion

The primary aim of this review was to identify and evaluate which assessments are currently used to investigate and diagnose CVI in children. Results reveal a lack of common practice in the assessment(s) utilised. A multi-assessment approach is often employed. Given the heterogeneous nature of CVI, this may be the most suitable approach with which to identify and describe CVI in a

clinical situation. This approach is also beneficial in that even if a child is unable to comply with one assessment method, they may be able to comply with another to provide meaningful information on the child's CVI status. The most commonly reported approaches employed by the highest scoring articles included i) results of visual function assessment and/or ophthalmologic examination, ii) consideration of a child's medical history, iii) structured history-taking of visual processing difficulties and iv) tests of visual perception. Prioritising these assessments may prove most valuable in forming a diagnosis of CVI. Development of sector-agreed guidelines for the assessment and diagnosis may be considered an appropriate next-step in an attempt to create some clarity on when to diagnose CVI. This will ensure children receive a timely diagnosis and ultimately receive the additional support they require. However, the challenge in creating such guidelines is acknowledged due to the heterogeneity of affected children.

Chapter 3

Techniques and assessments employed

3.0. Chapter overview

This chapter describes the assessments and techniques employed in subsequent chapters to determine whether investigation of cerebral visual impairment (CVI) was possible as part of an in-school vision assessment for children attending special schools.

3.1. Introduction

Systematic review of the literature has shown that a multi-assessment approach is often employed during the assessment and diagnosis of CVI in children (Chapter 2). The most commonly reported approaches employed to ascertain the presence of CVI by the highest scoring articles that met inclusion criteria in the systematic review included i) results of visual function assessment and/or ophthalmologic examination, ii) consideration of a child's medical history, iii) structured history-taking of visual processing difficulties and iv) tests of visual perception.

Considering this information, the following study (discussed in Chapter 5, 6 and 7) aimed to determine whether application of these approaches could be applied by eyecare professionals (e.g. optometrists and orthoptists) as part of an in-school vision assessment, described by the Eyecare in Special Schools Framework discussed in Chapter 1.7, to identify evidence of CVI in children with special educational needs. Tests were selected on the basis that they; 1)

could be applied in an in-school setting, 2) would be suitable for the cognitive and physical ability of the majority of pupils with special education needs (SEN), 3) could be conducted within the time constraints of the school timetable to allow multiple children to be assessed during the school day, and 4) were readily available to be applied across multiple geographical sites.

When considering a CVI diagnosis it is important to first consider the visual status of participants and the function of the anterior visual pathway to ensure visual difficulties experienced are not attributed to unrecognised and treatable vision deficits (Fazzi et al., 2007; Dutton, 2013). Where possible, visual deficits should be corrected and addressed prior to assessing for evidence of CVI, for example, if a child has a significant refractive error, spectacles should be provided and worn during completion of CVI assessments. Children with CVI often exhibit characteristic vision deficits (as discussed in Chapter 1) which, if present, may also help in providing a fuller picture of a child's vision and assist the diagnosis of CVI. Accordingly, participants in the present study underwent a full vision assessment.

As discussed previously, a well-established questioning tool which is commonly applied to elicit behaviours associated with CVI is the Visual Skills Inventory developed by Dutton and colleagues (Dutton et al., 2010b). This inventory has been applied to populations of children who are at high-risk of CVI (Houliston et al., 1999; Macintyre-Beon et al., 2012; Geldof et al., 2015; Mitry et al., 2016). The present study applied the VSI in a population with SEN to identify participants with evidence of CVI.

A number of commercially-available tests of visual perception were selected for use in the present study; the LEA mailbox, LEA rectangles and shape-sorter task. These tests were chosen as they are quick to administer and assess a range of visual perceptual abilities which are discussed in more detail later in this chapter (Warrington & James, 1988; Atkinson et al., 2002; Buultjens et al., 2010). Previous work has demonstrated that these tests are well accepted amongst young school-aged children in mainstream education (Williams et al., 2015), and as such their acceptability and performance in a population with SEN applied in an in-school setting was explored in the current study.

Difficulty interpreting visual information in a crowded environment is a commonly reported feature associated with CVI in childhood (Dutton et al., 2006; Fazzi et al., 2009; Good et al., 1994). Evidence of visual crowding difficulties can be elicited through use of questionnaires and inventories (Ortibus et al., 2011; Macintyre-Beon et al., 2012; Macintyre-Beon et al., 2013; Mitry et al., 2016). Some authors have also found deficits in crowded visual acuity in children with CVI and those with neurological damage. In their study, van der Zee et al. (2017) report that comparison of crowded and single optotype acuity (to allow calculation of a crowding ratio) helped identify children in their population with previously undiagnosed brain damage (van der Zee et al., 2017). Similarly, van Genderen et al. (2012) found that 41% of children with CVI and good visual acuity in their study population had a crowding ratio ≥2 compared with children who did not have a CVI diagnosis (van Genderen et al., 2012). Such findings warrant further investigation of

crowding ratios in children with SEN who are potentially at a greater risk of CVI due to their underlying neurodevelopmental anomalies. If a relationship between CVI and crowding ratios is evidenced in this population, there is the potential to use this measure as an easily-applied CVI screening method for children with SEN who are able to comply with optotype acuity testing. As such, crowded and single optotype visual acuity was assessed in the current study.

The Strengths and Difficulties Questionnaire (SDQ) is another readily available tool which is used widely in research and clinical practice to describe children's behaviour, emotions and relationships with others (Goodman, 1997). Geldof et al. (2015) applied the SDQ in a population of very preterm/very-low-birth-weight children and found differences in parental responses between children with and without CVI, with parents scoring children with CVI as having more difficulties (Geldof et al., 2015). This raises the question of whether responses on the parent or teacher version of the SDQ could assist in the identification and diagnosis of CVI in a population with SEN, hence the SDQ was also applied in the current study.

As discussed previously, the current study formed part of the overarching Special Education Eyecare (SEE) Project. The aim of the SEE project was to apply an Eyecare in Special Schools Framework (The Royal College of Ophthalmologists, 2016) to determine whether application of this framework helped to reduce unmet visual need among children attending special schools.

Aspects of this work have been published previously (Black, McConnell, et al., 2019; McKerr, McConnell, et al., 2020; Appendix 3 and 4 respectively).

3.2. Methods

3.2.1. Ethical approval

Ethical approval for this study was granted by Ulster University's Research Ethics Committee (REC/15/0125; see Appendix 5 for ethical approval letters). This research adhered to the principles of the Declaration of Helsinki. The author and all members of the research time obtained Access NI certificates and underwent safeguarding children and vulnerable adult training prior to conducing study assessment procedures. Prior to providing consent for their child to participate, parents were issued with study information leaflets. Children and young adults (aged 18 and over) were provided with this information in an accessible format. Written informed consent was obtained from parents of participating children under 18 years of age and from young adults aged 18 or over. Prior to conducting study assessment procedures, verbal assent was obtained from each child/young adult to ensure they were happy to participate. A child/young adult could withdraw their assent at any time throughout the assessment if they no longer wished to participate.

3.2.2. Recruitment

The Chief Executive of the Education and Library Board was contacted and informed of the intention to contact special schools in Northern Ireland. Following this, the largest special school in Northern Ireland was identified. The principal was contacted and fully informed about the study aims and

requirements. Agreement to participate was obtained, and a school permission form (see Appendix 6 for a blank copy) was completed and returned to the research team. Information packs were then distributed to all parents via the child's school bag. Packs consisted of a parent information sheet, child/young adult information sheet and parental consent form (Appendix 7). Teachers were provided with written and verbal information outlining the study purpose and requirements. Completed consent forms were returned to the child's form teacher who deposited the forms in a secure post-box at the school reception from which they were collected by the research team. Recruitment and testing were carried out by two experienced optometrists (author ELM and SAB) across two academic years (2016/17 and 2017/18).

3.2.3. Examination procedures

3.2.3.1. Parent and teacher questioning

Following consent, each participant's parent/carer and teacher were invited to complete three questionnaires.

3.2.3.1.1. Visual and Medical History

The first questionnaire gathered information on the participant's current visual status and visual history. Questions probed whether the participant had any previously diagnosed visual deficits, and if so, whether parents or teachers had adapted the participant's home or educational environment to ameliorate these visual deficits. Parents were also asked to provide information regarding their child's birth (e.g. duration of pregnancy, complications at birth) and

medical history (e.g. diagnosis of any medical conditions/syndromes) (see Appendix 8 and 9 for parent and teacher questionnaires respectively).

3.2.3.1.2. Visual Skills Inventory

The second questionnaire was the Visual Skills Inventory (VSI). As discussed in Chapter 2, the VSI is a widely used and accepted tool employed to explore characteristic behaviours and difficulties associated with CVI (Appendix 10). Several iterations of the VSI exist, varying in terms of the number of questions and subcategories included in the questionnaire. In the present study, questions were categorised according to the INSIGHT version of the inventory which contains six subsections structured to identify difficulties associated with 1. visual fields, 2. perception of movement, 3. visually guided movement, 4. searching for visual targets, 5. noticing multiple targets and 6. recognising target objects and navigating around (Mitry et al., 2016; Duke et al., 2019). Parents and teachers were asked to rate the participant's behaviour for each item included in the questionnaire on a five-point Likert scale depending on whether the participant exhibited the listed behaviours 'never', 'rarely', 'sometimes', 'often' or 'always'. There was an additional 'not applicable' option for each question.

Prior to carrying out analysis of the VSI, responses were reviewed to ensure only questionnaires where more than 50% had been completed were included, i.e. questionnaires were excluded from analysis if respondents answered 'not applicable' or had missing answers for more than half of the questions. In addition, Question 37 (Does your child find it difficult to keep to task for more

than five minutes?), Question 38 (Does your child find it difficult to get back to what they were doing after being distracted?) and Question 42 (Do quiet places/open countryside cause difficult behaviour?) were excluded from analysis as these questions are not included in more recent iterations of the VSI which have been used in published literature (Macintyre-Beon et al., 2013; Mitry et al., 2016).

The VSI does not have a standardised scoring method, however previous studies have assigned scores of 1 to 5 to responses ranging from ‘never’ to ‘always’ respectively (Macintyre-Beon et al., 2013; Mitry et al., 2016; Duke et al., 2019). Responses of ‘not applicable’ were not assigned a score (Macintyre-Beon et al., 2013). The same scoring method was employed in the present study. This allowed calculation of a mean score for each subsection of the VSI and for the total inventory (Mitry et al., 2016). Using this inventory, Mitry et al. (2016) suggest that a child can be described has having perceptual visual dysfunction (PVD) if they have a mean score of ≥3 (indicating problems occur at least ‘sometimes’ on average) in each or any subsection of the inventory. Responses on the parental VSI were used to stratify participants according to whether they exhibited evidence of CVI using these criteria.

3.2.3.1.3. Strengths and Difficulties Questionnaire

The third questionnaire was the Strengths and Difficulties Questionnaire (SDQ; Appendix 11) which was employed to explore each participant’s overall behaviour (Goodman, 1997). The SDQ comprises 25 items across five subscales used to identify emotional difficulties, conduct (behavioural)

difficulties, hyperactivity (and concentration) difficulties, peer relationship problems (difficulties getting along with other children), and prosocial (kind and helpful) behaviour. Each questionnaire also contains an ‘impact’ supplement which provides additional information on the participant’s difficulties with regard to duration of their difficulties, the amount of distress the difficulties cause the participant, the social impact of the difficulties and the burden of these difficulties on others. Each subscale was scored using a three-point scale; ‘not true’, ‘somewhat true’ and ‘certainly true’. Scores of 0, 1 and 2 were assigned to each response respectively. A total score of 10 was possible for each subscale, and 40 for the ‘total difficulties’ determined by totalling the score from each subsection except ‘kind and helpful behaviour’ which does not contribute to the ‘total difficulties’ score. Higher scores in each subscale indicate greater problems, except for ‘kind and helpful behaviour’ where a higher score indicates more positive behaviour.

For parents, the first two questionnaires were sent home and returned to school via the participant’s school bag prior to completing the visual assessment (as described below). The SDQ was completed verbally via telephone call with a member of the research team (Dr Lynne McKerr, School of Education, Queen’s University Belfast, or author ELM). Teachers were provided with written copies of all questionnaires for each participating pupil in their class. Completed questionnaires were collected by a member of the research team.

3.2.3.2. Vision assessment

Following parent and teacher questioning, each participant underwent a full vision assessment which was carried out on the school premises during the school day. Parents were invited to attend.

The following testing procedures were carried out where possible;

i) Binocular visual function assessment: ocular movements, ocular alignment, stereopsis.
ii) Visual acuity (distance and near)
iii) Visual field assessment
iv) Contrast sensitivity
v) Refraction and accommodative function
vi) Ocular health assessment

If a potentially correctable visual deficit was identified following the vision assessment, i.e. uncorrected refractive error or presence of an accommodative lag, spectacles were provided free of charge to correct these visual deficits. Thus, results presented in subsequent chapters reflect best-corrected refractive state. Where an atypical finding which warranted further investigation was discovered (for example, ocular health abnormality), onward referral to an appropriate healthcare professional was instigated.

3.2.3.2.1. Binocular visual function assessment

Ocular movements were assessed by directing the participant to follow a pen torch light positioned 40cm from the participant as it moved in eight cardinal

positions of gaze. Where cooperation allowed, participants were asked to follow the pen torch light as it deviated horizontally and vertically from the primary position in order to assess quality of smooth pursuit eye movements. Saccadic eye movements were also assessed horizontally and vertically from the participant's eye/midline by positioning two pen torch lights approximately 20cm apart. Participants were instructed to shift their gaze between the two light sources. The examiner objectively assessed the quality of ocular movements which were subsequently recorded as typical or atypical. Presence of nystagmus was also documented.

Optokinetic Nystagmus (OKN) responses were assessed binocularly using an OKN drum. The examiner observed the participant's visual response when the drum was rotated clockwise and anticlockwise and documented whether the response was symmetrical or asymmetrical in both directions, or absent.

Ocular alignment was assessed using a cover test at both distance (3m) and near fixation (40cm), with and without glasses where applicable, to assess the presence of a heterotropia or heterophoria *(*Figure 3.1; Rowe, 2012).

Figure 3.1: Assessing ocular alignment at near with cover test.

Stereopsis was assessed using the Frisby Near Stereotest. This test measures both ‘crossed’ (target appears to ‘pop’ out towards the subject) and ‘uncrossed’ (target appears to ‘fall away’ from the subject) stereoacuity. The Frisby stereotest is comprised of a demonstration plate and three test plates varying in thickness (6mm, 3mm and 1.5mm). The demonstration plate was first presented in order to determine the participant’s understanding of the task. Displayed on the plate were four equally sized boxes, with one box containing a circular, patterned target. The participant was instructed to “find the ball” by pointing at or touching the correct box on the plate. If the participant did not respond in this manner, the examiner could observe the participant’s eye movements to determine whether the “ball” had been successfully identified. Once understanding of the test had been established, participants were then presented with the test plates, beginning with thickest 6mm plate. The examiner presented the plate in the ‘crossed’ position. The participant was again asked to “find the ball”. Once successfully located, the examiner

randomly altered the orientation of the plate and the task was repeated. If the circular pattern was correctly identified, the 3mm thickness plate was presented. The process was repeated and if the participant gave accurate responses, the final 1.5mm plate was presented. Testing was carried out at 50cm which allowed testing of stereoacuity ranging from 215 to 55 seconds of arc (”). Stereoacuity better than or equal to 85” is considered normal in both primary and post-primary children when assessed using the Frisby Stereotest (Anketell et al., 2013).

3.2.3.2.2. Visual acuity

Binocular visual acuity was measured at distance (3m) and near (40cm), with best correction. In subsequent visual acuity analyses, the participant’s best-corrected visual acuity using the most complex test described was considered. A test suitable for the participant’s ability was selected, summarised in descending order of complexity as follows:

The Sonksen crowded logMAR test at 3m and 40cm was used if the participant was able to name or match letters using a corresponding matching card (Figure 3.2). This test assesses visual acuity ranging from 0.8logMAR to -0.3logMAR using a flip-chart booklet. Whether the participants could correctly identify the letters used in the Sonksen test was first determined using a matching card presented at near. If the participant was able to name or match all letters correctly, they were then presented with single letters displayed at 3m starting with the largest letter (0.8logMAR). Participants were asked to identify each letter in the single booklet until an error was made. Participants were then presented with the crowded version of this task, starting at an acuity

level two lines above the single acuity score, as per the manufacturer's instructions. Participants were then required to identify letters presented in sets of four letters surrounded by a crowding bar in descending order of size. Progression to the next line of crowded optotypes was achieved when the participant correctly identified at least two letters on each line. Threshold was recorded as the lowest acuity level where the participant correctly identified at least two optotypes. Visual acuity was scored letter-by-letter in accordance with the test instructions; each letter carried a weight of 0.025logMAR.

The Sonksen crowded logMAR near acuity test positioned 40cm from the participant was attempted binocularly with best-correction if a participant was able to comply with the Sonksen crowded logMAR test at 3m. As with the Sonksen crowded logMAR test at 3m, the 40cm chart contains four letters surrounded by a crowding bar and measures visual acuity ranging from 1.3logMAR to 0.0logMAR. The participant was asked to identify the first letter on each visual acuity line until an error was made. They were then asked to read the entire line of letters two lines above where the error was made. Threshold was recorded as the lowest visual acuity score where at least two letters were correctly identified. As with the 3m chart, visual acuity was recorded letter-by-letter in accordance with the test instructions. The Sonksen near acuity test invokes a 'floor effect' for visually normal observers as the lowest measurable score is restricted to 0.0logMAR.

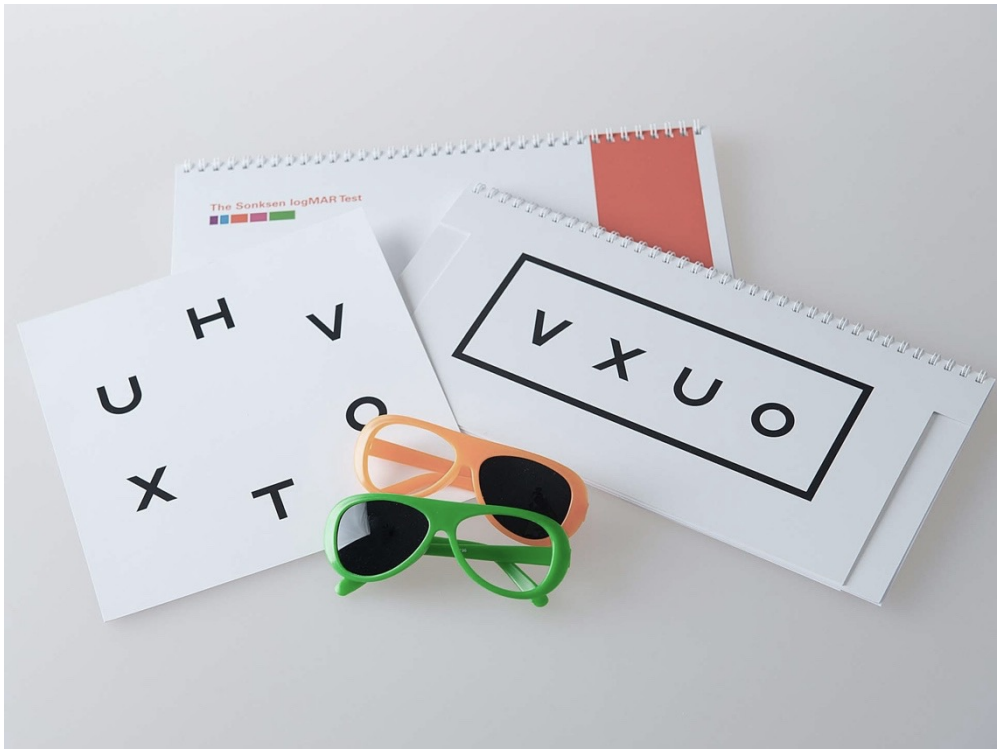


Figure 3.2: Sonksen crowded logMAR distance visual acuity flipchart, letter matching card and occlusion glasses.

If the participant was unable to comply with the demands of the Sonksen crowded logMAR chart, LEA crowded symbols at 3m were attempted (Figure 3.3). The LEA symbols are comprised of four simple shapes (house, circle, square, heart/apple). Each symbol appears as a small circle below the threshold of recognition (Hyvärinen et al., 1980; Becker et al., 2002). Prior to commencing testing, participants were asked to identify the four symbols on a matching card to ensure they could recognise all the symbols. They could do so by naming, matching or signing the symbols. The crowded LEA charts were presented using an internally illuminated cabinet displaying five optotypes on each line, with standardised progression of optotype sizes (Hyvärinen et al., 1980; Anstice & Thompson, 2014). The visual acuity chart was comprised of

13 lines testing visual acuity ranging from 0.8 to -0.4 logMAR at 3m distance. Visual acuity testing began by asking participants to identify the first or last symbol on each line until an error was made. The participant was then asked to identify the whole line of symbols two lines above where they had previously misidentified a symbol. If three or more symbols were correctly identified on a line, participants progressed to the next line and continued in this fashion until at least three symbols were misidentified. Visual acuity was recorded as the lowest line at which the child identified at least three symbols correctly, rather than single optotype scoring, according to the developer's instructions (LEA-Test Ltd, 2018; Becker et al., 2002). If a participant could not complete the crowded version of this test, the LEA single symbols were attempted at 3m, with testing conducted in the same manner as the LEA crowded visual acuity chart. The LEA singles chart is displayed using a flip-chart booklet and measures visual acuity ranging from 1.0logMAR to -0.3logMAR. Four symbols are presented on each page. The examiner used an opaque, L-shaped card to obscure three symbols. The participant was then required to identify the remaining symbol. If two out of four symbols were correctly identified at a given acuity level, the examiner then showed one of the symbols a second time to offer a fifth choice. As with the LEA crowded acuity chart, visual acuity threshold was recorded as the smallest optotype size where at least three symbols were correctly identified.

A binocular, best-corrected near visual acuity measure was attempted using the LEA crowded symbol test at 40cm for participants who were able to comply with the LEA crowded symbols at 3m. The near chart measures visual acuity

ranging from 0.7logMAR to -0.1logMAR. Testing was conducted using the same test procedure as described for the LEA crowded symbols chart at 3m. All participants who were able to comply with the Sonksen crowded logMAR test were also tested using the LEA crowded and single symbols at 3m to allow calculation of a crowding ratio as discussed in Section 3.2.3.5. Visual acuity scores using the LEA logMAR charts were recorded line-by-line.

Figure 3.3: LEA crowded symbol distance visual acuity chart positioned 3m from the participant.

Where a measure of recognition acuity using the aforementioned tests was not possible, a measure of resolution acuity was attempted using the Cardiff Acuity Test (Figure 3.4). This preferential looking test assesses 11 visual acuity levels ranging from 6/60 to 6/6 when positioned 1m from the subject, or 6/120 to 6/12 when positioned 50cm from the subject. The test contains three test cards for each visual acuity level. Each test card was presented at the participant's eye level where they were then required to identify the position of a picture presented either at the top or bottom of the test card. The examiner

was blinded to the position of the picture but observed the participant's eye movements to determine if the position of the picture had been correctly identified. To progress to the next card, correct identification of the picture on two out of three cards at each visual acuity level was required. Threshold was determined as the highest spatial frequency stimulus for which this level of success was achieved. Testing was first attempted at 1m and reduced to 50cm if the participant was not compliant at 1m. Visual acuity results obtained using the Cardiff Acuity Test were converted to logMAR notation for consistency with aforementioned visual acuity tests.

Figure 3.4: Cardiff Acuity Test cards.

If a formal measure of visual acuity could not be determined using the above-mentioned visual acuity tests, a functional, binocular measure of vision was determined using the Bradford Visual Function Box as described by Pilling et al. (2016). Different sized objects were introduced into the participant's visual field at distance between 30 and 50cm, and the participant's response was

observed (Pilling et al., 2016). The objects varied in shape, colour and size; presentation started with a push-up doll 130mm in height and finishing with a 6mm diameter red bead (Figure 3.5). Objects were presented in descending order of size.

Figure 3.5: Objects which form the Bradford Visual Function Box.

3.2.3.2.3. Visual field assessment

Binocular, gross visual field assessment was carried out using a perimeter arc technique with a 5cm diameter white Stycar ball. One examiner stood behind the participant and presented the Stycar ball, secured to a wooden rod, into the participant's visual field in eight positions of gaze. A second examiner, sitting opposite the participant, observed the participant's visual responses to when the Stycar ball was first noticed in the participant's visual field (Figure 3.6). Comment on the fullness and symmetry of the participant's visual field was documented following the assessment.

Figure 3.6: Gross, binocular visual field assessment using perimeter arc technique with 5cm diameter Stycar ball.

3.2.3.2.4. Contrast sensitivity

Binocular contrast sensitivity was measured from all participants using the Cardiff Contrast Test at 50cm with best-correction. This test comprises vanishing optotypes and uses a preferential looking technique, similar to the Cardiff Acuity Test. The test measures contrast sensitivity ranging from 2.17 (46%) to 100 (1%) across 12 different contrast levels. Targets of fixed spatial frequency are presented at decreasing levels of contrast. Contrast sensitivity was determined as the lowest contrast at which the stimulus position on two of three cards were correctly identified. Values less than 33.33 (3%) and 50 (2%) were considered outside the normal range for participants aged 3-4 years and greater than 4 years respectively (Barbareza et al., 2008).

3.2.3.2.5. Accommodative function and refractive error

Accommodative responses to a target at 25cm were assessed with best correction using dynamic retinoscopy. The Ulster-Cardiff accommodation cube was employed for this measure. The participant was required to view a visually detailed target at a fixed distance of 25cm (inducing a 4D demand; Figure 3.7). The examiner observed the participant's retinoscopy reflex and moved the retinoscope to the distance where the reflex was neutralised. The position of the retinoscope when neutral was observed identified the point at which the participant was focused. This distance was converted to a dioptric value and responses between 2.94 and 4.46D were considered accurate. Responses less than 2.94D were indicative of an accommodative lag (McClelland & Saunders, 2004).

Figure 3.7: Assessment of accommodative function through participant's bifocal spectacles using dynamic retinoscopy with the Ulster-Cardiff cube.

Cycloplegic retinoscopy was attempted on all participants, where consent from parents had been given, to determine magnitude of refractive error. One drop of Cyclopentolate Hydrochloride 1% was instilled in both eyes. After

instillation, subjects returned to class for 30 minutes before returning for cycloplegic retinoscopy using a trial frame and loose lenses where compliance allowed or using retinoscopy racks if the trial frame was not tolerated. Information sheets developed by the College of Optometrists which detailed the potential side effects of Cyclopentolate Hydrochloride were sent home to parents via the participant's schoolbag. Teachers were verbally informed of potential side effects by the examiners on the day of testing.

3.2.3.2.6. Ocular health assessment

Assessment of posterior ocular health was carried out following cycloplegia using indirect ophthalmoscopy with a 22D Volk lens and direct ophthalmoscope light to obtain a wide view of the fundus (Figure 3.8). Direct ophthalmoscopy was performed to examine the external eye, media and to obtain an enlarged view of the optic nerve and macula. Where cycloplegia was not applied, posterior ocular health was assessed using direct ophthalmoscopy.

Figure 3.8: Ocular health assessment using indirect ophthalmoscopy with 22D Volk lens and direct ophthalmoscope light.

3.2.3.3. Tests of visual perception

Following the visual assessment, and after vision deficits which required optometric management were corrected (e.g. uncorrected refractive error), participants were asked to complete three tests of visual perception.

3.2.3.3.1. LEA Mailbox task

The first task was the LEA Mailbox (Figure 3.9 and Figure 3.10); a test designed to assess a participant's perception of line orientation and visually guided motion. Participants were required to observe the position of a slit opening on a yellow, circular plastic disc and subsequently orientate their hand to post a white card (10x10cm) through the slit. The slit was presented in four orientations; 180, 90, 135 and 45 degrees. The examiner handed the participant the card eight times; the first four presentations of the card were in

the same orientation as the slit opening, and subsequent presentations were perpendicular to the slit opening. Scoring of the LEA mailbox task is described in Section 3.2.3.3.4.

Figure 3.9: Examiner explaining LEA Mailbox task to participant.

3.2.3.3.2. LEA Rectangles task

The second task was the LEA rectangles (Figure 3.10) designed to assess size perception and ability to reproduce visual objects. The task consists of two sets of five rectangles, which have a consistent surface area but differ in size and shape. One set of rectangles is black, the other is grey. Participants were required to complete three tasks using the rectangles. The first, ‘LEA method’, used the developer’s recommended test procedure: participants were asked to place the five grey rectangles on top of the five black rectangles which the examiner had positioned in descending order of height. The second and third task were developed by Williams et al. (2015), the first of which, ‘open

pattern', required the examiner to produce a simple open pattern using the rectangles, where each rectangle was spaced 1-2cm apart. The participant was then asked to reproduce the pattern next to the original using an identical set of rectangles. The final task, 'closed pattern', was the same as the 'open pattern', except the edges of adjacent rectangles were touching. As with the 'open pattern', the participant was required to reproduce the pattern presented by the examiner. For the latter two tasks, the order of the rectangles for each pattern was random. The shapes were presented to the participant on a plain white board to eliminate any visual distractions from the work surface and ensure maximum contrast with the background. Scoring of the LEA rectangles tasks is described in Section 3.2.3.3.4.

3.2.3.3.3. Shape Sorter task

The final test of visual perception was a shape sorter task which is based on a similar task developed by Atkinson et al. (2002) as part of a battery of tests to examine functional vision. The task assesses both shape recognition and

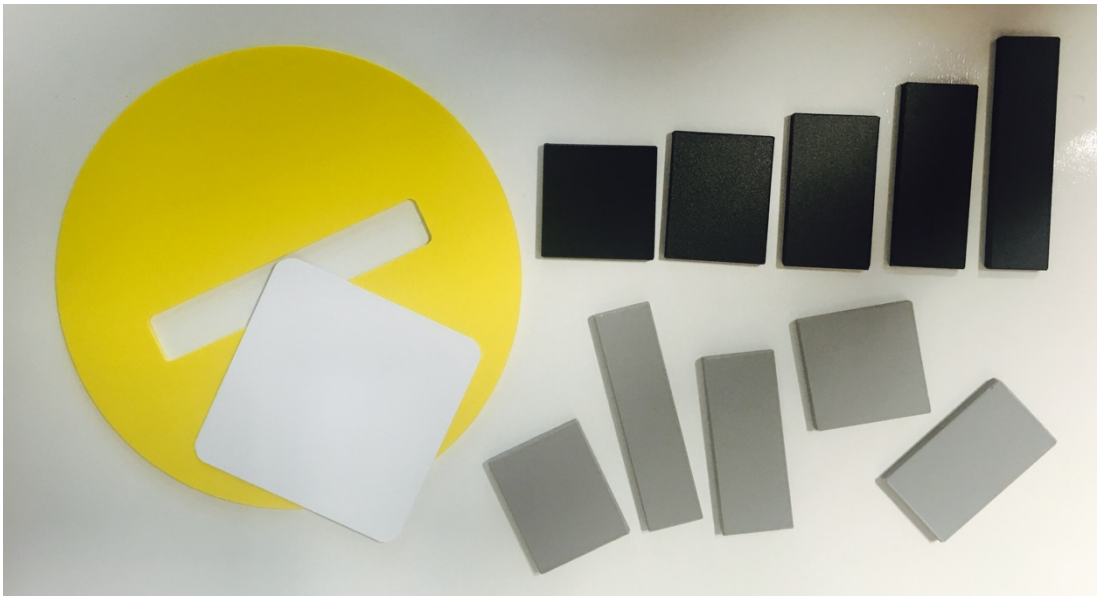


Figure 3.10: LEA Mailbox (left) and LEA rectangles task (right).

visually guided action (Atkinson et al., 2002). The participant was required to insert a wooden shape into an appropriately shaped well on a wooden board. Both a three- and a five-shape board were used (Figure 3.11). Participants were first presented with the three-shape board. All shapes were initially removed from the corresponding wells. The examiner then handed a shape to the participant who inserted it into the board. This was then removed, and the next shape was presented to the participant. If all three shapes were correctly inserted, the participant was presented with the five-shape board and the procedure was repeated. A record of which shapes were correctly/incorrectly inserted was recorded. Scoring of the shape sorter tasks is described in Section 3.2.3.3.4.

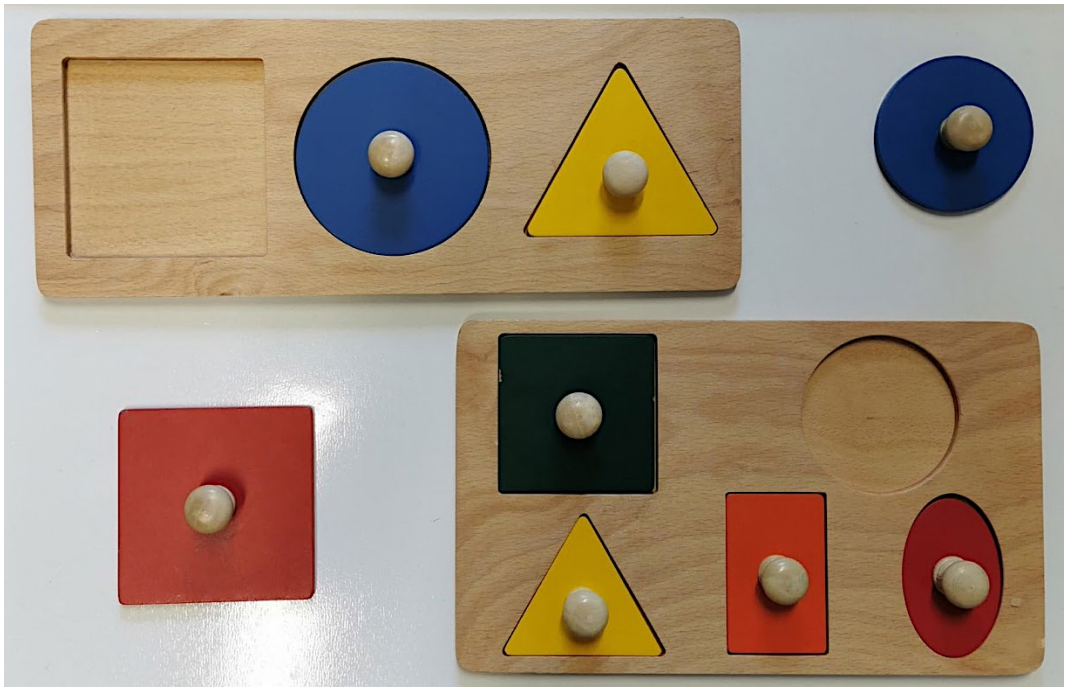


Figure 3.11: Three-shape (top) and five-shape (bottom) sorter task.

3.2.3.3.4. Scoring of tasks

Participants' performance on each task was scored according to whether they had 'no problems', 'minor/moderate problems' or 'major problems' (Williams et

al., 2015). Participants who were unable to comprehend or engage with the task were recorded as 'unable to perform' and their data were excluded from visual perceptual task analyses. Table 3.1 describes how each task was scored.

Task	No problems	Minor/moderate problems	Major problems	Unable to perform
LEA Mailbox	All correct	Up to 3 errors	3-8 errors	Unable to comprehend/engage with task
LEA Rectangles	All correct	2 errors	3-5 errors	Unable to comprehend/engage with task
Three-Shape sorter	All correct	1 error	2-3 errors	Unable to comprehend/engage with task
Five-Shape sorter	All correct	1-2 errors	3-5 errors	Unable to comprehend/engage with task

Table 3.1: Scores assigned to each visual perception task.

3.2.3.4. Visual behaviour observations

Observation of the participant's visual behaviour was documented throughout the assessment. This included whether the participant was aware of moving objects, elicited a normal blink reflex, had an abnormal head posture, made eye contact with the examiner, expressed visual latency when looking at a target, or had non-purposeful gaze. Observation of the participant's reaction to light was also documented. How each of these behaviours were observed and scored is described in Table 3.2. If a participant's 'awareness of movement' and 'blink reflex' were recorded as 'present', this was deemed a 'typical' response, whereas presence of 'visual latency' and 'non-purposeful gaze' was deemed 'atypical'. Reaction to light was classified as 'typical' if a participant executed appropriate eye movements towards the light source (pen

torch) and did not avoid it. Absent or inconsistent eye contact was deemed 'atypical'.

Observed behaviour	Definition	Score
Awareness of movement[1]	Does participant look towards examiner or objects presented in the participant's field of vision?	'Present' or 'not present'
Blink reflex[1]	Does participant blink in response to an object coming towards their face?	'Present' or 'not present'
Head posture[2]	Is participant's head posture deviated from the normal primary position?	'Normal' or 'Abnormal'
Eye contact	Does participant make eye contact with the examiner or avoid eye contact?	'Yes', 'No' or 'Inconsistent'
Visual latency[1]	Is there a delay in turning towards and looking at an object of regard?	'Present' or 'not present'
Non-purposeful gaze[1]	Does participant show non-purposeful gaze (i.e. staring aimlessly into space)?	'Present' or 'not present'
Reaction to light[1]	Does participant turn towards pen torch light or do they look away from/avoid this?	'Turns towards' or 'avoids'

Table 3.2: Battery of observed visual behaviours definitions and scoring used in the present study, defined according to [1]Roman-Lantzy, 2007a criteria, or [2]AAPOS definition.

3.2.3.5. Crowding ratios: Comparison of crowded and single optotype visual acuity

For participants who were able to comply with recognition visual acuity testing by either naming, matching or signing optotypes, a comparison of crowded and single optotype visual acuity was explored using the LEA symbols. Acuity testing was carried out using the crowded and single version of the LEA symbol test charts high (100%; black on white) contrast. The LEA symbols were selected for this comparison as it was expected that a broader range of participants could comply with this test rather than the Sonksen logMAR acuity

test. Testing procedures for the LEA symbols have been described previously (Section 3.2.3.2.2.). Crowded optotype visual acuity was tested first, followed by the LEA single optotypes. If a measure on both the crowded and single optotype acuity test charts was achieved, calculation of a crowding ratio was possible. To calculate a crowding ratio for each participant, logMAR visual acuity scores were first converted to MAR acuity equivalents. The crowded MAR visual acuity was then divided by the single MAR visual acuity (see example in Figure 3.12). If a participant had a crowding ratio of 1, this indicated their visual acuity scores on both the crowded and single LEA symbols acuity charts were the same. If the crowding ratio was >1, this indicated the participant's single optotype visual acuity score was better than their crowded optotype visual acuity score. If a participant achieved a crowding ratio <1, this indicated their crowded optotype visual acuity score was better than the single optotype visual acuity score.

Crowding Ratio Calculation example

Participant achieved the following visual acuity scores using the high contrast LEA symbols acuity charts:

Crowded optotype score = 0.3logMAR

Single optotype score = 0.1logMAR

Calculation of MAR

MAR were determined using the following formula:

$$\textbf{MAR} = 10^{\textbf{logMAR Score}}$$

Therefore, using the above example,

$$\text{Crowded MAR} = 10^{0.3} = 1.995$$

$$\text{Single MAR} = 10^{0.1} = 1.259$$

Calculation of crowding ratio

Crowding ratio was calculated using the following formula:

$$\frac{\textbf{Crowded MAR}}{\textbf{Single MAR}}$$

Therefore, using the example above,

$$\text{Crowding ratio} = \frac{1.995}{1.259} = 1.58$$

Therefore, in this example, the participant has a **crowding ratio of 1.58** measured using the crowded and single optotype LEA symbol visual acuity charts at high contrast.

Figure 3.12: Example showing how crowding ratios were calculated for each participant.

3.2.4. Parent and teacher reporting

Results of the in-school vision assessment and responses from the parental questionnaires were used to create a 'Vision Report' which was provided to parents, teachers and other relevant healthcare professionals following the vision assessment (Appendix 12). The Vision Report is described in detail in Chapter 8, however, in brief, it detailed the results of the aforementioned assessment procedures in layman's terms. Where a visual deficit was identified throughout the assessment, advice and strategies were provided to parents and teachers on how they could ameliorate the impact of the visual deficit on aspects of the participant's daily living through modification of the home or educational environment. For example, if a child had reduced visual acuity, advice was provided on appropriate print size which would be easily discriminable for this child. If a child had reduced contrast sensitivity, parents and teachers were advised to use high contrast print and/or play materials in the child's environment and increase lighting in the child's environment. If difficulties associated with CVI were identified on the VSI, such as difficulty interpreting information in a crowded or 'busy' format, practical advice regarding the reduction of clutter in the child's home environment or workspace was detailed.

3.2.5. Follow-up vision assessments

Two to five months after the initial vision assessment, each participant was re-assessed (by author ELM and SAB) using the same procedures described in Section 3.2.3.2. The purpose of this follow-up assessment was to determine whether any vision needs or deficits which were identified during the first vision

assessment had been mitigated at the second assessment. This was a key component of the SEE Project. Results of the follow-up vision assessment were used to determine whether providing comprehensive eyecare for children attending special schools, with subsequent provision of written reports to parents and teachers, was effective in reducing unmet visual needs. Parent and teacher opinion of the in-school vision assessment and reporting of visual and CVI status was evaluated at the end of the study. The methods and results of this evaluation are reported in Chapter 8. To ensure all participants were tested with appropriate refractive correction, this follow-up visit enabled assessment on the tests of visual perception (see Section 3.2.3.3) and visual acuity crowding ratios (see Section 3.2.3.5) if a participant had been found to require refractive correction at their initial assessment. The purpose of this was to ensure CVI assessments were carried out under 'best-corrected' conditions.

3.2.6. Typically developing control population attending mainstream education

To allow comparison of crowding ratio and parental VSI results obtained from participants with SEN, a group of typically developing children attending mainstream education was recruited to act as a control group. This facilitated direct comparisons to be made between the population with SEN and typically developing control group in order to ascertain whether crowding ratios and parental VSI responses differed between these two populations. The sample of children attending mainstream education are discussed in more detail in Chapter 4.

3.2.7. Study steering group

Prior to commencing the study, a steering group was formed which included, in addition to the research team, parents and teachers of children with special educational needs, an orthoptist and the Head of Optometry in the Belfast Health and Social Care Trust. The purpose of the steering group was to ensure the views and needs of service users (i.e. children, parents and teachers) were considered at the heart of the project. Parents and teachers also provided valuable feedback into the study recruitment materials, such as comment on the suitability of parent and child information leaflets, and recruitment activity such as facilitating research team attendance at the school's annual 'Summer Fair' to discuss the study with prospective participants.

3.2.8. Pilot study

Prior to conducting the main study at the largest special school in Northern Ireland, a pilot study was initiated at Roddensvale Special School (Black, 2019). The purpose of the pilot study was manifold; it provided the opportunity to trial the study recruitment materials, Vision Report template and parent and teacher questionnaires. In addition, the pilot study proved invaluable in refining the vision assessment procedures administered during the study and providing the author with training in the vision assessment of children with SEN. The author gained vital information regarding how to adapt the assessment procedures to suit the needs of each child in order to achieve maximal compliance. Throughout the vision assessment, differences in behavior between children with varying diagnoses was evident, for example, many children with autism spectrum disorder cooperated best in a calm,

controlled environment compared to some children with Down syndrome who preferred a more exciting and animated experience.

3.2.9. Data entry, analysis and statistics

Each participant was assigned a unique identifying code to ensure data remained anonymised. Data were initially entered into Microsoft Excel 2016 where error checking and cleaning occurred prior to transfer into a statistical software package (IBM SPSS Statistics Version 25). Data were then coded prior to analysis. A combination of parametric and non-parametric analyses was employed dependent on the normality of the data as determined by Shapiro-Wilk test of normality.

3.3. Conclusion

This chapter has detailed the assessment procedures employed in the studies detailed in Chapter 4, 5, 6 and 7 of this thesis.

Chapter 4

Investigating crowded and uncrowded visual acuity and cerebral visual impairment (CVI) in typically developing children in mainstream education

4.0. Chapter overview

This chapter describes results of crowded and uncrowded optotype acuity testing using the LEA symbols on a population of typically developing children in mainstream education. Responses on the Visual Skills Inventory for this typically developing population are also considered. Participants in this chapter will act as a control group to allow comparison of performance with the population with special educational needs (SEN) in subsequent chapters.

4.1. Introduction

Visual crowding is a well-established phenomenon which refers to the increased difficulty experienced in discriminating between visual stimuli when they are closely flanked by other visual stimuli (Flom et al., 1963). Visual crowding has been evidenced in young children (4-6 years) with normal vision (Jeon et al., 2010; Dekker et al., 2012), strabismic and amblyopic children (Rydberg, 1997; Rydberg et al., 1999), and visually impaired children (Pardhan, 1997; Huurneman et al., 2014; Stiers et al., 2004). The effect of visual crowding typically reduces with increasing age. Atkinson et al. (1988) report that crowding responses become adult-like between 5 to 7 years of age. Norgett and Siderov (2011) report that maturation of crowded visual acuity is

still occurring between 4 and 9 years. Other work has shown continuing maturation up to 11 years of age and into adolescence (Jeon et al., 2010; Huurneman et al., 2012).

Interpretation of visual information in a crowded scene is a complex process. Several areas of the brain (V1-V4 and later in visual processing) have been suggested as the neurological sites where crowded visual information is processed, indicating that interpretation of crowded information does not occur at one single level of visual processing, but rather at multiple levels along the visual pathway (Whitney & Levi, 2011). As such, it is unsurprising that crowding deficits are commonly reported in childhood when visual pathways are still developing (Jeon et al., 2010), and amongst children with neurological damage affecting the visual pathways (Jacobson et al., 1996; Pike et al., 1994).

Assessment of visual crowding can be carried out by comparing visual acuity measured using crowded optotypes with visual acuity measured using single optotypes (Dekker et al., 2012; van Genderen et al., 2012; van der Zee et al., 2017). Using this method, determination of a ‘crowding ratio’ (CR) is possible. This ratio is calculated by dividing the acuity score obtained from a crowded optotype test with that obtained using a single optotype test (or vice versa depending on the unit of assessment). The CR has been proposed as a potential screening method used to identify children with previously unrecognised neurological damage who may be at risk of CVI (van der Zee et al., 2017). Van Genderen et al. (2012) also report that an abnormal crowding

ratio may be indicative of dorsal stream dysfunction associated with CVI as over 40% of children (aged five to 16 years) diagnosed with CVI had an abnormal crowding ratio compared to children without a CVI diagnosis (van Genderen et al., 2012), however further studies are required to explore this finding.

Another method which can be used to identify a child's difficulty to interpret and process visual information in a crowded environment is the application of parental questioning. The Visual Skills Inventory (VSI) is designed to identify whether a child has difficulties interpreting complex visual scenes, in addition to other aspects of visual processing (Macintyre-Beon et al., 2012). As discussed in Chapter 2, the VSI is a tool commonly used to investigate and diagnose CVI in children (Mitry et al., 2016).

In order to allow interpretation of results obtained from children with special education needs in subsequent chapters, it was first necessary to obtain normative data from typically developing children attending mainstream primary education. While crowding ratio data using the LEA symbols is available in the scientific literature (Dekker et al., 2012), testing was not carried out in an in-school setting. As discussed in Chapter 3, subsequent chapters of this thesis discuss assessments carried out as part of an in-school vision assessment for children in special schools. Therefore normative data within an in-school setting was desirable to facilitate a more representative comparison of results between a typically developing and population with

SEN. As such, the purpose of this chapter is to address the following questions:

1) What are the expected crowding ratios measured with the LEA symbols acuity test in a typically developing population?
2) How do parents score typically developing children attending a mainstream primary school in Northern Ireland on the Visual Skills Inventory questionnaire?

4.2. Methods

4.2.1. Ethical approval

Ethical approval was granted for this study by Ulster University's Research Ethics Committee (REC/17/0088 and REC/16/0061; see Appendix 13 for ethical approval letters).

4.2.2. Recruitment

Parents of typically developing children attending mainstream primary school who were participating in a study investigating the impact of sustained near tasks on accommodative performance were eligible to participate. Children across all year groups (P1 to P7) were included.

4.2.3. Examination procedures

4.2.3.1. Crowded and single optotype acuity testing

Visual acuity testing was carried out in the child's school during the school day in December 2017. On a different examination day, participants received a full eye examination, including cycloplegic refraction and detection of strabismus

using a cover test. Refractive errors requiring correction were identified and corrected prior to conducting visual acuity testing. Binocular, best-corrected crowded and single optotype visual acuity testing was carried out using the LEA symbols at high contrast. Testing procedures have been described in detail previously (Chapter 3.2.3.2.2). Testing was carried out binocularly as this provides a better representation of a child's functional vision. Visual acuity testing was carried out by investigators ELM, KJS and JAL.

4.2.3.2. Visual Skills Inventory

The VSI has been described previously (Chapter 3.2.3.1.1). Parents of children participating in the 'sustained near tasks' study who indicated they were happy to be re-contacted about future research studies were sent an invite letter (Appendix 14) and VSI questionnaire (Appendix 10) which were sent home via the child's school bag. Completed VSIs were returned to the child's form teacher, from whom author ELM then collected the questionnaires.

4.3. Results

4.3.1. Recruitment

Eighty-one typically developing children across all academic years (P1 to P7) were recruited.

4.3.2. Success rates

A successful measure of crowded and single optotype acuity using the LEA symbols was possible in all children, except one who was excluded from

analysis as they lost interest during acuity testing and did not complete the test. Thirty-four parents returned a VSI for their child (42.0%).

4.3.3. Participant characteristics

The mean (± standard deviation, SD) age of all participants was 8.53 (±1.31) years, ranging from 6.0 to 10.83 years. One child had an alternating exotropia, three were exophoric and one was esophoric with distance fixation. The remaining participants were orthophoric when fixating in the distance (n=76, 93.8%). The mean (± SD) spherical equivalent refractiver error (SER) determined using cycloplegic retinoscopy was +1.55 (±1.49) dioptres and ranged from -1.25 to +7.25 dioptres (median +1.25 dioptres).

4.3.4. LEA symbols visual acuity results

Binocular optotype visual acuity results for both the crowded and single LEA acuity tests for all participants for whom a successful measure was possible (n=80) are shown in Table 4.1 and Figure 4.1. Non-parametric statistics have been applied as the data were not normally distributed (Shapiro-Wilk, $p<0.001$ for both tests). Figure 4.2 shows each participant's crowded optotype acuity compared with single optotype acuity. Wilcoxon signed rank test revealed there was a significant difference between single optotype acuity and crowded optotype acuity ($p<0.001$), with significantly better acuity scores achieved with single optotype presentation (n=53 children). Twenty-six children demonstrated equivalent crowded and single acuities.

LEA Acuity Test	Median (logMAR)	IQR (logMAR)	Range (logMAR)
Crowded optotypes	-0.10	-0.10 to 0.00	-0.40 to 0.10
Single optotypes	-0.20	-0.20 to -0.10	-0.30 to 0.10

Table 4.1: LogMAR median, interquartile range (IQR) and range of each LEA symbol acuity test.

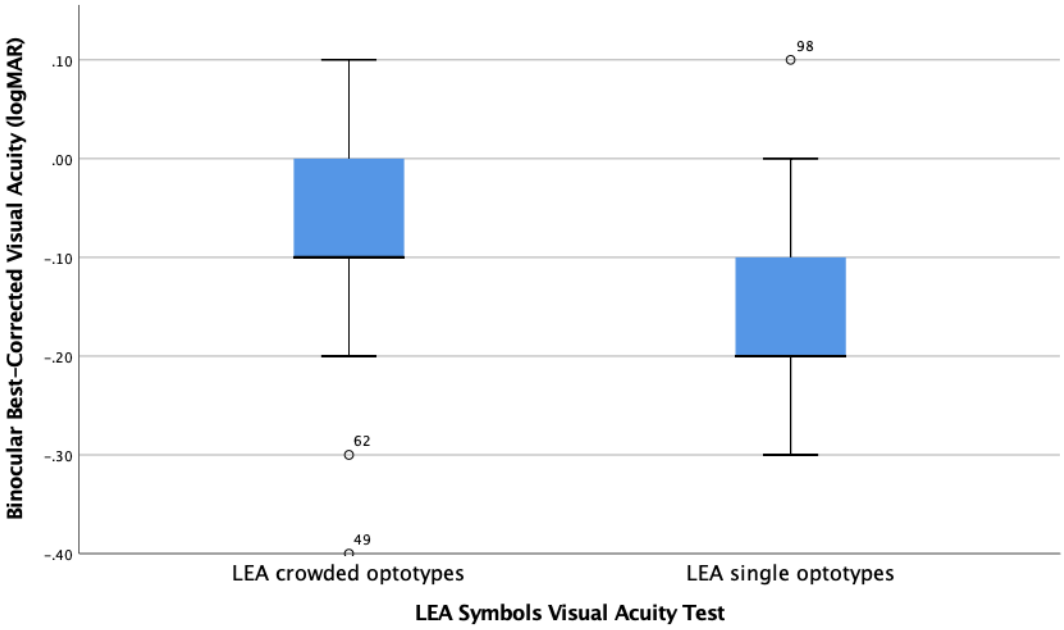


Figure 4.1: Box plots showing results for each LEA symbol acuity test for all typically developing participants for whom a valid measure was obtained (n=80). The solid black line indicates the median and the box indicates the interquartile range. Whiskers indicate 5th and 95th centiles. Outliers are represented by open circles extending beyond the whiskers.

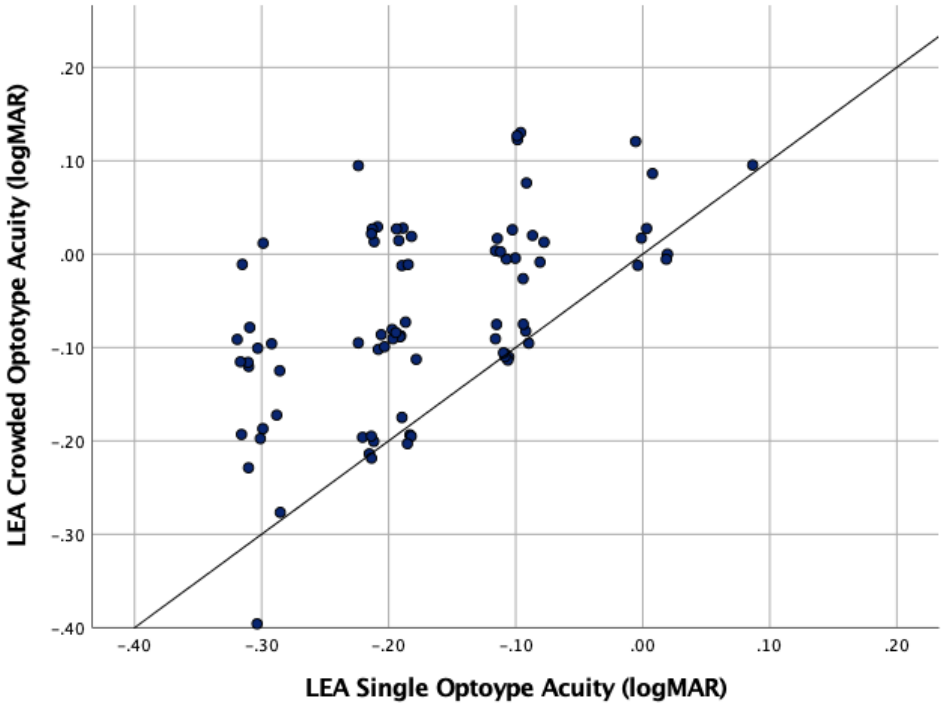


Figure 4.2: Crowding optotype acuity compared with single optotype acuity for each typically developing participant. Note data points have been jittered on x axis to better present individual data.

4.3.5. Visual acuity crowding ratios

Crowding ratios were calculated as described in Chapter 3.2.3.5. For the typically developing study population, the mean crowding ratio was 1.29. To determine what was considered a 'normal' crowding ratio, the 90th percentile was considered, giving a value of 1.58. Participants outside this range were considered to have a crowding ratio 'outside normal limits' (n=3; Figure 4.3). Spearman's rho analysis revealed there was no significant association between age of participants and crowding ratios measured with the LEA symbols (rho=-0.136, p=0.232).

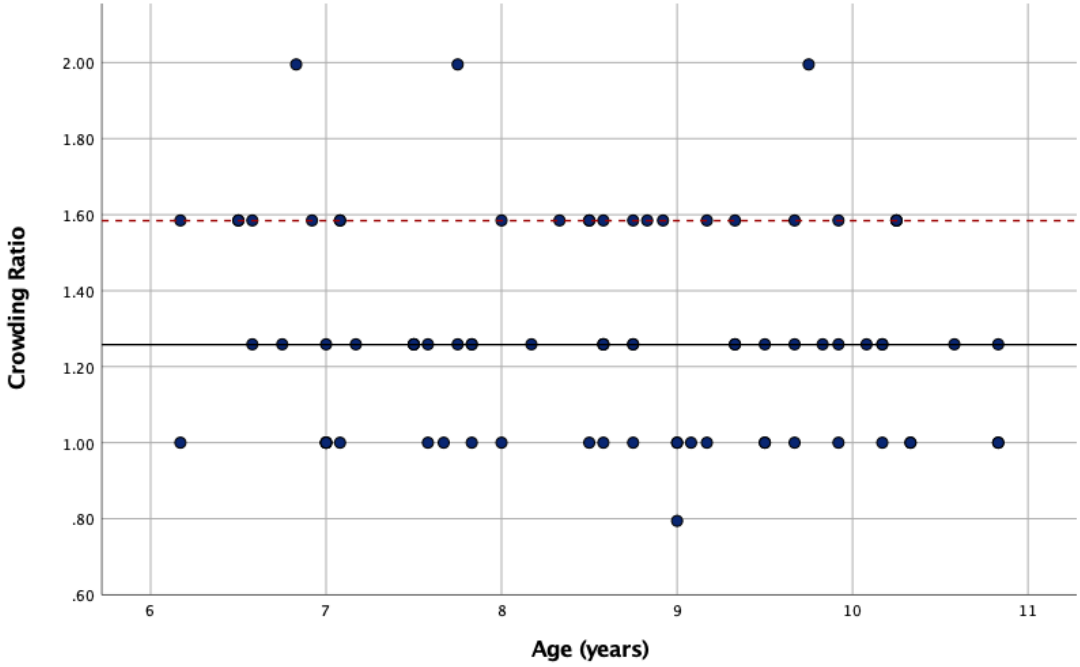


Figure 4.3: Crowding ratio (CR) for each typically developing participant. Black solid line represents median CR, red dashed line represents the 90th percentile.

4.3.6. Visual Skills Inventory

A VSI was returned by parents of 34 children (42.0%; mean age 8.04±1.27 years, range 6.0 to 10.25 years). Figure 4.4 illustrates the responses for the total inventory and each of the six subsections included in the VSI (described in Section 3.2.3.1.2). Mean and median responses for each section of the VSI are shown in Table 4.4. All subsections of the questionnaire had a mean score less than 2 indicating that difficulties were reported less than 'rarely' on average. The section with the highest average score, indicating the most difficulties, was 'noticing multiple targets' which relates to attending to more than one visual stimulus at a time.

Inventory section	Median (IQR)	Mean score ± SD (range)
Total inventory mean score	1.32 (1.05 to 1.52)	1.39 ± 0.43 (0.98 to 2.82)
Section 1. Visual fields	1.38 (1.00 to 1.64)	1.47 ± 0.54 (1.00 to 3.17)
Section 2. Perception of movement	1.20 (1.00 to 1.45)	1.35 ± 0.50 (1.00 to 3.20)
Section 3. Visually guided movement	1.00 (1.00 to 1.22)	1.19 ± 0.38 (1.00 to 2.78)
Section 4. Searching for visual targets	1.50 (1.00 to 1.89)	1.55 ± 0.54 (1.00 to 2.89)
Section 5. Noticing multiple targets	1.40 (1.00 to 2.00)	1.70 ± 0.79 (1.00 to 4.20)
Section 6. Recognising target objects and navigating around	1.06 (1.00 to 1.25)	1.20 ± 0.37 (1.00 to 2.63)

Table 4.2: Median, interquartile range (IQR), mean, standard deviation and range of scores for each subsection of the visual skills inventory for typically developing children.

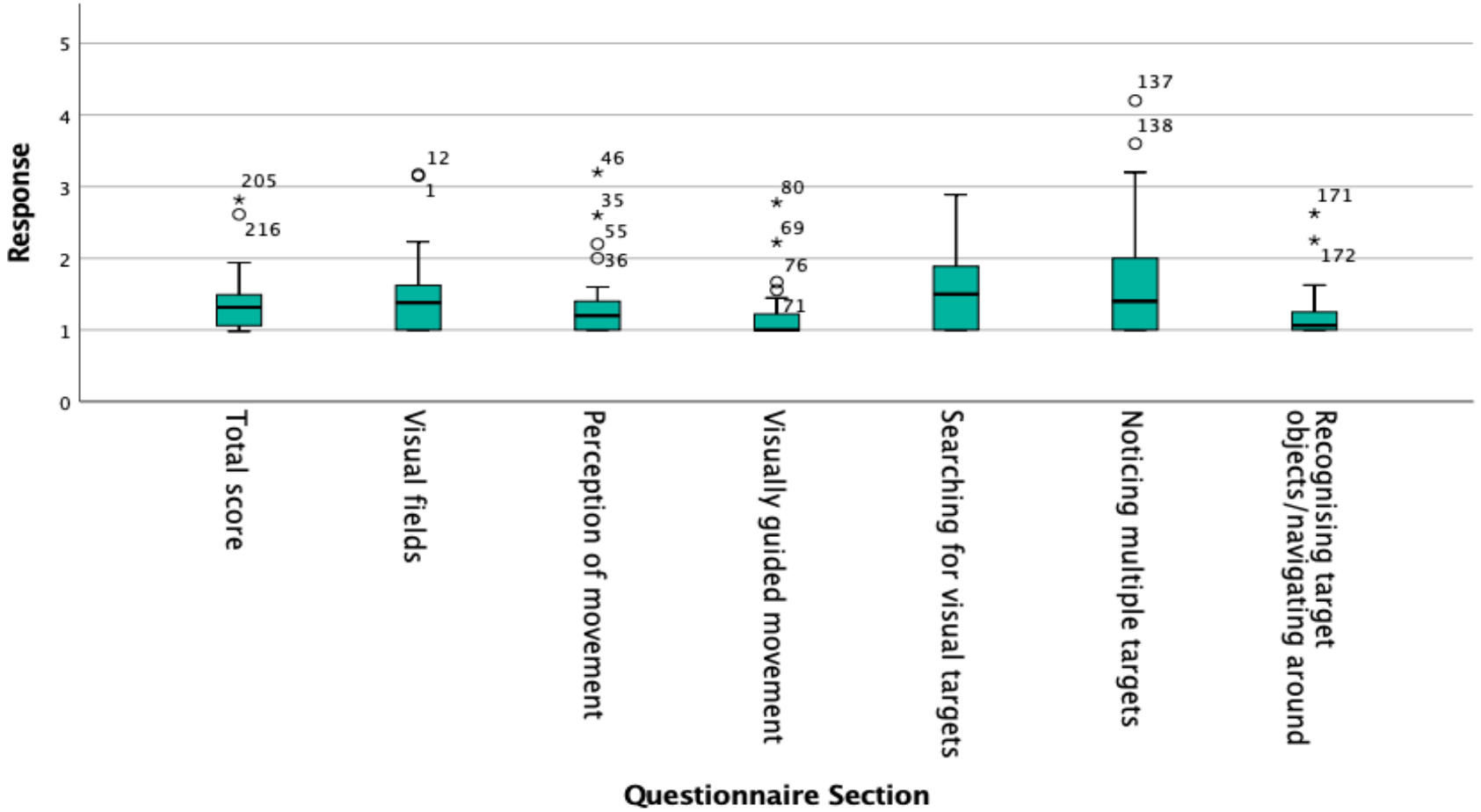


Figure 4.4: Box plots showing responses for the total questionnaire and each subsection of the VSI for the typically developing population. Y-axis scale 1, 2, 3, 4, 5 represents responses of 'never', 'rarely', 'sometimes', 'often' or 'always' respectively. The solid black line indicates the median and the box indicates the interquartile range. Whiskers indicate 5th and 95th centiles. Outliers are represented by open circles or asterisks extending beyond the whiskers.

4.3.6.1. Participants meeting evidence of CVI criteria

In accordance with criteria described by Mitry et al. (2016) and Duke et al., (2019), a mean score of ≥3 in each or any subsection of the VSI was used to define whether a child presented with difficulties associated with CVI. In the typically developing population described in the present chapter, three participants had scores of ≥3 in one or more sections. Their individual scores for each section of the VSI are shown in Table 4.5.

Inventory section	Participant 1 6.5 years, male	Participant 2 6 years, male	Participant 3 7.75 years, male
Total inventory mean score	2.82	1.94	2.61
Section 1: Visual fields	3.17	1.46	3.15
Section 2: Perception of movement	2.60	2.20	3.20
Section 3: Visually guided movement	2.22	1.22	2.78
Section 4: Searching for visual targets	2.78	2.00	2.33
Section 5: Noticing multiple targets	4.20	3.60	3.20
Section 6: Recognising target objects and navigating around	2.63	2.25	1.13
High contrast crowding ratio	Excluded from analysis	1.56	1.30

Table 4.3: Mean score for each subsection of the visual skills inventory for typically developing participants meeting evidence of CVI criteria. Shaded areas illustrate sections with a mean score ≥3.

All participants who met the evidence of CVI criteria were male whose age ranged from six to 7.75 years. One participant had reported difficulties in one section only, one had difficulties in two sections and one had difficulties in three sections. All participants had difficulties reported in the 'noticing multiple targets' section. Two had difficulties relating to 'visual fields' and one had difficulties with 'perception of movement'. All of these sections relate to dorsal stream dysfunction. No difficulties related to ventral stream dysfunction were reported. Participant 3's parent added a comment on the VSI questionnaire stating that the child was diagnosed as having 'tics and absence seizures'; this indicates an underlying neurological issue and may account for his reported difficulties on the VSI. No other significant medical histories were reported.

4.3.6.2. Comparison of crowding ratios and CVI criteria using the VSI

All participants meeting the evidence of CVI criteria (n=3) were identified as having problems noticing multiple targets, indicating difficulty attending to more than one visual stimuli at a time. None of the participants had a mean score ≥3 in the 'searching for visual targets' section, which most closely relates to difficulties interpreting visual information in a crowded environment. While Participant 2 and 3 had better single optotype acuity scores than crowded optotype acuity scores measured using the LEA symbols (two lines and one line better respectively), the crowding ratio was within the normal limit for both participants (1.56 and 1.30 respectively). Participant 1 lost interest during visual acuity testing and was excluded from previous crowding ratio analysis.

Of the three participants who were identified as having a crowding ratio outside normal limits (>1.58), a parent VSI was returned for two. For one participant all items were scored less than ‘rarely’ on average (range 1.0 to 1.75 mean score for all subsections). For the second participant, all sections were scored less than ‘sometimes’ on average (range 1.0 to 2.23 mean score for all subsections). Mean scores on the ‘searching for visual targets’ section (most relevant to interpreting visual information in a crowded environment) were 1.44 and 1.75 for both participants.

4.4. Discussion

4.4.1. Visual acuity results

The majority of typically developing participants in the present study exhibited better single optotype acuity compared to crowded optotype acuity when tested with high contrast LEA symbols charts, which is in agreement with previous studies (e.g. Simmers et al., 1997; Morad et al., 1999; Norgett & Siderov, 2011). Spearman’s rho analysis revealed a significant improvement in visual acuity with increasing age across both visual acuity tests. These findings are in agreement with Dekker et al. (2012) who reported an improvement in binocular visual acuity in typically developing children aged four to 12 years when tested with crowded and single LEA symbols (Dekker et al., 2012). Likewise, Little et al. (2013) also report that, in a typically developing population of 119 children aged 5.8 to 11.8 years, crowded visual acuity measured monocularly with the LEA symbols improved with increasing age. Norgett & Siderov (2011) also report an improvement in monocular visual

acuity in typically developing children aged four to nine years using the crowded Kay Pictures test.

Jeon et al. (2010) show an improvement in single optotype acuity with age and report that groups of children aged eight and 11 years exhibit better binocular visual acuity when tested with single presentation of the Sloan Letter Tumbling E compared to a group of five-year-old children. However, when the Tumbling E was presented in a crowded format surrounded by flanking bars, no significant difference in visual acuity scores was found between the younger and older age groups (5, 8 and 11-year-olds), with all groups exhibiting worse crowded optotype acuity compared to an adult population (Jeon et al., 2010). This lack of reported improvement in crowded optotype acuity with age differs from the aforementioned studies. A reason for this may be due to variation in optotypes used. The spacing between the test optotype and flanking bars was smaller in Jeon et al.'s study, making discrimination of the test optotype more complex. The tumbling E has also previously been reported as a more difficult optotype to discriminate compared to other optotypes used in visual acuity testing (Bailey et al., 2012).

4.4.2. Crowding ratios

The mean crowding ratio generated from high contrast optotype visual acuity scores in the present study was 1.29. This is somewhat better than the mean CR of 1.57 reported by van der Zee et al. (2017) for five to seven-year-old typically developing children. The slightly higher CR noted in van der Zee et al.'s sample may be due to the use of the Cambridge Crowding Cards to

assess acuity and the wider age range of participants. The Cambridge Crowding Cards present letter optotypes rather than symbols; a more challenging task for young children which is likely to yield greater differences in single compared to crowded optotype acuities (van der Zee et al., 2017). Pardhan (1997) reports that in a population of 25 normally-sighted adult participants, mean crowding ratio measured using the Regan letter chart was 1.11. This indicates that development of crowding thresholds in the current population is not complete by age 11. This is consistent with previous work which reports crowded visual acuity is still developing up until adolescence (Jeon et al., 2010; Huurneman et al., 2012).

The present study suggests that, when tested using LEA high contrast crowded and single optotype acuity charts, a crowding ratio greater than 1.58 is outside the normal limit for typically developing children of primary school age. In practical terms, this means that children who have a crowded optotype acuity three or more lines worse than the acuity recorded using a single or isolated high contrast optotype should be considered as having atypical visual crowding. Applying this criterion may help to identify children who require further investigation to identify the cause of their crowding deficit. It also aids in identifying children who may require practical advice to alleviate the impact of visual crowding issues in the child's environment, for example using well-spaced and fewer words on a page when reading. As both crowded and single acuity improved with age, the crowding ratio remained constant with advancing age. This is consistent with findings from Dekker et al. (2012) who report a constant CR in their study population from the age of six to 12 years using high contrast LEA symbol acuity charts.

Results from the present study are closely aligned with those of Dekker et al. (2012). Dekker et al. (2012) tested typically developing children aged four to 12 years on both the crowded and single high contrast LEA symbol acuity charts and reported that a crowding ratio of ≥2.0 was outside the normal limits. Testing was also carried out binocularly, allowing a direct comparison with results from the present study. Mean CR values for Dekker et al.'s six to 12-year-old sample was 1.31 which is also comparable to the mean CR in the present study (mean 1.29).

4.4.3. Visual Skills Inventory

Children included in the present study were, in general, not reported as having problems associated with CVI as assessed using the VSI. This finding is consistent with the report from Macintyre-Beon et al. (2013) who applied the VSI to a 'control' population of 130 typically developing children aged 4.7 to 11.7 years. Macintyre-Beon at al. (2013) report a maximum of five children whose parents reported difficulties on at least one item contained within the VSI. The majority of questions in the inventory elicited no evidence of visual processing difficulty, consistent with the present study (Macintyre-Beon et al., 2013). Likewise, Hellgren et al. (2020) applied the VSI to a population of typically developing 6.5-year-olds and reported that for the majority of questions, behaviours were reported to occur less than 'rarely' on average, consistent with the current study.

Of the three children who were identified by their parent as having problems in at least one section of the VSI in the present study, all had difficulties in the

‘noticing multiple targets’ section, indicating they have difficulty attending to more than one visual stimuli at a time. None were reported as having difficulties in the section most closely linked to the interpretation of visual information in a crowded or busy environment (Section 4 – searching for visual targets), which is consistent with results of visual acuity testing; two of the participants identified as having problems on the VSI had CR scores within normal limits. On the contrary, two of the three participants in the typically developing population who had an abnormal crowding ratio had parent VSI responses available. Neither of these participants were scored as having problems in the ‘searching for visual targets’ section. Although this is a very small sample to allow comparison, it indicates that results from the parental VSI and optotype visual acuity testing may not correlate well. Possible explanation for this is that visual acuity testing is carried out under strict conditions using high contrast optotypes. While this provides an indication of the child’s visual function, it does not provide a clear picture of how the child functions with daily tasks which are carried out under varying light and environmental conditions. For example, one of the questions included in the VSI is ‘Does your child have difficulty finding an item on a supermarket or cupboard shelf?’. Depending on their visual processing ability, some children may find this real-world task more difficult as it requires identification of an object in the presence of multiple surrounding objects (rather than four adjacent symbols), in an environment where there are many other visual and auditory stimuli which compete for the child’s attention. In comparison, visual acuity testing is carried out in a quiet examination room with the child required to attend to one task only. Other children may find visual acuity testing more challenging as the optotypes are smaller than real-world objects. The child is

also required to identify optotypes from a distance, whereas if they are locating an object in a supermarket (as indicated by the VSI question) they can alter their viewing distance. Another possible explanation for the poor correlation between CRs and VSI responses is that the parent is answering on behalf of the child using the VSI. Perhaps if the child was responding to whether they experienced difficulties with certain tasks, results may be more comparable. This may be possible for a typically developing population, however the VSI is not designed to be used in this way and direct questioning of children who have learning or communication disabilities is not an appropriate method.

4.5. Conclusion

In conclusion, results from the present study indicate that a crowding ratio >1.58 measured using the LEA symbols at high contrast can be considered outside normal limits in typically developing, primary school-aged children. Typically developing children generally do not exhibit characteristics associated with CVI identified using the Visual Skills Inventory. Results from the present study will be used to define what is ‘normal’ for a typically developing group of children when considering results from a special educational needs sample in subsequent chapters.

Chapter 5

Investigating the visual profile of a population with Special Educational Needs (SEN)

5.0. Chapter overview

This chapter presents the visual profile of participants with SEN determined using the vision assessment procedures outlined in Section 3.2.3.2.

5.1. Introduction

In order to explore cerebral visual impairment (CVI) and different approaches to identifying CVI in a population with SEN through in-school assessment, the children with SEN required a full eye examination to establish visual status and address correctable visual deficits in the first instance. The purpose of this chapter is to determine and describe the visual characteristics of a population with SEN in Northern Ireland and compare this with previously published literature.

5.2. Methods

Methods and procedures employed in the present study have been discussed in detail in Chapter 3.

5.3. Results

5.3.1. Response rates

A total of 335 pupils attending the largest special school in Northern Ireland were invited to participate, of which 200 parents returned a consent form (59.7% response rate).

5.3.2. Participant characteristics

5.3.2.1. Gender

Seventy percent of participants were male (n=140), representative of the total special educational needs population in Northern Ireland (69.3% male, 30.7% female; available from 2016/17 NI School census data) and the Castle Tower School population (69.6% male, 30.3% female).

5.3.2.2. Age

Participants ranged in age from 3.58 to 19.75 years (mean 10.73±3.85). There was no significant difference in age profile between genders (t=1.208, p=0.229).

5.3.2.3. Level of learning disability

Level of learning disability was derived from the classification included in each participant's Statement of Educational Need (StEN), a document which details a child's educational needs, goals, and actions required to address these needs (NI Direct Government Services, 2018). The number of participants classified into each level of learning disability are described in Table 5.1.

Learning disability	Number of participants (%)
Profound and Multiple Learning Difficulties (PMLD)	2 (1.0)
Severe Learning Difficulties (SLD)	69 (34.5)
Moderate/Severe Learning Difficulties (MLD/SLD)	27 (13.5)
Moderate Learning Difficulties (MLD)	80 (40)
Mild/Moderate Learning Difficulties	1 (0.5)
Complex interaction of needs	1 (0.5)
Delayed learning	1 (0.5)
No permission to access / Statement not in file / information not present on Statement	7 / 6 / 6 (9.5)

Table 5.1: Level of learning disability classification of participants

5.3.2.4. Medical diagnoses and birth history

Information regarding the participants' medical diagnoses was provided through parental questionnaire (as detailed in Section 3.2.3.1.1.) and was available for 171 (85.5%) participants. Table 5.2 describes the medical diagnoses of participants; 42 participants had more than one diagnosis. All diagnoses are included in Table 5.2, thus the total number of diagnoses presented equates to more than 100%.

Medical diagnosis	Number of children (%)
Autism Spectrum Disorder (ASD)	61 (35.7)
Attention Deficit Hyperactivity Disorder (ADHD)	20 (11.7)
Down syndrome (DS)	16 (9.4)
Global Developmental Delay (GDD)	16 (9.4)
Epilepsy	14 (8.2)
Cerebral palsy (CP)	5 (2.9)
Asthma	5 (2.9)
Aspergers	4 (2.3)

Sensory Processing Disorder	3 (1.8)
Dyspraxia	3 (1.8)
Hydrocephalus	3 (1.8)
Hypotonia	2 (1.2)
Prader-Willi Syndrome	2 (1.2)
Heart murmur	2 (1.2)
Glue ear	2 (1.2)
Potocki-Lupski Syndrome	2 (1.2)
Deletion of Chromosome 10	2 (1.2)
Fragile X Syndrome	2 (1.2)
Brain cyst	2 (1.2)
Low muscle tone	2 (1.2)
Underactive thyroid	2 (1.2)
Atrio/Ventricular Septal Defect	2 (1.2)
Marfan Syndrome	1 (0.6)
Microcephaly	1 (0.6)
Sleep apnoea	1 (0.6)
Factor XI deficiency	1 (0.6)
Diabetes	1 (0.6)
Ataxia	1 (0.6)
Hypospadias	1 (0.6)
Hypertension	1 (0.6)
Spina bifida	1 (0.6)
Velocardiofacial Syndrome	1 (0.6)
Neurofibromatosis type 1	1 (0.6)
Polymicrogyria	1 (0.6)
No nerve protection left side of brain	1 (0.6)
Arthrogryposis	1 (0.6)
Osgood-Schlatter disease	1 (0.6)
Anxiety	1 (0.6)
Kernicterus	1 (0.6)
Immune deficiency	1 (0.6)
Holoprosencephaly	1 (0.6)
Cornelia de Lange Syndrome	1 (0.6)
Dancing Eye Syndrome	1 (0.6)
Anal stenosis	1 (0.6)
Dystonia	1 (0.6)
Genetic disorder (unspecified)	1 (0.6)
Grey matter heterotopia	1 (0.6)
Congenital heart disease	1 (0.6)

Table 5.2: Medical diagnoses of participants with SEN according to parental report.

Table 5.3 describes the birth history of participants derived through parental questionnaire. The World Health Organisation (WHO) definition of preterm birth was used to classify participants according to gestational age (GA) at birth as described in Table 5.3 (WHO, 2018a). The level of learning disability of participants for each birth classification is also documented in Table 5.3.

WHO classification	**Number of participants (%)**	**Level of learning disability**
Full term (GA ≥37 weeks)	134 (78.4)	45 SLD 20 MLD/SLD 59 MLD 1 Delayed learning *1 Not specified on StEN* *3 No permission to view StEN* *5 StEN not in file*
Moderate to late preterm (≥32 GA <37 weeks)	19 (11.1)	2 PMLD 6 SLD 3 MLD/SLD 6 MLD 1 Complex interaction of needs *1 No permission to view StEN*
Very preterm (≥28 GA <32 weeks)	5 (2.9)	2 SLD 1 MLD/SLD 1 MLD *1 No permission to view StEN*
Extremely preterm (GA <28 weeks)	2 (1.2)	1 SLD *1 Not specified on StEN*
GA unknown/not stated in parent questionnaire	11 (6.4)	5 SLD 3 MLD *1 Not specified on StEN* *2 No permission to view StEN*

Table 5.3: Birth history of participants with SEN according to parental report.

Fisher's exact test revealed there was no significant relationship between birth history and level of learning disability ($p=0.801$). Only participants with MLD,

MLD/SLD and SLD were included in analysis due to the small number of participants within each of the other level of learning disability classifications.

5.3.3. Visual Profile of Participants

5.3.3.1. Refractive error

A measure of refractive error was achieved in all participants. There was a strong correlation between spherical equivalent refractive error (SER) of the right and left eyes in the population with SEN (Spearman's rho, $\rho=0.909$, $p<0.001$). As such, results from the right eye are presented and used for all subsequent analyses.

Frequency of refractive error type (myopia, emmetropia, low or moderate hyperopia) is shown in Table 5.4. In order to allow comparison with data from typically developing (TD) children aged 6-7 and 12-13 years who participated in the NICER study (an epidemiological study of childhood refractive error for children living in Northern Ireland; O'Donoghue et al., 2010), participants with SEN were grouped according to whether they were in primary or post-primary education at the time of testing. Given that refractive error changes with age in TD populations, types of refractive error found in the SEN primary and post-primary groups were then compared with those reported for typically developing 6-7 and 12-13-year-olds. Mann-Whitney U analysis revealed no significant difference in types of refractive error between primary participants with SEN and typically developing 6-7-year-olds nor post-primary participants with SEN and typically developing 12-13-year-olds ($U=20085.5$, $p=0.655$ and $U=30700.0$, $p=0.927$ respectively).

	Myopia (≤-0.50D)	Emmetropia (>-0.50 to <+0.50)	Low hyperopia (≥+0.50 to <+2.00)	Moderate hyperopia (≥+2.00)	Range, D
Population with SEN (n=200)	27 (13.5%)	45 (22.5%)	78 (39.0%)	50 (25.0%)	-14.00 to 9.25
6-7-year-olds (n=390)	8 (2.1%)	68 (17.4%)	228 (58.5%)	86 (22.1%)	-1.13 to 9.00
12-13-year olds (n=657)	96 (14.6%)	178 (27.1%)	305 (46.4%)	78 (11.9%)	-5.63 to 10.75

Table 5.4: Types of refractive error found in population with SEN compared with typically developing children derived from O'Donoghue et al., (2010).

5.3.3.2. Visual acuity

Best corrected visual acuity (BCVA) was measured using a test suitable for the participant's ability as described in Section 3.2.3.2.3. The visual acuity charts employed to ascertain visual acuity scores at distance and near and the profile of their use are shown in Table 5.5.

Visual acuity test	Number of children (%)
Distance	
Formal measure of distance visual acuity achieved	197 (98.5)
Sonksen crowded letters at 3m	121 (60.5)
LEA crowded symbols at 3m	32 (16.0)
LEA single symbols at 3m	1 (0.5)
Cardiff acuity test at 1m	39 (19.5)
Cardiff acuity test at 50cm	4 (2.0)
Bradford Visual Function Box	1 (0.5)
Measure not possible	2 (1.0)
Near	
Formal measure of near visual acuity achieved	147 (73.5%)
Sonksen crowded letters at 40cm	121 (60.5)
LEA crowded symbols at 40cm	26 (13.0)
Measure not possible	53 (26.5)

Table 5.5: Charts used to ascertain visual acuity scores measured at distance and near for participants with SEN.

5.3.3.2.1. Visual acuity results

Participants' binocular BCVA at both distance and near are reported. Binocular acuity is presented as this better represents the participants' functional vision and is the most appropriate acuity metric to compare with subsequent tests used to probe for evidence of CVI, all of which were carried out binocularly.

Median, interquartile range (IQR) and range of distance and near visual acuities for all participants are shown in Table 5.6. Figure 5.1 plots the binocular logMAR distance visual acuity scores for each participant according to age, with normative data from typically developing 3 to 8-year-olds derived from Sonksen et al. (2008) as a comparison.

	Median	**IQR**	**Range**
Distance visual acuity (logMAR)	0.000	-0.125 to 0.100	-0.300 to 1.300
Near visual acuity (logMAR)	0.025	0.000 to 0.125	0.000 to 0.600

Table 5.6: Binocular distance and near visual acuity scores for all participants with SEN for whom a formal measure of visual acuity was possible.

The World Health Organisation defines visual impairment as visual acuity (distance or near) poorer than 0.3logMAR (WHO, 2018b). Applying these criteria to the distance and/or near acuities measured in the population with SEN identified ten participants with a distance visual impairment and seven participants with a near visual impairment. Two participants were visually impaired at both distance and near.

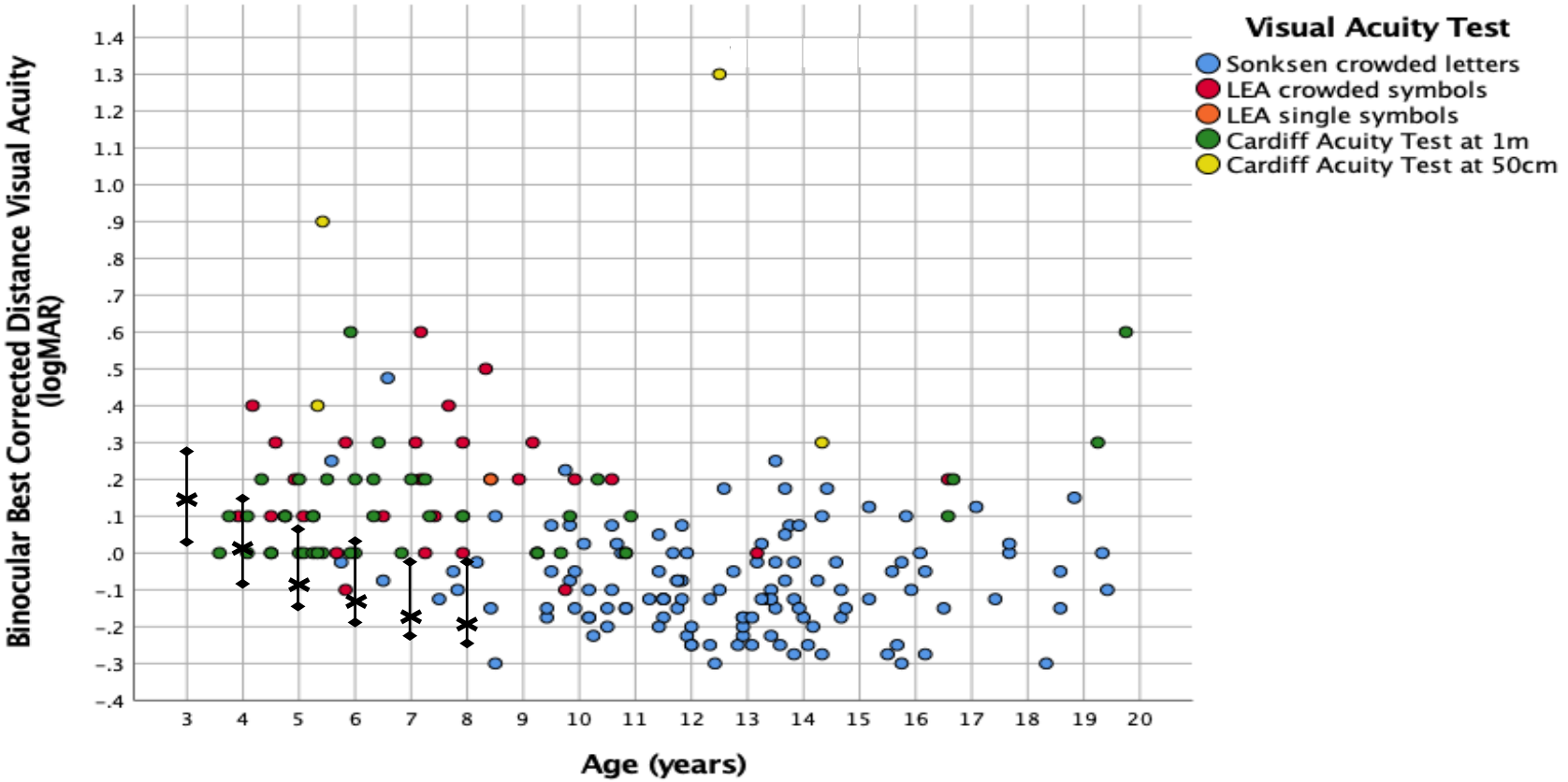


Figure 5.1: Binocular, best-corrected logMAR distance visual acuity values for all participants with SEN for whom a formal measure of visual acuity was achieved (n=197). Coloured dots represent individual acuity scores for study participants according to visual acuity test used. Black crosses represent normative median binocular logMAR visual acuity scores for children aged 3 to 8 years measured using the Sonksen crowded logMAR chart at 3m. Black bars represent the 10th to 90th percentile for the normative data derived from Sonksen et al. (2008).

5.3.3.3. Accommodation

Seventeen (8.5%) participants presented with a significant accommodative lag to a 4D target. A significant lag was defined using the 95% limits derived for a 4D demand from McClelland & Saunders (2004). Spectacles were provided to correct accommodative lag, either in the form of single vision or bifocals if a child was already wearing single vision distance spectacles, prior to completing visual perceptual tests and near visual assessments.

5.3.3.4. Contrast sensitivity

A normal contrast sensitivity value was defined as ≤3% contrast for 3-year-olds and ≤2% for children aged 4 years or older measured using the Cardiff Contrast Test. A measure was obtained for 183 participants (91.5%). Thirty participants (15%) had poorer contrast sensitivity measures than expected for a child of their age. A threshold measurement was not achieved for the remaining 17 participants (8.5%).

5.3.3.5. Ocular movements and alignment

5.3.3.5.1. Ocular movements

The number of participants who had typical or atypical smooth pursuits and saccadic eye movements, measured both horizontally and vertically are displayed in Table 5.7. Nystagmus was observed in nine participants.

	Typical, n (%)	Atypical, n (%)	Not possible to assess, n (%)
Smooth pursuits (horizontal)	158 (79.0)	20 (10.0)	22 (11.0)
Smooth pursuits (vertical)	157 (78.5)	20 (10.0)	23 (11.5)
Saccades (horizontal)	171 (85.5)	4 (2.0)	25 (12.5)
Saccades (vertical)	165 (82.5)	7 (3.5)	28 (14.0)

Table 5.7: Results of smooth pursuit and saccadic eye movement assessment.

5.3.3.5.2. Ocular alignment

A cover test to assess ocular alignment at near fixation was performed successfully on all participants. A successful measure at distance fixation was achieved for 198 (99.0%) participants. Results at both distance and near are shown in Table 5.8. Thirty-eight participants had a deviation at both distance and near.

	Ocular alignment	Number of participants (%)
Distance	Orthophoria	158 (79.0)
	Exotropia	15 (7.5)
	Esotropia	15 (7.5)
	Exophoria	5 (2.5)
	Esophoria	3 (1.5)
	Exo- and hypertropia	1 (0.5)
	Eso- and hypertropia	1 (0.5)
	Not possible	2 (1.0)
Near	Orthophoria	137 (68.5)
	Exotropia	13 (7.5)
	Esotropia	22 (11.0)
	Exophoria	21 (10.5)
	Esophoria	4 (2.0)
	Exo- and hypertropia	1 (0.5)
	Eso- and hypertropia	1 (0.5)
	Exo- and hyperphoria	1 (0.5)

Table 5.8: Ocular alignment of all participants at distance and near.

5.3.3.6. Optokinetic nystagmus (OKN)

Binocular OKN responses for all participants are shown in Table 5.9.

OKN Response	Number of participants, n (%)
Normal	165 (82.5)
Normal right to left, no response left to right	3 (1.5)
Normal left to right, no response right to left	1 (0.5)
Normal right to left, slow response left to right	10 (5.0)
Normal left to right, slow response right to left	4 (2.0)
Present but slow in both directions	2 (1.0)
No response	3 (1.5)
Assessment not possible	12 (6.0)

Table 5.9: Optokinetic nystagmus responses for all participants.

5.3.3.7. Ocular health

Table 5.10 describes the findings from the ocular health assessment attempted on all participants.

Ocular health	Number of participants, n (%)
No abnormalities detected	168 (84)
Blepharitis	4 (2)
Blocked tear ducts	3 (1.5)
Lens opacity	3 (1.5)
Disc atrophy	2 (1)
Ptosis	2 (1)
Tortuous retinal blood vessels	1 (0.5)
Myelination of retinal nerve fibres	1 (0.5)
Pale fundus	1 (0.5)
Optic disc drusen	1 (0.5)
Posterior synechiae	1 (0.5)
Optic nerve head pallor	1 (0.5)
Intraocular lens	1 (0.5)
Ectopia lentis	1 (0.5)
Partial view only	14 (7)
Not possible	1 (0.5)

Table 5.10: Results from ocular health assessment in all participants. Participants may have more than one condition.

5.3.3.8. Visual fields

Gross visual field defects were detected in four participants; two had a restriction on the left-hand side, one on the right-hand side and one had a general constriction to both right and left fields. A measure was not possible in 15 (7.5%) participants. All other participants (90.5%) had grossly full and symmetrical visual fields.

5.3.3.9. Stereopsis

Assessment of stereopsis using the Frisby Stereotest was possible in 80% of participants (n=160). Of these, 47.5% had normal stereopsis (n=95), defined as stereoacuity ≤85" (Anketell et al., 2013). Twenty-two participants engaged with the test, but failed to demonstrate a response to the stereo target, 7% (n=14) achieved a stereo acuity of 215" and 14.5% (n=29) achieved 110".

5.4. Discussion

It is well established that children with developmental disability and special educational needs are at a higher risk of vision deficits compared to typically developing children, for example significant refractive errors, reduced visual acuity and strabismus (Donaldson et al., 2019; Woodhouse et al., 2014; Das et al., 2010; Black et al., 2019; Gogate et al., 2011; Kaur et al., 2016; Salt & Sargent, 2014; Nielsen et al., 2007a; Creavin and Brown, 2009).

In their study of children with SEN, Das et al. (2010) used cycloplegic refraction to determine refractive error and report a similar incidence of refractive error to that found in the present study (Das et al., 2010). Lower rates of hyperopia

and higher rates of myopia compared with the present study population were reported by Woodhouse et al. (2004) and Donaldson et al. (2019) who assessed the visual profile of children attending special schools in Wales and England respectively. Cycloplegic refraction was carried out in a minority of participants in their study populations, and as such hyperopia may be underestimated and myopia overestimated (Woodhouse et al., 2004; Donaldson et al., 2019; Fotedar et al., 2007; Morgan et al., 2015). Participants with Down syndrome and cerebral palsy in the current population exhibited higher degrees of hyperopia and astigmatism compared to typically developing children (O'Donoghue et al., 2010; Black, 2019). This finding is consistent with previously reported literature and indicates a failure to emmetropise in these subgroups of children (Woodhouse et al., 1997; Creavin & Brown, 2009; Saunders et al., 2010).

Binocular, best-corrected visual acuity of participants with SEN in the present study ranged from -0.30 to 1.30logMAR indicating that some participants exhibited excellent visual acuities and others presented with severely impaired visual acuity. Whether level of learning disability and/or a diagnosis of a medical condition or syndrome was associated with visual acuity scores in the current study population has been explored in detail elsewhere (Black, 2019). Black (2019) showed that participants with severe learning difficulties and Down syndrome exhibited significantly poorer visual acuity scores compared to participants with autism spectrum disorder or 'no/other' medical diagnoses. This is consistent with previously reported literature (Courage et al., 1994; Woodhouse et al., 1996; Nielson et al., 2007a; Creavin & Brown, 2009; Little

et al., 2013). Level of visual acuity is important to consider when administering assessments to probe for evidence of CVI to ensure that a reduction in visual acuity is not interfering with performance or ability to complete such tests.

Throughout the vision assessment a fixed working distance of 3m was employed using the Sonksen and LEA symbol acuity charts, unless a participant was unable to read the largest letters/symbols on the vision chart; in this instance the chart was moved closer to the participant. Due to the limitations in room size, it was not possible to move the chart further back (e.g. to 4m) to increase the complexity of the task in the event that a participant was able to read the lowest line on the acuity chart. This was only problematic for a minority of participants, however the author acknowledges that in these instances the visual acuity measured at 3m may not truly reflect the participant's visual acuity threshold.

Contrast sensitivity develops rapidly over the first six months of life (Atkinson et al., 1977; Milling et al., 2014). The age at which contrast sensitivity fully matures is still unclear. Leat et al. (2009) carried out a literature review in an attempt to ascertain when contrast sensitivity thresholds become adult-like. They found large variability in results with some studies reporting adult-like responses by seven years, while others report thresholds are still not adult-like by eight years of age using subjective psychophysical methods (Leat et al., 2009). Leat hypothesises that the use of psychophysical methods may not be appropriate when determining the age at which contrast sensitivity thresholds become adult-like due to differences in how children respond to

such tests compared to adults, e.g. shorter attention span or use of different criteria when required to provide a yes/no response. Using objective (sweep VEP) methods, Almoqbel reports that children exhibit adult-like responses at age 9-12 years which may provide a more accurate estimate as responses are less reliant on participant responses (Almoqbel, 2011). Using the Cardiff Contrast Test, measures of contrast sensitivity are reported to be adult-like by two years of age in visually normal children (Barbareza et al., 2008). However, this test is reported as having a ceiling effect which is likely to account for this lower reported age (John et al., 2004). Visual acuity results obtained using the Cardiff Acuity Test (which follows the same design and test principles as the Cardiff Contrast Test) are reported to overestimate true visual acuity thresholds (Woodhouse et al., 2007). As such, results obtained with the Cardiff Contrast Test may also be overestimated which could further account for the lower reported adult-like contrast sensitivity threshold. In the present study, 15% of participants demonstrated reduced contrast sensitivity. Previous studies report contrast sensitivity deficits in children with Down syndrome, developmental delay and those born prematurely (Courage et al., 1997; Nielson et al., 2007b; Fazzi et al., 2012). Reduced contrast sensitivity is also reported to co-occur in children cerebral visual impairment and amblyopia (Chatzistefanou et al., 1995; Shiow-Wen & Cheng-Jen, 2001; Good et al., 2012). It has been proposed that post-retinal immaturities affecting the visual pathway and visual cortex affect the development of contrast sensitivity in children (Ellemberg et al., 1999; Adams & Courage, 2002). As such, it is unsurprising that children with developmental disabilities and conditions

affecting brain development are likely to present with contrast sensitivity deficits.

McClelland and Saunders (2004) report that normal accommodative responses to a target at 25cm for typically developing children aged 4-15 years range from 2.94D to 4.46D using dynamic retinoscopy. It is well established that children with cerebral palsy and Down syndrome often present with an accommodative lag (McClelland et al., 2006; Woodhouse et al., 1993; Woodhouse et al., 2000; Cregg et al., 2001). Likewise, a study by Anketell et al. demonstrated that accommodative deficits are more common in children with ASD compared to typically developing children (Anketell et al., 2018) Of the 17 participants who presented with an accommodative lag in the present study, 41.2% had Down syndrome, 35.7% had ASD and 17.6% had cerebral palsy; findings consistent with the literature. Neurological changes in the brainstem affecting innervation of the ciliary body is proposed as a likely explanation for the reduction in accurate accommodative responses in children with ASD (Anketell et al., 2018). It has been hypothesised that damage to the basal ganglia and cerebellum may account for the reduced accommodative response in children with cerebral palsy (McClelland et al., 2006). In children with Down syndrome, the mechanism to explain the reduction in accommodative response remains unclear. It has been evidenced that children with Down syndrome retain the physical ability to accommodate indicating the lack of response is likely due to defective neural or muscular control (Cregg et al., 2001; Doyle et al., 2016). Prior to assessing for evidence of CVI it is important to address and correct accommodative deficits to ensure

performance is not hindered by or attributed to lack of clarity caused by reduced accommodation.

Children with cerebral palsy have previously been reported as having a higher incidence of visual field deficits. These deficits are caused by lesions involving the retro-geniculate visual pathways which commonly occur in cerebral palsy (Fazzi et al., 2012). Due to the nature and location of such lesions, it is unsurprising that visual field deficits in cerebral palsy often co-occur with a diagnosis of cerebral visual impairment. In their sample of 129 children with cerebral palsy, Fazzi et al. (2012) report that 22.5% had a reduced visual field. In the present study, of the four participants who presented with a visual field deficit, three (75.0%) were recorded as having cerebral palsy through parental report. Medical history for the other participant was not available.

Findings from the present study are in agreement with previously reported literature which reports that children with developmental disability commonly present with strabismus and ocular movement disorders (Nielsen et al., 2007a; Creavin & Brown, 2009; Das et al., 2010; Fazzi et al., 2012; Woodhouse et al., 2014; Donaldson et al., 2019). The occipito-parietal cortex, frontal lobe, basal ganglia, superior colliculus, cerebellum and brainstem are responsible for controlling saccadic eye movements (Kung and Willcox, 2007). A reduction in the speed, over- or undershoot of saccadic eye movements can be an indication of a deficit affecting the cerebellum, basal ganglia and brainstem. Deficits in smooth pursuit eye movements are also indicative of a disorder affecting the parietal, temporal and occipital lobes (Lekwuwa & Barnes, 1996;

Heide et al., 1996). Therefore, if a child has a developmental disability which affects the development or function of the brain in these areas, an ocular movement deficit is likely to be present.

In the present study 11.5% of participants had an atypical optokinetic nystagmus response. Optokinetic nystagmus is an oculomotor reflex which helps stabilise images viewed by the retina (Gottlob, 2000). It is observed when viewing a moving object and is comprised of two phases: a slow phase and fast phase. The slow phase smoothly tracks a moving object while the fast phase consists of a saccadic response in the opposite direction (Balaban and Furman, 2017). Cioni et al. (1997) report that the binocular OKN response is typically normal from birth onwards (Cioni et al., 1997). Asymmetric OKN responses are reported to be indicative of a lesion in the parietal lobe of the brain (McGee, 2007). A reduced or absent response is observed whenever the stimulus is presented towards the side of the lesion (McGee, 2007; Sharpe & Sundaram, 2010). An atypical response has previously been described in children with periventricular leukomalacia and cerebral visual impairment where deficits in the parietal lobe are common (Cioni et al., 1997; Fazzi et al., 2007).

5.5. Conclusion

When assessing for evidence of CVI in children it is first important to have an understanding of the child's more 'basic' visual functions (i.e. functions affecting the anterior visual pathway). This chapter has presented the visual profile of participants with SEN included in the present study. Results are

consistent with previous scientific literature describing the visual status of children with learning disabilities. Where possible, visual deficits (such as refractive error and accommodative deficits) identified during the vision assessment were corrected prior to carrying out the CVI assessments presented in the next chapter.

Chapter 6

Investigating visual processing and behavioural characteristics in a population with Special Educational Needs (SEN)

6.0. Chapter overview

This chapter presents the results of the population with SEN on more specific assessments to probe for evidence of cerebral visual impairment (CVI), including parent and teacher visual skills inventories (VSI) and strengths and difficulties questionnaires (SDQs), observation of visual behaviours, tests of visual perception and crowding ratios.

6.1. Introduction

To determine whether evidence of CVI could be elicited during an in-school vision assessment, a number of measures were applied to the population with SEN as described in Chapter 3. The primary tool used in the present study to elicit evidence of CVI behaviours was the parental VSI. This tool was used to stratify participants into a CVI and non-CVI group, discussed in Chapter 7. Rationale for applying this inventory to identify participants with evidence of CVI is that it is a well-established and widely-utilised tool which was designed specifically to identify CVI-related behaviours. Previous work has also outlined criteria, replicated in the present study, for defining children as having perceptual visual dysfunction based on responses on this tool (Mitry et al., 2016; Duke et al., 2019). Other methods of assessment will be evaluated

alongside this tool to determine whether they could augment the process of identifying CVI in addition to consideration of responses on the VSI. This will be assessed by comparing performance on selected assessments between participants stratified into a CVI and non-CVI group (Chapter 7).

Prior to this, the performance profile of the population with SEN as a whole on selected assessments was investigated. Evaluation of success rates and test performance are compared to typically developing children where possible through comparison with published data (e.g. Meltzer et al., 2000; Williams et al., 2015). Where normative data are not available, results are compared with typically developing children whose performance is described in Chapter 4.

This chapter will address the following questions:

1) How do parents and teachers score participants with SEN on the VSI and how does this compare with typically developing children in mainstream education?
2) How does a population with SEN perform on commercially-available visual perceptual tests compared with typically developing children in mainstream education?
3) What crowding ratios for isolated vs crowded high contrast optotypes are demonstrated by a population with SEN and how do these compare with typically developing children in mainstream education?
4) What are the strengths and difficulties experienced by a population with SEN as elicited by the SDQ, and how do these compare with typically developing children in the UK?

6.2. Methods

Methods and procedures employed in the present study have been discussed in detail in Chapter 3.

6.3 Results

6.3.1. Visual Skills Inventory

6.3.1.1. Parental responses on the Visual Skills Inventory

6.3.1.1.1. Return rates

Table 6.1 shows the return rates for the parental VSI. The data from 13 participants for whom an inventory was returned were excluded from analysis as less than 50% of the inventory was completed. A total of 150 inventory responses (75.0% of the total study population) were available for analysis. Of the 13 participants for whom the parent VSI was excluded from analysis, two had profound and multiple learning difficulties (PMLD), four had severe learning difficulties (SLD), three had moderate learning difficulties (MLD) and one had MLD/SLD. Level of learning disability was unknown for the remaining two participants. Three participants in the excluded group were identified as having cerebral palsy (representing 60% of those reported as having cerebral palsy in the total study population) and were wheelchair bound. Mean (± standard deviation, SD) age of participants whose data were excluded was 8.80 (±1.14) years (range 3.58 to 17.42 years).

VSI	Number of participants (%)
Return	163 (81.5)
No return	37 (18.5)
Excluded due to incomplete response	13 (8.0% of those who returned an inventory)
Total included in analysis	**150 (75.0)**

Table 6.1: Return rates and number of participants included in parental VSI analysis

6.3.1.1.2. Characteristics of participants for whom a parent VSI was included in analysis

The mean (±SD) age of participants whose parental inventories were considered valid for analysis was 10.7 (± 3.9) years, 102 (68.0%) were male. Forty-eight (32.0%) were reported has having SLD, 23 (15.3%) MLD/SLD, 66 (44.0%) MLD, one (0.7%) had a 'complex interaction of needs' and a further one (0.7%) was classified as having 'delayed learning'. Detail on level of learning disability was unavailable for the remaining 11 (7.3%) participants. Characteristics of participants whose parental responses to the VSI were included/excluded from analysis did not differ significantly in terms of age, gender and level of learning disability ($t=-0.423$, $p=0.673$; $\chi^2=1.143$, $p=0.285$; and $\chi^2=4.591$, $p=0.101$ respectively).

6.3.1.1.3. Responses for each VSI subsection

Figure 6.1 illustrates the responses for the total inventory (total score) and each of the six subsections of the VSI. Mean responses for each section are shown in Table 6.2. "Noticing multiple targets" was the section which was most commonly reported as problematic with a mean score of 2.56 overall.

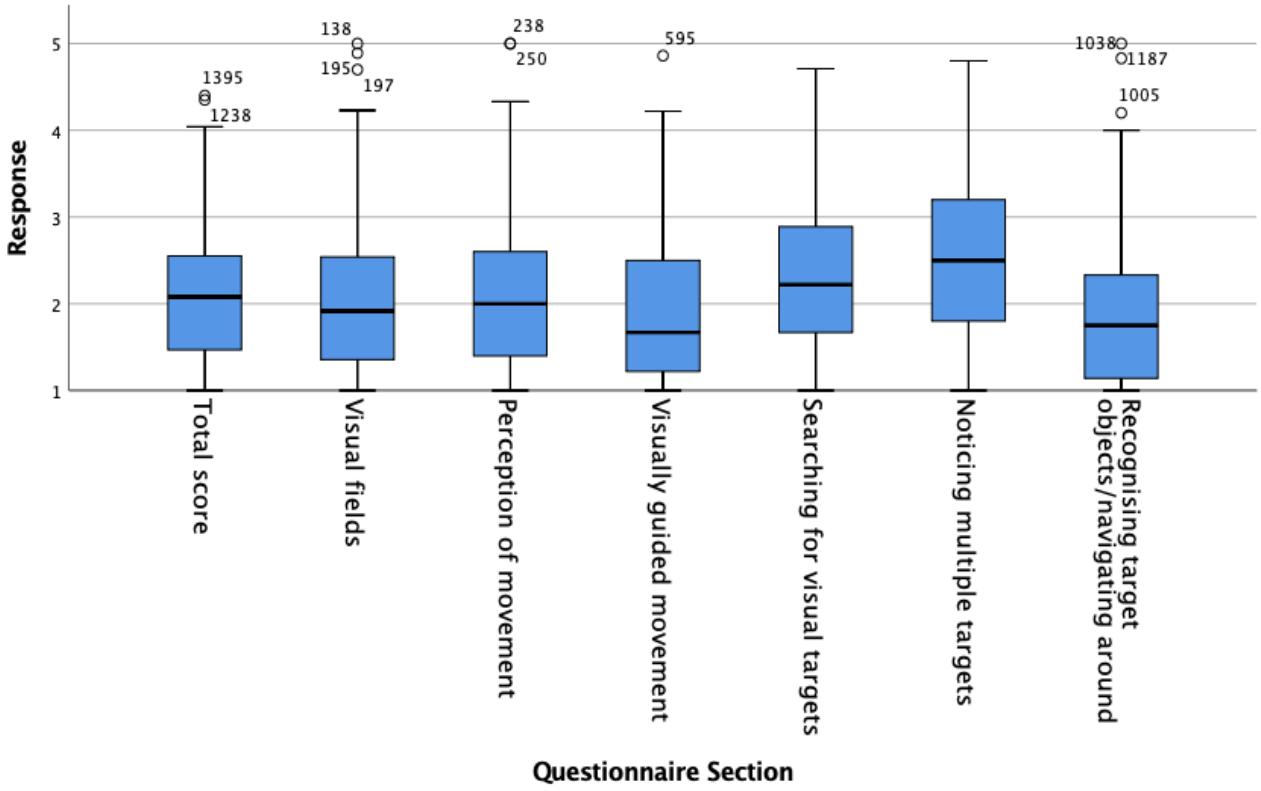


Figure 6.1: Box plots showing parental responses for the total inventory (total score) and each subsection of the VSI. Y-axis scale 1, 2, 3, 4, 5 represents responses of 'never', 'rarely', 'sometimes', 'often' or 'always' respectively. The solid black line indicates the median and the box indicates the interquartile range. Whiskers indicate 5th and 95th centiles. Outliers are represented by circles extending beyond the whiskers.

6.3.1.1.4. Comparison of population with SEN and typically developing control group

A population of 81 typically developing children attending a mainstream primary school were recruited to allow comparison with the population with SEN as discussed in Chapter 4. Of these 81 children, parents of 34 (42.0%) returned a VSI. Mean responses for each section of the VSI are shown in

Table 6.2. All subsections of the inventories returned by parents of the typically developing control group had a mean score of less than 2 meaning that difficulties were reported less than ‘rarely’ on average.

An independent samples t-test was carried out to determine whether there was a significant difference in mean parental responses between the typically developing control population and population with SEN for each subsection of the VSI and the overall total inventory mean score. This analysis revealed that there was a significant difference between groups for all subsections of the VSI ($p<0.001$ for all, Table 6.2), with the population with SEN consistently scoring higher (indicating more difficulties) than the typically developing control population. ‘Noticing multiple targets’ was the section which was reported, on average, as having the most difficulties for both the typically developing controls and population with SEN (2.56 vs 1.70 respectively).

VSI section	Population with SEN mean score ±SD (n=150)	Control population mean score ±SD (n=34)	SEN and Control group comparison (t-test)
Total inventory mean score	2.11 ± 0.76	1.39 ± 0.43	t=-5.284, p<0.001
Section 1. Visual fields	2.09 ± 0.93	1.47 ± 0.54	t=-3.780, p<0.001
Section 2. Perception of movement	2.09 ± 0.93	1.35 ± 0.50	t=-4.510, p<0.001
Section 3. Visually guided movement	1.93 ± 0.89	1.19 ± 0.38	t=-4.789, p<0.001
Section 4. Searching for visual targets	2.29 ± 0.88	1.55 ± 0.54	t=-4.659, p<0.001
Section 5. Noticing multiple targets	2.56 ± 0.98	1.70 ± 0.79	t=-4.761, p<0.001
Section 6. Recognising target objects and navigating around	1.88 ± 0.82	1.20 ± 0.37	t=-4.729, p<0.001

Table 6.2: Mean ± standard deviation (SD) score for each subsection of the parent VSI for the population with SEN and typically developing controls, including results from t-test comparing scores between both populations.

6.3.1.2. Teacher responses on the Visual Skills Inventory

Teachers of participants with SEN were asked to complete the same VSI as that given to parents, with slight changes to the wording of some questions to make them more relevant to the teachers, for example changing ‘your child’ to ‘this child’. Scoring was conducted in the same way as that of the parent inventories (described in Chapter 3) and the same questions were excluded from analysis (i.e. Questions 37, 38 and 42).

6.3.1.2.1. Return rates

Inventories relating to 165 participants were returned by teachers (82.5%). However, inventories relating to 40 participants were excluded from analysis in the instances where over half of the questions were answered as either 'Not Applicable' or were not completed, in accordance with the inclusion criteria applied to the parental VSI. As such, teacher-reported VSI data from 125 pupils (62.5%) were available for subsequent analyses.

6.3.1.2.2. Characteristics of included participants

The mean (±SD) age of participants whose teacher inventories were considered valid for analysis was 10.9 (± 4.3) years. Thirty-six (28.8%) were female, 89 (71.2%) were male. Forty-four (35.2%) participants for whom teacher VSI responses were considered valid for analysis were reported has having SLD, 20 (16.0%) MLD/SLD, 50 (40.0%) MLD, one (0.8%) had a 'Mild/MLD' and a further one (0.8%) was classified as having 'delayed learning'. Level of learning disability was unavailable for the remaining 9 (7.2%) participants. Characteristics of participants whose teacher responses to the VSI questionnaire were included/excluded from analysis did not differ significantly in terms of age, gender or level of learning disability ($t=0.946$, $p=0.345$; $\chi^2=0.229$, $p=0.633$; and $\chi^2=1.235$, $p=0.539$ respectively).

6.3.1.2.3. Responses for each VSI subsection

Figure 6.2 illustrates the responses of teachers across the total inventory (total score) and within each of the six subsections of the VSI. Mean responses for

each subsection are shown in Table 6.3. ‘Noticing multiple targets’ and ‘searching for visual targets’ were the areas for which most difficulty was reported by teachers.

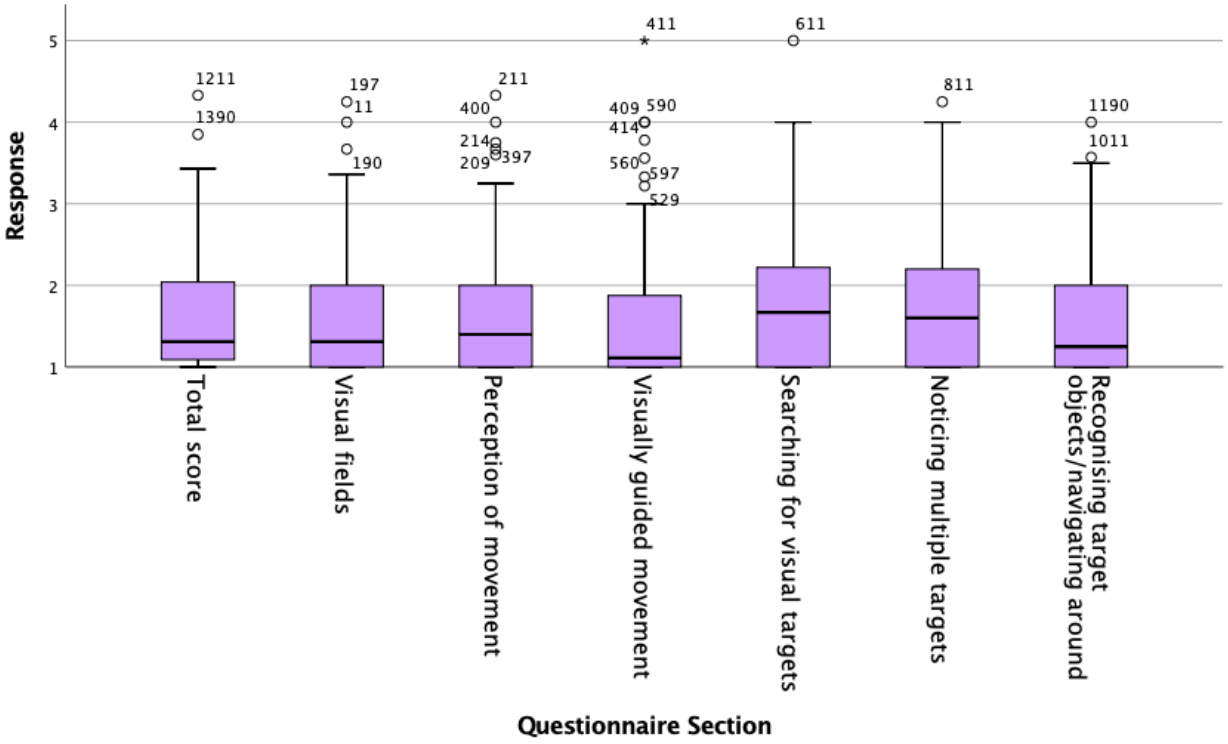


Figure 6.2: Box plots showing teacher responses for the total inventory and each subsection of the VSI. Y-axis scale 1, 2, 3, 4, 5 represents responses of ‘never’, ‘rarely’, ‘sometimes’, ‘often’ or ‘always’ respectively. The solid black line indicates the median and the box indicates the interquartile range. Whiskers indicate 5th and 95th centiles. Outliers are represented by circles and asterisks extending beyond the whiskers.

6.3.1.2.4. Comparison of parent and teacher VSI responses

A paired samples t-test was carried out to determine whether mean responses provided by parents and teachers differed significantly for each subsection and across the total inventory. This analysis revealed significant differences across all sections ($p \leq 0.001$ for all, Table 6.3), with parents scoring participants as having more difficulties (higher scores) in all subsections compared to teachers.

VSI section	Teacher VSI mean score ± SD (n=125)	Parent VSI mean score ± SD (n=150)	Mean difference in parent and teacher scores	Parent and teacher comparison (t-test)
Total inventory mean score	1.62 ± 0.66	2.11 ± 0.76	0.49	t=6.335, p<0.001
Section 1. Visual fields	1.59 ± 0.71	2.09 ± 0.93	0.50	t=5.841, p<0.001
Section 2. Perception of movement	1.65 ± 0.77	2.09 ± 0.93	0.44	t=3.729, p<0.001
Section 3. Visually guided movement	1.50 ± 0.77	1.93 ± 0.89	0.43	t=3.953, p<0.001
Section 4. Searching for visual targets	1.77 ± 0.81	2.29 ± 0.88	0.55	t=5.267, p<0.001
Section 5. Noticing multiple targets	1.77 ± 0.76	2.56 ± 0.98	0.79	t=7.711, p<0.001
Section 6. Recognising target objects and navigating around	1.57 ± 0.76	1.88 ± 0.82	0.31	t=3.322, p=0.001

Table 6.3: Mean ± SD score for each subsection of the VSI questionnaire for teachers and parents, including results from t-test comparing both responses.

6.3.2. Tests of visual perception

Success rates and results on each test of visual perception (discussed in Chapter 3) for all participants are shown in Table 6.4. Scoring of these tasks are described in Section 3.2.3.3.4.

Test of visual perception	No problems, n (%)	Minor/ moderate problems, n (%)	Major problems, n (%)	Unable to perform, n (%)	Unknown, n (%)
LEA Mailbox	171 (85.5)	7 (3.5)	0 (0.0)	22 (11.0)	
LEA Rectangles: Open	88 (44.0)	35 (17.5)	13 (6.5)	64 (32.0)	
LEA Rectangles: Closed	84 (42.0)	36 (18.0)	18 (9.0)	62 (31.0)	
LEA Rectangles: LEA method	111 (55.5)	25 (12.5)	7 (3.5)	56 (28.0)	1 (0.5)
3-Shape Sorter	178 (89.0)	0 (0.0)	6 (3.0)	16 (8.0)	
5-Shape Sorter	169 (84.5)	7 (3.5)	3 (1.5)	21 (10.5)	

Table 6.4: Results of each visual perceptual test for all participants with SEN.

6.3.2.1. LEA Mailbox test

The LEA mailbox was successfully completed with 'no problems' by 171 (85.5%) participants. Of the seven participants who had 'minor/moderate problems', three struggled orienting the card when it was presented by the examiner perpendicular to the slit orientation. One participant had difficulty successfully orienting the card when the slit was in the vertical orientation only. Referral was made to a paediatric ophthalmologist and subsequently this child was diagnosed with a subtle visual processing deficit.

6.3.2.1.1. Level of learning disability

Participants who were 'unable to perform' the test were significantly more likely to have SLD (Fisher's exact test =22.751, $p<0.001$). Of the participants who attempted the test and had either 'no' or 'minor/moderate' problems, there was

no significant association in performance between level of learning disability groups (Fisher's exact test=1.909, p=0.277).

6.3.2.1.2. Association with visual function characteristics

Performance on the LEA mailbox test was grouped according to whether the participants had 'no problems' or 'problems'. The latter category included scores of 'minor/moderate' or 'major' problems. Participants who were 'unable to perform' the task were excluded from this analysis. Visual function characteristics were grouped according to whether they were 'normal/typical' or 'outside the normal range/atypical'. Fisher's exact test analysis was then carried out to determine if there was a relationship between visual characteristics which may affect performance on the tests of visual perception and participants' performance on the LEA mailbox task (Table 6.5). These analyses revealed that participants with poorer contrast sensitivity and/or atypical vertical eye movements were more likely to have problems on the LEA mailbox task.

LEA mailbox task		Any problems on LEA Mailbox test?		Fisher's exact test
		No, n	Yes, n	
Near visual acuity	Normal	138	1	p=1.000
	Outside normal range	6	0	
Contrast sensitivity	Normal	148	1	**p<0.001**
	Outside normal range	18	5	
Stereopsis	Normal	93	1	p=0.562
	Outside normal range	59	2	
Nystagmus	Present	6	0	p=1.000
	Absent	165	7	
Horizontal pursuits	Typical	142	3	p=0.094
	Atypical	16	2	
Vertical pursuits	Typical	142	2	**p=0.010**
	Atypical	15	3	
Horizontal saccades	Typical	159	2	p=1.000
	Atypical	1	0	
Vertical saccades	Typical	156	1	**p=0.049**
	Atypical	3	1	
Near strabismus	Present	28	0	p=0.598
	Absent	143	7	

Table 6.5: Visual function measures according to performance on LEA Mailbox task. Bold text indicates a significant result.

6.3.2.2. LEA Rectangles test

Of all the visual perceptual tasks, performance on the LEA rectangles was the poorest (Table 6.4). The open pattern had the most participants who were unable to perform this task closely followed by closed pattern. Almost a third of participants were 'unable to perform' either of these tasks (32.0% and 31.0% respectively). Of those who were able to attempt the task, the closed pattern actually exhibited greater problems. Approximately a quarter of participants were recorded as having 'minor to major problems' with these tasks. The 'LEA method', which involved setting the shapes on top of each other, was completed with 'no problems' by 55.0% of participants. The results of this task were not recorded for one participant.

6.3.2.2.1. Level of learning disability

Level of learning disability was significantly associated with performance on the 'open pattern' and 'LEA method' rectangles tasks (Fisher's exact test=19.193, $p<0.001$ for 'open pattern' and Fisher's exact=12.883, $p=0.007$ for 'LEA method'). Participants with MLD performed significantly better than those with SLD. No such relationship was evident for the 'closed pattern' task (Fisher's exact test=2.989, $p=0.563$). Successful completion of the 'LEA method' was higher across all three learning disability groups (MLD, MLD/SLD, SLD) compared with the 'open' and 'closed' pattern. Results for each task grouped according to level of learning disability are shown in Table 6.6. Participants recorded as 'unable to perform' were excluded from Fisher's exact test analysis.

Level of learning disability	No problems, n (%)	Minor/ moderate problems, n (%)	Major problems, n (%)	Fisher's exact test	Unable to perform* n (%)
Open rectangles pattern					
SLD	16 (23.2)	5 (7.2)	9 (13.0)	**19.193 p<0.001**	39 (56.5)
MLD/SLD	12 (44.4)	7 (25.9)	0 (0.0)		8 (29.6)
MLD	46 (57.5)	23 (28.7)	2 (2.5)		9 (11.3)
Closed rectangles pattern					
SLD	17 (24.6)	9 (13.0)	7 (10.1)	2.989 p=0.563	36 (52.2)
MLD/SLD	12 (44.4)	5 (18.5)	2 (7.4)		8 (29.6)
MLD	46 (57.5)	18 (22.5)	7 (8.8)		9 (11.3)
LEA method					
SLD	20 (29.0)	12 (17.4)	5 (7.2)	**12.883 p=0.007**	32 (46.4)
MLD/SLD	15 (55.6)	4 (14.8)	0 (0.0)		8 (29.6)
MLD	61 (76.3)	9 (11.3)	2 (2.5)		8 (10.0)

Table 6.6: Results of each LEA rectangles task grouped according to level of learning disability. *Participants recorded as 'unable to perform' were excluded from Fisher's exact analysis. Bold text indicates a significant result.

6.3.2.2.2. Association with visual function characteristics

As with the Mailbox task, scores on the LEA rectangles tasks were grouped into 'no problems' or 'problems'. The latter category included scores of 'minor/moderate' or 'major' problems. Participants who were 'unable to perform' the task were excluded from analysis. Visual function characteristics were grouped according to whether they were 'normal/typical' or 'outside the normal range/atypical'. Chi-squared/Fisher's exact analysis was then carried out to determine if there was a relationship between visual characteristics and performance on the LEA rectangles tasks (Table 6.7). These analyses revealed that for the LEA 'open pattern' rectangles task, participants with atypical smooth pursuit eye movements were more likely to have problems on the task. For the 'LEA method' task, participants were more likely to perform poorly if they had poorer contrast sensitivity, reduced stereopsis, atypical

smooth pursuit eye movements and/or a near strabismus. No significant associations with performance and visual characteristics were revealed for the 'closed pattern' task.

LEA open rectangles task		**Any problems on LEA Open rectangles task?**		**Chi-squared/Fisher's exact test**
		No, n	**Yes, n**	
Near visual acuity	Normal	86	45	p=0.281
	Outside normal range	1	2	
Contrast sensitivity	Normal	84	57	p=1.000
	Outside normal range	3	1	
Stereopsis	Normal	57	27	p=0.340
	Outside normal range	27	19	
Nystagmus	Present	3	2	p=1.000
	Absent	85	46	
Horizontal pursuits	Typical	81	36	**p=0.006**
	Atypical	4	10	
Vertical pursuits	Typical	81	36	**p=0.011**
	Atypical	4	9	
Horizontal saccades	Typical	86	45	p=0.348
	Atypical	0	1	
Vertical saccades	Typical	85	44	p=0.122
	Atypical	0	2	
Near strabismus	Present	11	8	p=0.606
	Absent	77	40	

LEA closed rectangles task		Any problems on LEA Closed rectangles task?		Chi-squared/Fisher's exact test
		No, n	Yes, n	
Near visual acuity	Normal	81	51	p=0.643
	Outside normal range	2	2	
Contrast sensitivity	Normal	81	52	p=0.647
	Outside normal range	2	2	
Stereopsis	Normal	55	31	X^2=1.158 p=0.350
	Outside normal range	25	21	
Nystagmus	Present	3	2	p=1.000
	Absent	81	52	
Horizontal pursuits	Typical	72	46	X^2=0.079 p=1.000
	Atypical	8	6	
Vertical pursuits	Typical	73	45	X^2=0.317 p=0.766
	Atypical	7	6	
Horizontal saccades	Typical	83	50	p=0.381
	Atypical	0	1	
Vertical saccades	Typical	81	49	p=0.558
	Atypical	1	2	
Near strabismus	Present	9	10	X^2=1.686 p=0.214
	Absent	75	44	
LEA method rectangles task		**Any problems on LEA Method rectangles task?**		**Chi-squared/Fisher's exact test**
		No, n	**Yes, n**	
Near visual acuity	Normal	107	27	p=0.604
	Outside normal range	4	2	

Contrast sensitivity	Normal	108	27	**p=0.021**
	Outside normal range	2	4	
Stereopsis	Normal	76	13	**p=0.027**
	Outside normal range	33	15	
Nystagmus	Present	5	1	p=1.000
	Absent	106	31	
Horizontal pursuits	Typical	100	23	**p=0.014**
	Atypical	7	7	
Vertical pursuits	Typical	101	22	**p=0.007**
	Atypical	6	7	
Horizontal saccades	Typical	110	28	p=0.209
	Atypical	0	1	
Vertical saccades	Typical	108	27	p=0.112
	Atypical	1	2	
Near strabismus	Present	13	9	**p=0.047**
	Absent	98	23	

Table 6.7: Visual function measures according to performance on each LEA rectangles task. Bold text indicates a significant result.

6.3.2.3. Shape sorter task

The three-shape sorter task was the most successfully completed test of visual perception, with 89.0% of participants inserting all three shapes correctly. All of these participants progressed to the five-shape sorter task, where this was successfully completed by 169 participants (84.5%).

6.3.2.3.1. Level of learning disability

Fisher's exact test showed a significant difference between level of learning disability groups (MLD, MLD/SLD and SLD) and test performance on the three-shape sorter task, where participants with SLD were more commonly scored as having 'major problems' (Fisher's exact=5.456, p=0.047). No significant association in performance between learning disability groups was evident for the five-shape sorter (Fisher's exact test=3.129, p=0.574).

6.3.2.3.2. Association with visual function characteristics

As with the other tests of visual perception, scores on the shape sorter tasks were categorised into two groups depending on whether the participants demonstrated 'no problems' or 'problems' completing the task. The latter category included scores of 'minor/moderate' or 'major' problems. Participants who were 'unable to perform' the task were excluded from analysis. Visual function characteristics were grouped according to whether they were 'normal/typical' or 'outside the normal range/atypical'. Fisher's exact test was then carried out to determine if there was a relationship between visual characteristics and performance on the shape sorter tasks (Table 6.8). These analyses revealed that for both of the shape sorter tasks, participants with

contrast sensitivity outside the normal range were more likely to have problems. Participants with atypical vertical smooth pursuit eye movements were also more likely to have difficulties with the three-shape sorter task.

Three-shape sorter		**Any problems on three-shape sorter task?**		**Fisher's exact test**
		No, n	**Yes, n**	
Near visual acuity	Normal	139	0	Not possible
	Outside normal range	7	0	
Contrast sensitivity	Normal	150	1	**p=0.008**
	Outside normal range	21	3	
Stereopsis	Normal	95	0	p=0.157
	Outside normal range	61	2	
Nystagmus	Present	6	0	p=1.000
	Absent	172	6	
Horizontal pursuits	Typical	146	4	p=0.137
	Atypical	17	2	
Vertical pursuits	Typical	146	3	**p=0.020**
	Atypical	16	3	
Horizontal saccades	Typical	162	3	p=1.000
	Atypical	1	0	
Vertical saccades	Typical	159	2	p=0.071
	Atypical	3	1	
Near strabismus	Present	29	1	p=1.000
	Absent	149	5	

Five-shape sorter		Any problems on five-shape sorter task?		Fisher's exact test
		No, n	Yes, n	
Near visual acuity	Normal	136	3	p=1.000
	Outside normal range	7	0	
Contrast sensitivity	Normal	147	4	**p=0.002**
	Outside normal range	16	5	
Stereopsis	Normal	93	2	p=0.058
	Outside normal range	56	6	
Nystagmus	Present	6	0	p=1.000
	Absent	163	10	
Horizontal pursuits	Typical	140	6	p=0.214
	Atypical	16	2	
Vertical pursuits	Typical	140	6	p=0.197
	Atypical	15	2	
Horizontal saccades	Typical	155	7	p=1.000
	Atypical	1	0	
Vertical saccades	Typical	152	7	p=1.000
	Atypical	3	0	
Near strabismus	Present	27	3	p=0.375
	Absent	142	7	

Table 6.8: Visual function measures according to performance on the three- and five-shape sorter tasks. Bold text indicates a significant result.

6.3.3. Visual behaviour observations

All participants presented with a normal blink reflex. One was recorded as having ‘abnormal awareness of movement’ and two exhibited ‘visual latency’. Eye contact was recorded as ‘atypical’ in 28 participants. Of these, eight did not make eye contact and 20 made inconsistent eye contact. Ten participants expressed non-purposeful gaze at times throughout the assessment. ‘Reaction to light’ was deemed normal for the majority of participants, except nine individuals who avoided or turned away from light sources.

Abnormal head posture was noted for 11 participants; four presented with chin depression, and three demonstrated a face turn. Three participants had a head tilt and one had a constant involuntary oscillation of their head due to a systemic medical condition. For three participants, their head was supported by a bespoke head support on their wheelchair. All participants with a face turn had nystagmus, one also had a left exotropia and one a left esotropia. Two participants with chin depression had nystagmus, two had an esotropia (one left esotopria and one right esotropia) and one had a right exotropia. The remaining participant had chin depression due to behavioural issues associated with autism spectrum disorder rather than an ocular deficit. Two participants with a head tilt had visual field restrictions and one was exotropic (alternating).

6.3.4. Crowded optotype visual acuity and crowding ratios

6.3.4.1. Crowded and single optotype visual acuity measured with the LEA symbols

6.3.4.1.1. Success rates

The high contrast crowded and single optotype LEA acuity charts were each successfully completed by 157 participants (78.5%). A successful score on both charts was achieved by 156 participants (78.0%). Participants with SLD were significantly less likely to complete both LEA symbols charts (X^2=35.807, p<0.001 for crowded optotype chart and X^2=34.097, p<0.001 for single optotype chart).

6.3.4.1.2. Visual acuity results

Results for each LEA symbols distance visual acuity chart for all participants who complied with testing are shown in Table 6.9 and Figure 6.3. Testing was carried out binocularly with best-correction.

LEA Acuity Test	Median (logMAR)	IQR (logMAR)	Range (logMAR)
Crowded optotypes	0.00	-0.10 to 0.10	-0.40 to 0.60
Single optotypes	-0.10	-0.20 to 0.00	-0.30 to 0.70

Table 6.9: Median, interquartile range and range of each LEA symbol acuity chart for participants with SEN who complied with acuity testing.

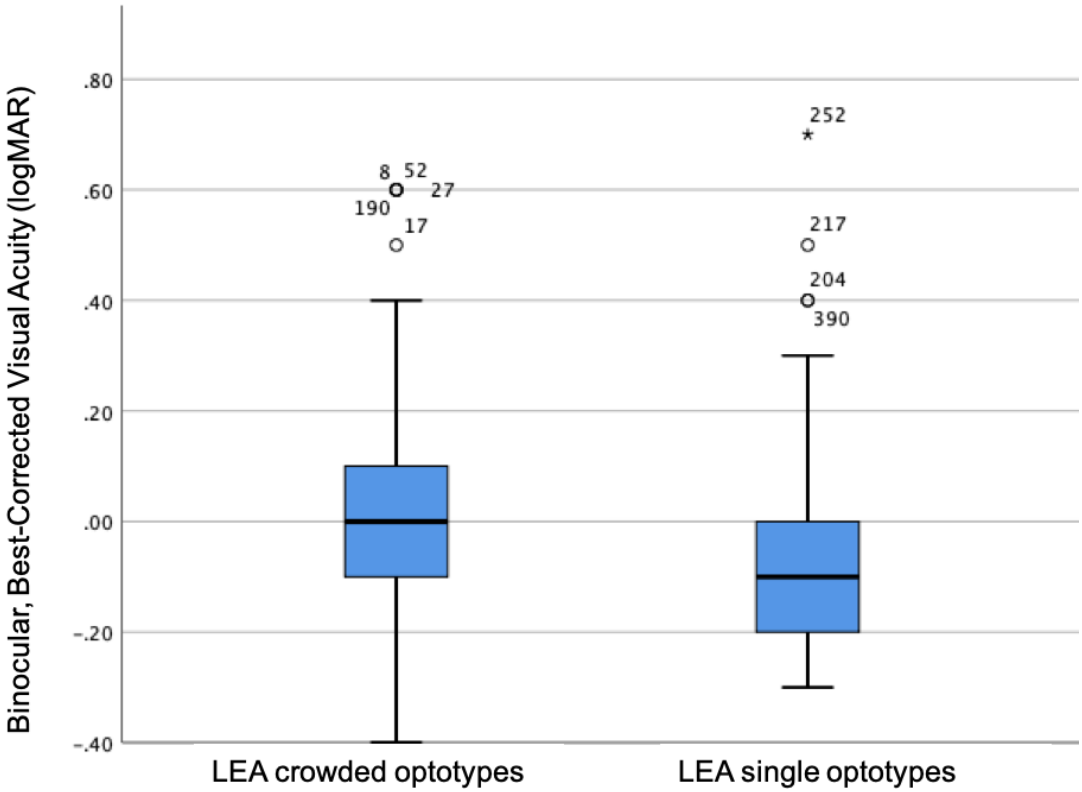


Figure 6.3: Box plots showing binocular, best-corrected distance visual acuity scores on the crowded and single optotype LEA symbol acuity charts for the entire population with SEN who successfully completed each test. The solid black line indicates the median and the box indicates the interquartile range. Whiskers indicate 5th and 95th centiles. Outliers are represented by circles and asterisks extending beyond the whiskers.

Wilcoxon signed rank test revealed there was a significant difference between LEA single optotype acuity scores and crowded optotype acuity scores for the population with SEN ($p<0.001$), with the majority of participants achieving better acuity scores on the single optotype acuity chart (n=120). Eight participants had better crowded optotype acuity and the remaining 28 participants had the same acuity scores on both tests. Figure 6.4 shows the results for participants crowded optotype acuity scores compared to single optotype acuity scores.

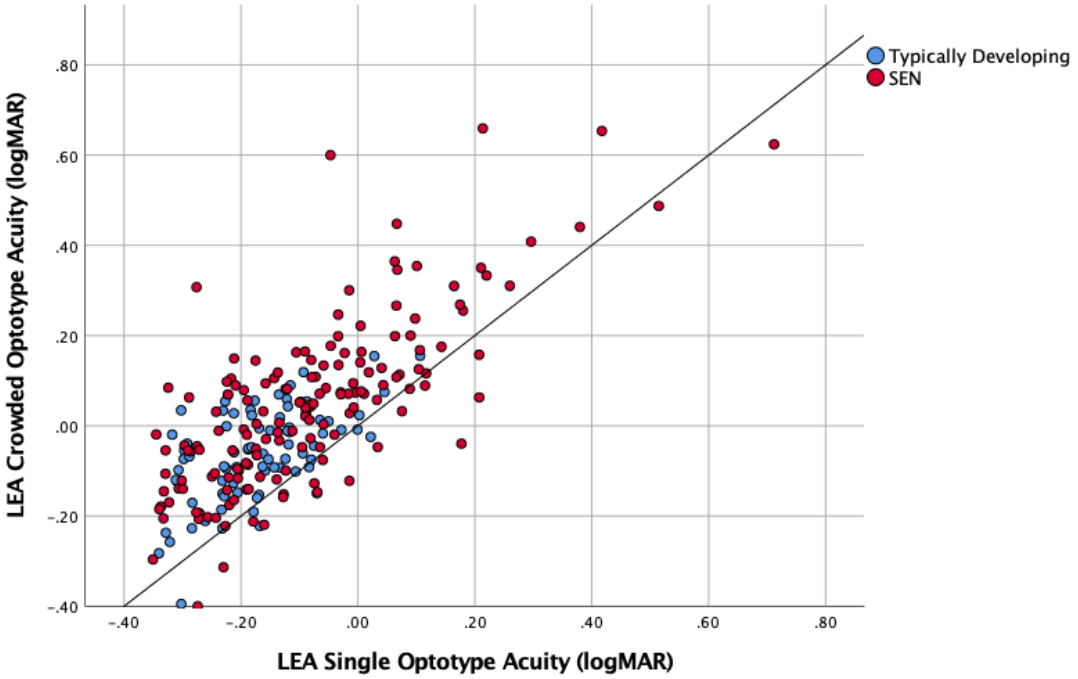


Figure 6.4: Binocular, best-corrected LEA crowded optotype acuity compared with single optotype acuity presented for each participant with SEN who successfully completed both tests (red dots). Data from typically developing children described in Chapter 4 have been included for comparison (blue dots). The solid black line represents line of equality for acuity scores. Data points have been jittered to prevent overlap.

6.3.4.1.3. Level of learning disability

Kruskal-Wallis test revealed there was a significant difference in visual acuity scores between level of learning disability groups (MLD, MLD/SLD and SLD) across both the LEA crowded and single optotype test charts ($H=14.904$, $p=0.001$ for crowded optotypes and $H=11.139$, $p=0.004$ for single optotypes). Post-hoc analysis with Bonferroni correction revealed the difference was between participants with MLD and SLD, with the latter achieving significantly poorer optotype acuity scores on both LEA test charts ($U=956.5$, $p<0.001$ for crowded optotypes and $U=1104.5$, $p=0.002$ for single optotypes).

6.3.4.1.4. Comparison of LEA optotype acuity scores between typically developing control group and population with SEN

A Mann-Whitney U test was carried out to determine whether there was a significant difference between optotype acuity scores between the typically developing control group (discussed in Chapter 4) and population with SEN for both the crowded and single optotype LEA acuity charts. This revealed there was a significant difference between the population with SEN and typically developing control group for both charts, with the SEN group achieving significantly worse visual acuities (Table 6.10).

LEA Acuity Test	Population with SEN, Mdn (IQR)	Typically developing population, Mdn (IQR)	SEN and Typically developing group comparison (Mann-Whitney U)
Crowded optotypes	0.00 (-0.10 to 0.10)	-0.10 (-0.10 to 0.00)	3609.5 (p<0.001)
Single optotypes	-0.10 (-0.20 to 0.00)	-0.20 (-0.20 to -0.10)	4418.0 (p<0.001)

Table 6.10: Median and interquartile range of each LEA symbol acuity chart for the population with SEN and typically developing control population. Mann-Whitney U results reveal a significant difference in optotype acuity scores between both groups. Mdn=median, IQR=interquartile range

6.3.4.2. Visual acuity crowding ratios

Visual acuity crowding ratios were calculated for each participant by dividing the LEA crowded optotype acuity score by the LEA single optotype acuity score as discussed in Chapter 3.2.3.5. Descriptive statistic results for crowding ratios are shown in Table 6.11, along with data from the typically developing control group discussed in Chapter 4. Figure 6.5 shows box plots for crowding ratios for both the population with SEN and typically developing control population. Individual crowding ratios for participants with SEN are shown in Figure 6.6.

6.3.4.2.1. Level of learning disability

There was no significant association between crowding ratios and level of learning disability groups (X^2 =1.721, p=0.442.)

6.3.4.2.2. Comparison of population with SEN and typically developing control group

Mann-Whitney U tests revealed no significant difference in crowding ratio between the typically developing control group and the population with SEN (Table 6.11).

Population with SEN		Typically developing control group		Mann-Whitney U comparison
Mean ± SD (range)	**Median (IQR)**	**Mean ± SD (range)**	**Median (IQR)**	
1.40 ± 0.46 (0.63 to 3.98)	1.26 (1.26 to 1.58)	1.29 ± 0.27 (0.79 to 2.00)	1.26 (1.00 to 1.58)	U=5384.0 p=0.072

Table 6.11: Descriptive statistics for crowding ratios for the population with SEN and typically developing control group. Mann-Whitney U analysis revealed no significant difference in crowding ratios between both groups.

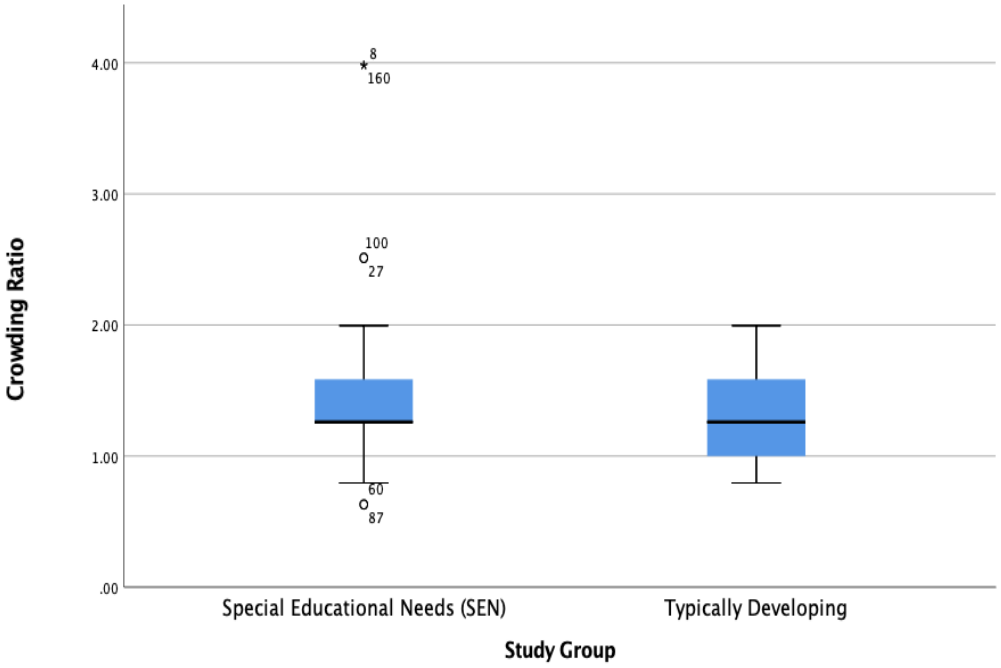


Figure 6.5: Box plots showing crowding ratios for both the population with SEN and typically developing control group. The solid black line indicates the median and the box indicates the interquartile range. Whiskers indicate 5th and 95th centiles. Outliers are represented by open circles or asterisks extending beyond the whiskers.

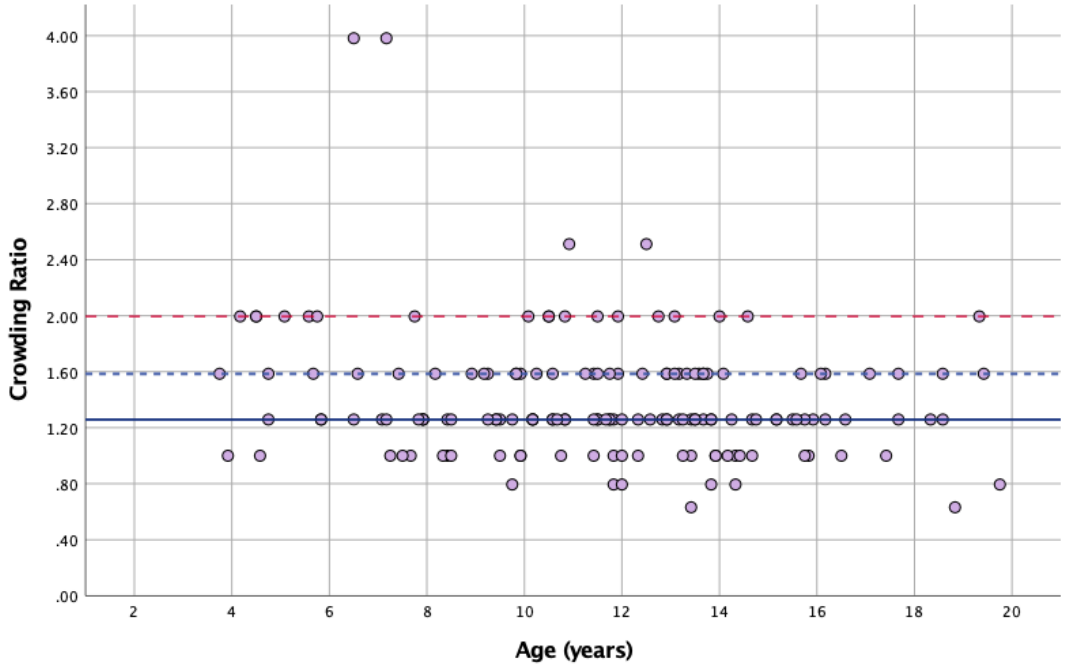


Figure 6.6: Individual crowding ratios for each participant with SEN. The blue solid line represents the median for both the population with SEN and typically developing control population (Mdn=1.26 for both groups). The red dashed line represents the 90th percentile for the population with SEN and the blue dashed line represents the 90th percentile for the typically developing control population.

6.3.4.2.3. Participants with SEN with a crowding ratio outside the normal range

A crowding ratio greater than 1.58 was considered outside the normal range in the typically developing control population described in Chapter 4. Applying this criterion to the results of the population with SEN identified 22 participants (14.1%) with a crowding ratio outside the normal range. There was no significant difference in level of learning disability between the participants with a normal crowding ratio and those with a crowding ratio outside the normal range (X^2=1.721, p=0.442).

To determine whether presence of a visual deficit or abnormality was associated with a crowding ratio outside the normal range in the population with SEN, chi-square analysis was carried out. This revealed participants with a crowding ratio outside the normal range were more likely to have atypical vertical saccadic and smooth pursuit eye movements. None of the other visual deficits were significantly associated with crowding ratios outside the normal range (Table 6.12).

	Normal crowding ratio, n	Crowding ratio outside normal range, n	Chi-square analysis
Distance strabismus	12	2	χ^2=0.029, p=1.000
Nystagmus	6	0	χ^2=1.024, p=0.596
Contrast sensitivity deficit	6	3	χ^2=3.061, p=0.110
Horizontal pursuits	12	4	χ^2=1.761, p=0.245
Atypical vertical pursuits	10	5	**χ^2=5.024, p=0.041**
Atypical horizontal saccades	0	0	Not possible
Atypical vertical saccades	0	2	**χ^2=13.669, p=0.016**
Atypical OKN response	18	4	χ^2 =0.352, p=0.741

Table 6.12: Participants with atypical visual characteristics according to presence of normal crowding ratio or a crowding ratio outside the normal range. Bold text indicates a significant result.

6.3.5. Strengths and Difficulties Questionnaire

6.3.5.1. Parent responses on the SDQ

6.3.5.1.1. Return Rates

The SDQ was completed by parents of 181 participants (90.5%). Of the 19 participants for whom a questionnaire was not completed, seven parents did not return the questionnaires to the research team, two withdrew consent to complete the questionnaire, one did not give permission to be contacted to complete any questionnaires as part of the study, one child was off school due to long-term illness, and one participant was over 18 and did not require parent/carer input. For seven participants, the class teacher deemed the SDQ inappropriate due to the participant's severe learning difficulties, and as such

the parents were not contacted to complete this. Those children whose teacher deemed the questionnaire inappropriate for their level of ability either had PMLD (n=2), SLD (n=2), delayed learning (n=1) or a complex interaction of needs (n=1) according to their Statement of Educational Need.

6.3.5.1.2. Parent SDQ scores by section

Descriptive statistics for each section of the SDQ for all participants for whom a questionnaire was returned are shown in Table 6.13.

Section of questionnaire	Group	Median	IQR	Range
Overall Stress*	All participants	18	9	3 - 34
	MLD	18	9	3 – 34
	MLD/SLD	19	8.5	6 – 33
	SLD	17	9	4 – 32
Emotional difficulties	All participants	4	3.5	0 – 10
	MLD	5	4.25	0 – 10
	MLD/SLD	5	3	2 – 10
	SLD	3	3	0 – 10
Behavioural difficulties	All participants	2	3	0 – 10
	MLD	2	3	0 – 9
	MLD/SLD	2	3	0 – 9
	SLD	2	3	0 – 10
Hyperactivity or concentration difficulties	All participants	8	4	1 - 10
	MLD	8.5	4	1 - 10
	MLD/SLD	8	4	3 - 10
	SLD	8	4.25	1 - 10
Difficulties getting along with other children	All participants	4	3	0 – 10
	MLD	4	2	0 – 10
	MLD/SLD	3	3	0 – 9
	SLD	4	3	0 - 8
Kind and helpful behaviour	All participants	7	5	0 – 10
	MLD	8	4.25	0 – 10
	MLD/SLD	7	4.25	0 - 7
	SLD	7	7	0 – 10
Impact score	All participants	2	5	0 – 10
	MLD	2	3.5	0 – 10
	MLD/SLD	2.5	4.25	0 – 9
	SLD	2	5	0 – 10

Table 6.13: Median, interquartile range (IQR) and range of scores for participants for whom a parent SDQ was returned.

*Overall stress score is calculated by summing scores on the ‘emotional’, ‘behavioural’, ‘hyperactivity and concentration difficulties’ and ‘difficulties getting along with other children’ scores. The highest possible score is 40 for this section.

6.3.5.1.3. Comparison of parent SDQ scores with normative data

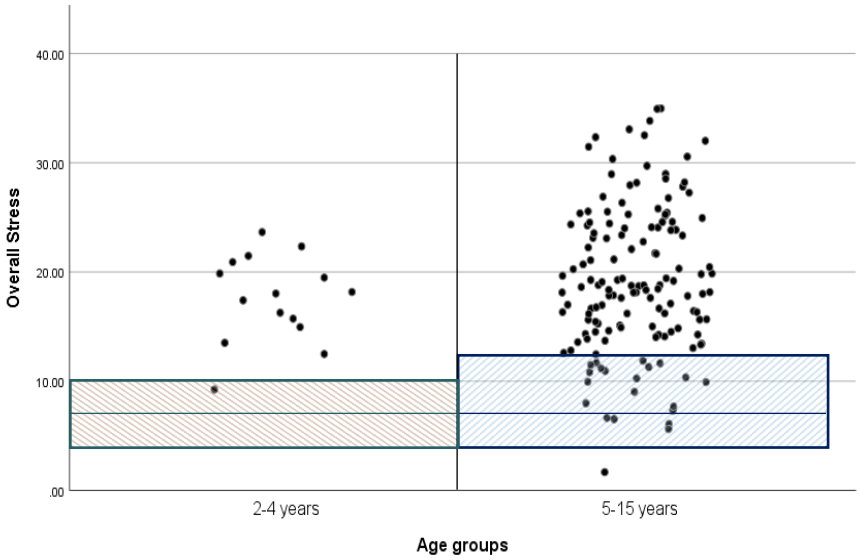
UK normative data for the SDQ are available on the developer's website (www.sdqinfo.com). These data are available for two age groups: 2-4-year-olds and 5-15-year-olds. Data for the 2-4-year-old group were derived from two sources: 1) parents in Dumfries completing the SDQ when their children started nursery school (n=1,353), and 2) parents in the Glasgow and Clyde area completing the SDQ as part of a health assessment carried out by their health visitor/public health nurse (n=10,239; Youth in Mind; 2014). For the 5-15-year-old group, data were derived from a large national survey of child and adolescent mental health carried out by the Office for National Statistics funded by the Department of Health (Meltzer et al., 2000). Responses from parents were available for 11,592 children in the 2-4-year-old group across all sections of the SDQ, except the 'Impact' section in which only data from the Dumfries sample were available (n=1,353 children). Responses for the 5-15-year-old group were available for 10,298 children across all subsections.

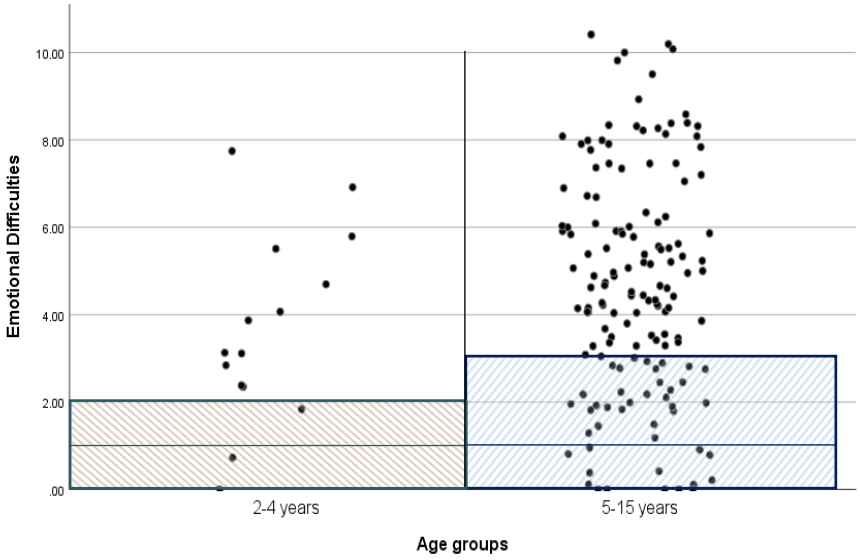
Mean, standard deviation and percentage of respondents for each individual score were available. Using this information, it was possible to calculate a median and interquartile range for each group and compare this with the study population, which was split into the same age groups for consistency. The 2-4-year-old group included 15 participants and the 5-15-year-old group included 148 participants. Mann-Whitney U tests were carried out to determine if the scores for each subsection differed significantly between the population with SEN and the normative data. For both age groups, across all SDQ subsections, scores for the population with SEN were significantly worse compared to normative data ($p<0.05$ for all; Table 6.14). Figure 6.7 displays

individual scores from the population with SEN compared with normative data. The shaded area in these figures represent the median and IQR for the normative data and the individual data points represent scores for the population with SEN.

SDQ Subsection	Normative data vs population with SEN, Mann Whitney U, p	
	2-4-year-old group	5-15-year-old group
Overall stress	U=11317.5 p<0.000	U=169163.5 p<0.000
Emotional difficulties	U=25660 p<0.000	U=313943 p<0.000
Behaviour difficulties	U=61150.5 p=0.042	U=497566 p<0.000
Hyperactivity and concentration difficulties	U=19781 p<0.000	U=197626 p<0.000
Difficulties getting along with other children	U=17938 p<0.000	U=296169.5 p<0.000
Kind and helpful behaviour	U=41024.5 p<0.000	U=464888 p<0.000
Impact score	U=3366 p<0.000	U=291500.5 p<0.000

Table 6.14: Mann-Whitney U comparison of parent SDQ scores between UK normative data and participants with SEN on each subsection of the SDQ.


Overall Stress
40.00
30.00
20.00
10.00
.00
2-4 years
5-15 years
Age groups


Emotional Difficulties
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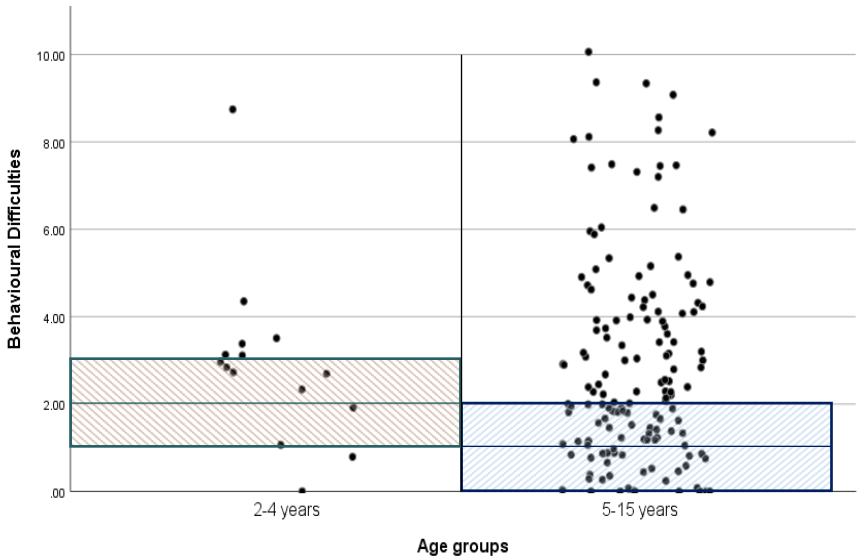
8.00
6.00
4.00
2.00
.00
2-4 years
5-15 years
Age groups


Behavioural Difficulties
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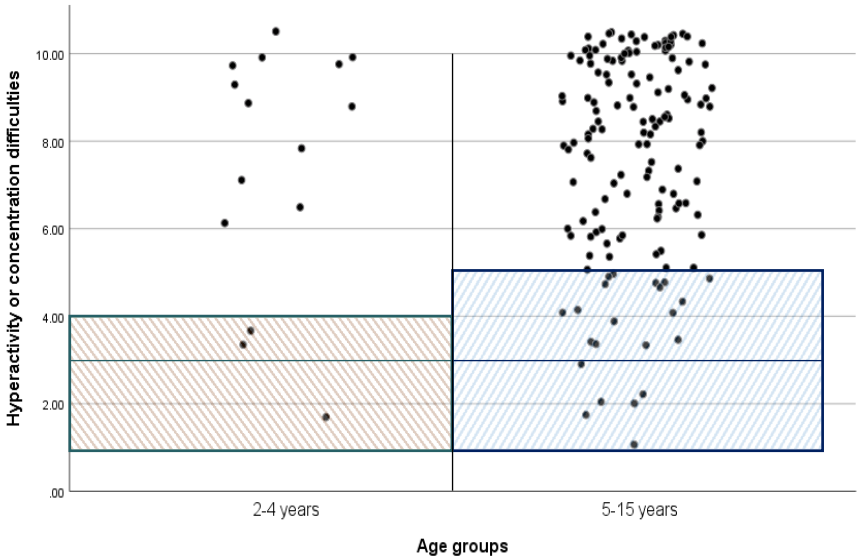
8.00
6.00
4.00
2.00
.00
2-4 years
5-15 years
Age groups


Hyperactivity or concentration difficulties
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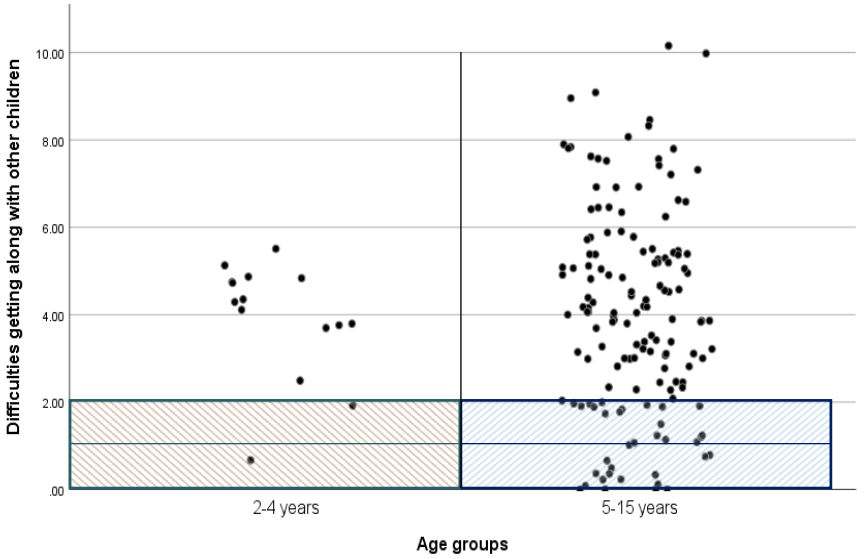
8.00
6.00
4.00
2.00
.00
2-4 years
5-15 years
Age groups


Difficulties getting along with other children
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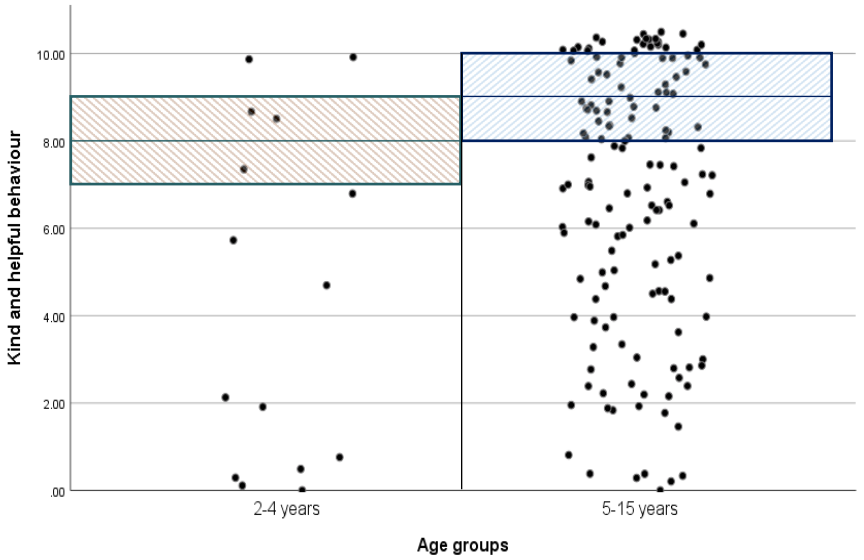
6.00
4.00
2.00
.00
2-4 years
5-15 years
Age groups


Kind and helpful behaviour
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8.00
6.00
4.00
2.00
.00
2-4 years
5-15 years
Age groups

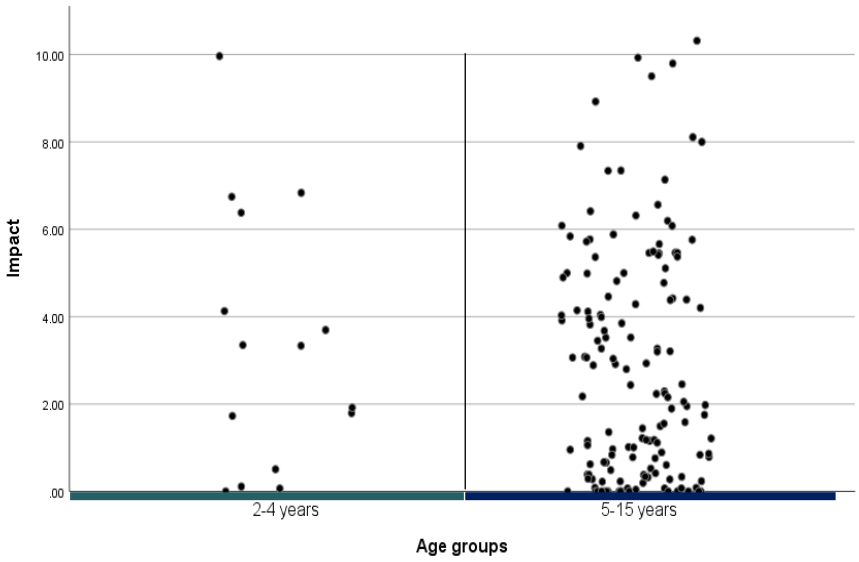


Figure 6.7: Comparison of parent SDQ scores for each subsection between UK normative data and the population with SEN by 2-4-year old and 5-15-year-old age groups. Shaded areas represent interquartile range for the normative data, with midline equating to the median score. Individual data points represent the current study population. Data points outside the shaded area represent individuals who fall outside the normal range of scores.

6.3.5.1.4. Comparison of parent SDQ scores between level of learning disability groups

A Kruskal-Wallis test revealed there was a significant difference between learning disability groups (MLD, MLD/SLD and SLD) and overall stress, emotional difficulties and kind and helpful behaviour subsection scores on the parent SDQ. The scores of all other subsections did not differ significantly between level of learning disability groups (Table 6.15).

SDQ Section	Kruskal-Wallis test, H (p)
Overall Stress	**H=7.220 p=0.027**
Emotional Difficulties	**H=11.062 p=0.004**
Behavioural Difficulties	H=0.120 p=0.942
Hyperactivity and concentration difficulties	H=3.304 p=0.219
Difficulties getting along with other children	H=2.934 p=0.231
Kind and helpful behaviour	**H=9.350 p=0.009**
Impact score	H=0.034 p=0.983

Table 6.15: Comparison of level of learning disability groups and parent SDQ scores per section. Bold text indicates a significant difference between groups.

Results from post-hoc analysis using Bonferroni correction (indicating a required significance level p=0.017 for three groups) are shown in Table 6.16. This revealed there was a significant difference between MLD and SLD groups across all three sections ($p<0.017$ for all), where the SLD group were scored higher (indicating more difficulties) than the MLD group. There was no

significant difference between MLD and MLD/SLD, and MLD/SLD and SLD groups across all sections (p>0.017 for all).

SDQ Section	MLD vs MLD/SLD, U (p)	MLD vs SLD, U (p)	MLD/SLD vs SLD, U (p)
Overall stress	U=875.5 p=0.690	**U=1654** **p=0.008**	U=612.5 p=0.153
Emotional difficulties	U=939.5 p=0.859	**U=1588** **p=0.002**	U=553.5 p=0.020
Kind and helpful behaviour	U=761.5 p=0.109	**U=1621.5** **p=0.003**	U=712.5 p=0.389

Table 6.16: Post-hoc analysis using Mann-Whitney U with Bonferroni correction for level of learning disability groups per section. Bold responses indicate a significant difference between groups.

6.3.5.2. Teacher responses on the SDQ

6.3.5.2.1. Return rates

Teachers were provided with a hard copy of the SDQ to complete for each pupil in their class. This was completed by teachers of 184 children (92.0%). Of the 16 participants for whom the teacher SDQ was not completed, the class teacher deemed the SDQ inappropriate for seven participants due to the severity of their learning disability, one parent did not grant permission for the teacher to complete questionnaires, one parent withdrew consent to complete any questionnaires and seven questionnaires were not returned by the class teacher.

6.3.5.2.2. Teacher SDQ scores by section

Descriptive statistics for each section of the SDQ for all participants for whom a teacher questionnaire was returned are shown in Table 6.17.

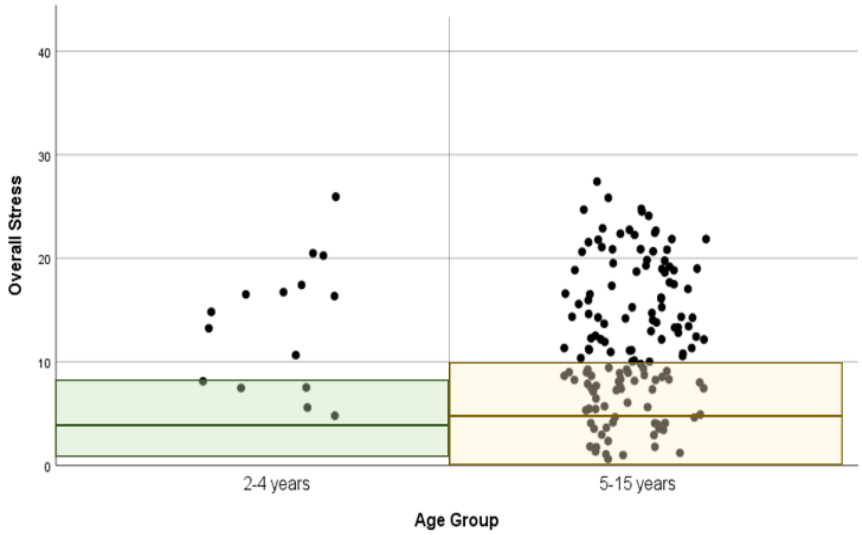
Section of questionnaire	Group	Median	IQR	Range
Overall Stress*	All participants	11	10	1 – 26
	MLD	11	9.25	1 – 25
	MLD/SLD	9.5	12.5	3 – 26
	SLD	12	10.5	1 – 24
Emotional difficulties	All participants	2	4	0 – 10
	MLD	2.5	4	0 – 9
	MLD/SLD	2	4	0 – 9
	SLD	2	5	0 – 10
Behavioural difficulties	All participants	1	3	0 – 10
	MLD	1	3	0 – 7
	MLD/SLD	1	2	0 – 5
	SLD	1	3	0 – 10
Hyperactivity or concentration difficulties	All participants	5	5	0 – 10
	MLD	5	4	0 – 10
	MLD/SLD	5	5.5	1 – 10
	SLD	6	5	0 – 10
Difficulties getting along with other children	All participants	2	4	0 – 9
	MLD	2	4	0 – 7
	MLD/SLD	2	5	0 – 9
	SLD	2	4.25	0 – 8
Kind and helpful behaviour	All participants	5	5	0 – 10
	MLD	6	5	0 – 10
	MLD/SLD	5.5	6.25	0 – 10
	SLD	5	5	0 – 10
Impact score	All participants	0	2	0 – 6
	MLD	0	2	0 – 6
	MLD/SLD	1	2.5	0 – 4
	SLD	1	3	0 – 5

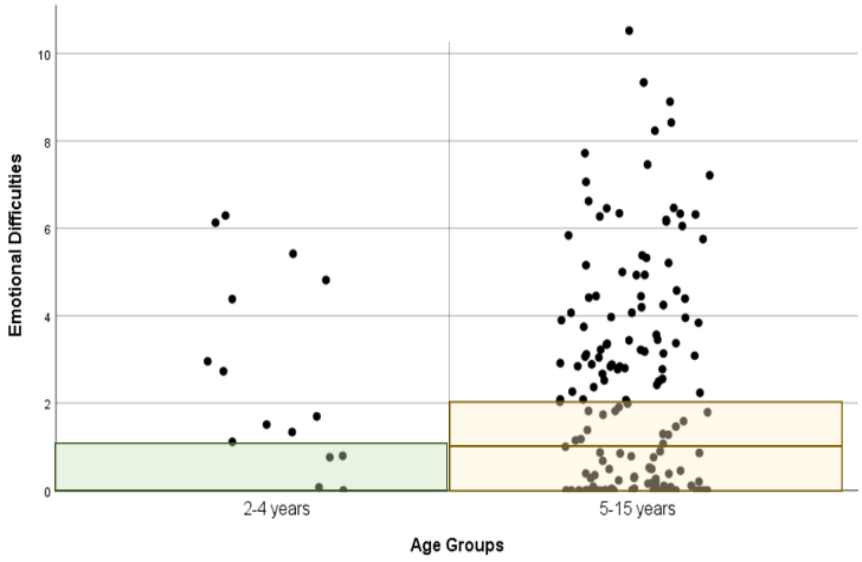
Table 6.17: Median, interquartile range (IQR) and range of scores for participants for whom a teacher SDQ was returned.
*Overall stress score is calculated by summing scores on the 'emotional', 'behavioural', 'hyperactivity and concentration difficulties' and 'difficulties getting along with other children' scores. The highest possible score is 40 for this section.

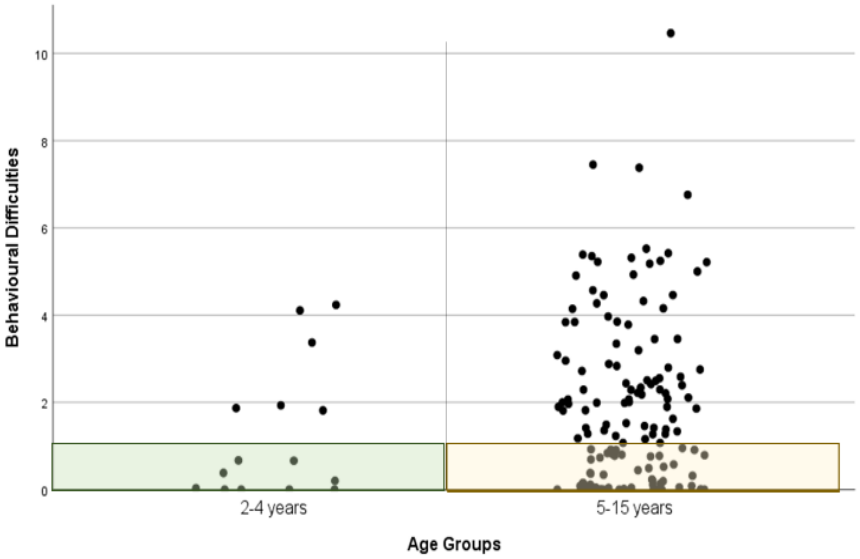
6.3.5.2.3. Comparison of teacher SDQ scores with normative data

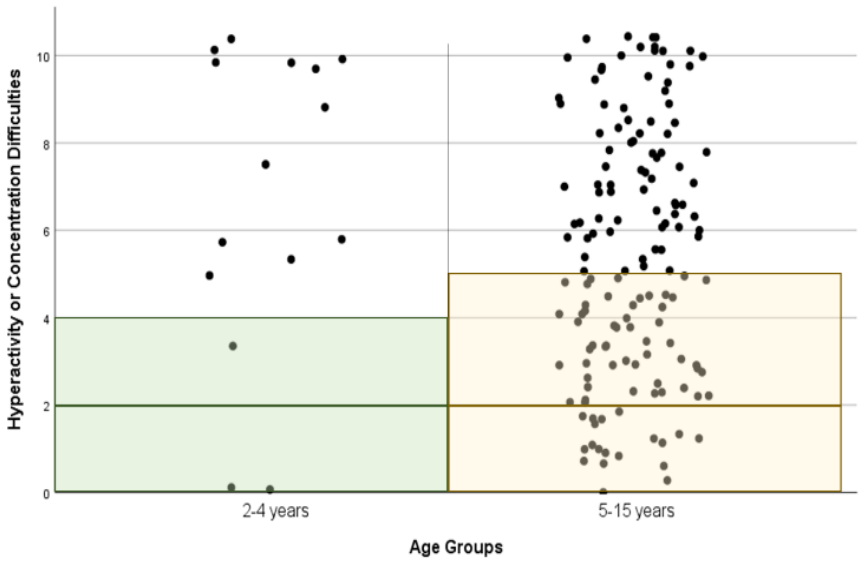
As with the parent SDQ, UK normative data for two age groups, 2-4-year-olds and 5-15-year-olds, was available for the teacher SDQ from the developer's website (www.sdqinfo.com). Responses from teachers were available for 10,004 children in the 2-4-year-old group across all sections of the SDQ, except the 'Impact' section for which this data was not available. Responses for the 5-15-year-old group were available for 8,208 children across all subsections. Similar to the method applied to parent-generated data, a median and interquartile range for each age group was calculated from the available mean, standard deviation and percentage of respondents for each individual score for the normative data. This was compared to the population with SEN in the present study and consisted of data for 15 participants in the 2-4-year-old group and 150 participants in the 5-15-year-old group. Figure 6.8 displays the results from the population with SEN compared with the normative data. The shaded area in these figures represent the median and IQR for the normative data and the individual data points represent individual scores for the population with SEN.

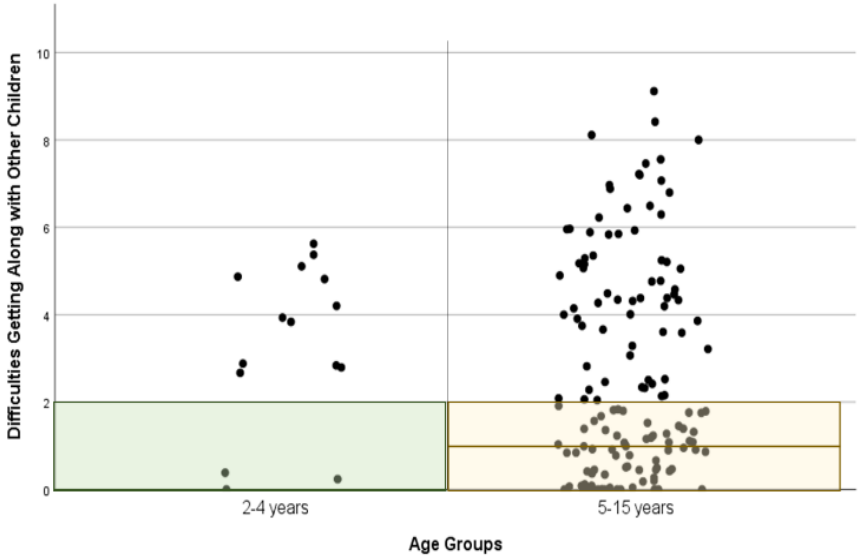
Mann-Whitney U tests were carried out to determine if the scores for each subsection of the teacher SDQ differed significantly between the population with SEN and normative data. For both age groups and across all SDQ subsections, scores for the population with SEN were significantly worse compared to normative data ($p<0.05$ for all) except for behavioural difficulties in the 2-4-year-old group, which showed no significant difference between groups ($p=0.099$; Table 6.18).

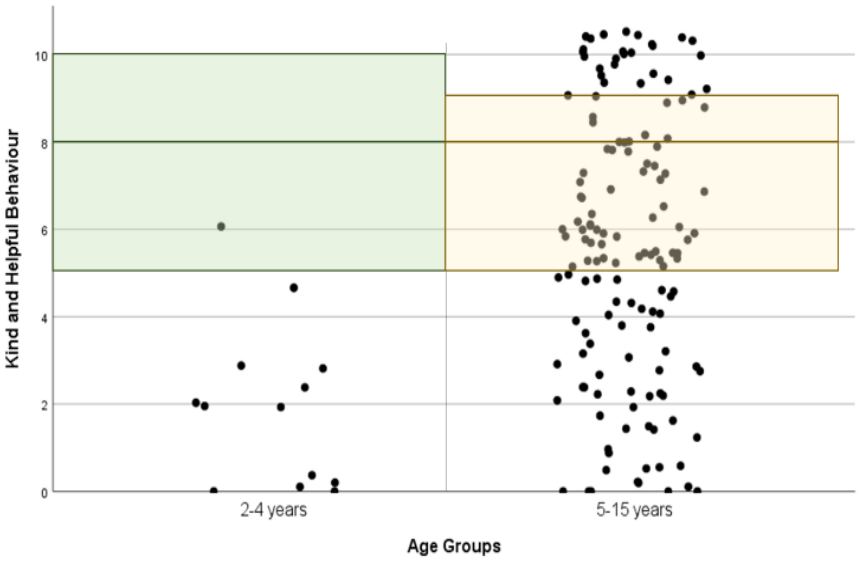

Overall Stress
40
30
20
10
0
2-4 years
5-15 years
Age Group


Emotional Difficulties
10
8
6
4
2
0
2-4 years
5-15 years
Age Groups


Behavioural Difficulties
10
8
6
4
2
0
2-4 years
5-15 years
Age Groups


Hyperactivity or Concentration Difficulties
10
8
6
4
2
0
2-4 years
5-15 years
Age Groups


Difficulties Getting Along with Other Children
10
8
6
4
2
0
2-4 years
5-15 years
Age Groups


Kind and Helpful Behaviour
10
8
6
4
2
0
2-4 years
5-15 years
Age Groups

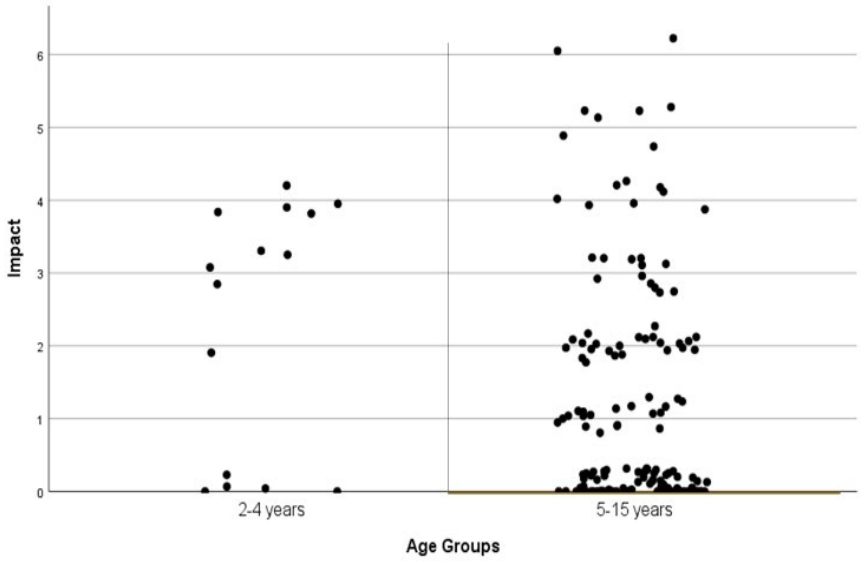


Figure 6.8: Comparison of teacher SDQ scores for each subsection between UK normative data and the population with SEN by 2-4-year old and 5-15-year-old age groups. Shaded areas represent interquartile range for the normative data, with midline equating to the median score. Individual data points represent the current study population. Data points outside the shaded area represent individuals who fall outside the normal range of scores.

SDQ Subsection	Normative data vs population with SEN, Mann Whitney U, p	
	2-4-year-old group	5-15-year-old group
Overall stress	U=23879.5 p<0.001	U=296715.0 p<0.001
Emotional difficulties	U=36651.5 p<0.001	U=460093.0 p<0.001
Behaviour difficulties	U=59273.5 p=0.099	U=364592.5 p<0.001
Hyperactivity and concentration difficulties	U=28580.0 p<0.001	U=314540.0 p<0.001
Difficulties getting along with other children	U=34734.0 p<0.001	U=411642.0 p<0.001
Kind and helpful behaviour	U=8430.5 p<0.001	U=395853.0 p<0.001
Impact score	No normative data available	U=427719.0 p<0.001

Table 6.18: Mann-Whitney U comparison of scores between normative data compared with population with SEN on each subsection of the teacher SDQ.

6.3.5.2.4. Comparison of teacher SDQ scores between level of learning disability groups

A Kruskal-Wallis test revealed there was no statistically significant difference across level of learning disability for any subsection of the teacher SDQ ($p>0.05$ for all; Table 6.19).

SDQ Section	Kruskal-Wallis test, H, p
Overall Stress	H=1.924 p=0.382
Emotional Difficulties	H=0.541 p=0.763
Behavioural Difficulties	H=0.942 p=0.624
Hyperactivity and concentration difficulties	H=0.289 p=0.865
Difficulties getting along with other children	H=1.375 p=0.503
Kind and helpful behaviour	H=5.629 p=0.060
Impact score	H=2.426 p=0.297

Table 6.19: Kruskal-Wallis test assessing relationship between level of learning disability groups and teacher SDQ scores.

6.3.5.2.5. Comparison of parent and teacher SDQ scores

A Wilcoxon signed rank test was carried out to determine whether parent SDQ scores differed significantly from teacher SDQ scores for the population with SEN for each subsection of the SDQ. In all subsections there was a significant difference between parent and teacher scores. Parents scored the participants as having more difficulties compared to teachers in all sections except kind and helpful behaviour where parents scored their children as exhibiting more positive behaviours compared to teachers (Table 6.20).

	Parent SDQ score, Mdn (IQR)	**Teacher SDQ score, Mdn (IQR)**	**Wilcoxon signed rank test, p**
Overall Stress	18 (14 to 23)	11 (7.25 to 17)	p<0.001
Emotional Difficulties	4 (2 to 6)	2 (0 to 3.75)	p<0.001
Behavioural Difficulties	2 2 to 6)	1 (0 to 2.75)	p<0.001
Hyperactivity and concentration difficulties	8 (6 to 10)	5 (3 to 7.75)	p<0.001
Difficulties getting along with other children	4 (2 to 5)	2 (0 to 4)	p<0.001
Kind and helpful behaviour	7 (4 to 9)	5 (2.25 to 8)	p<0.001
Impact score	2 (0 to 5)	0 (0 to 2)	p<0.001

Table 6.20: Comparison of parent with teacher SDQ subsection scores for the population with SEN.

6.4. Discussion

6.4.1. Visual skills inventory

In the present study, problems associated with ‘noticing multiple targets’ were most frequently reported by parents of participants with SEN. Similar results have previously been reported by Mitry et al. (2016) where noticing multiple targets was reported as one of the highest scoring sections (indicating the most difficulties) in a population of children with cerebral palsy (Mitry et al., 2016). Mitry et al. (2016) applied the INSIGHT version of the VSI and reported the highest scoring subsection in their study population was in relation to problems with visual fields, somewhat unsurprising as children with cerebral palsy often exhibit visual field deficits as has been discussed previously (Fazzi et al., 2012).

In their population of prematurely-born children, Macintyre-Beon et al. (2012) report that problems associated with ventral stream dysfunction were least frequently reported. This is in keeping with the present study, in which problems associated with recognising target objects and navigating around (Section 6; ventral stream functions) were reported infrequently by parents of participants with SEN. Ortibus et al. (2011) report similar findings; in a population of children diagnosed with CVI, problems associated with ventral stream dysfunction were reported least often.

Houliston et al. (1999) report that application of a reduced version of the VSI to a population of children with hydrocephalus and cognitive visual dysfunction identified more difficulties compared with a group of control children (Houliston

et al., 1999). Similar results are reported by Geldof et al. (2015), who applied the VSI to a group of very preterm/very-low-birth-weight children with CVI (study population) and a group of control children with normal birth history. Geldof et al. (2015) found that the study population had greater parent-reported difficulties across all subsections of the VSI compared to the control group (Geldof et al., 2015). Participants with SEN in the present study were also found to have significantly more difficulties on all subsections of the VSI compared to a typically developing control population ($p<0.001$ for all subsections). Difficulties identified using the VSI are associated with problems processing visual information in the dorsal and ventral visual pathways located within the brain. In the current study, parent-reported medical history revealed several participants presented with medical diagnoses that affect neurological function, which may account for the greater incidence of reported difficulties among the population with SEN compared to the typically developing cohort.

6.4.2. Tests of visual perception

Williams et al. (2015) performed the LEA mailbox and LEA rectangles (open and closed pattern) tasks on 214 typically developing children attending mainstream education, who ranged in age from 4-11 years. In their sample, all children were successfully able to complete the LEA mailbox and LEA rectangles tasks. Almost all children (96.0%) were scored as having ‘no problems’ on the LEA mailbox task, with the remainder exhibiting ‘minor/moderate problems’ only (Williams et al., 2015). Participants with SEN in the present study performed better on the LEA mailbox compared with the LEA rectangles task, however results were poorer than the typically

developing population reported by Williams et al. (2015). In the population with SEN in the present study, 11% were recorded as ‘unable to perform’ the LEA mailbox task and 85.5% completed the LEA mailbox task with ‘no problems’.

For the ‘open pattern’ and ‘closed pattern’ LEA rectangles task, 74.4% and 73.8% of typically developing children were able to perform the tasks with ‘no problems’ (Williams et al., 2015). This is in contrast to participants with SEN in the present study, in which only 43.5% and 42.0% were able to perform the ‘open pattern’ and ‘closed pattern’ rectangles tasks with ‘no problems’ respectively. ‘Minor/moderate problems’ on the ‘open pattern’ and ‘closed pattern’ were reported less often in the population with SEN compared to the typically developing population reported by Williams et al. (17.5% for ‘open pattern’ and 19% for ‘closed pattern’ for the population with SEN compared with 22% on each task for the typically developing population), however ‘major difficulties/unable to perform’ the task were reported much more frequently in the population with SEN compared to typically developing children for both the ‘open pattern’ (38.5% vs 6.1% respectively) and ‘closed pattern’ (40% vs 4.2% respectively). In the present study, participants with SEN scored similarly well on both the ‘open’ and ‘closed’ pattern tasks, similar to results reported by Williams et al. (2015) for typically developing children.

The shape-sorter task examines a child’s ability to recognise objects, a function of the temporal lobes, and plan and execute visually guided motion, a function of the parietal lobes (Atkinson et al., 2002; Milner and Goodale, 1995). Atkinson et al. (2002) report that typically developing children aged 18 months or older should be able to successfully complete a three-shape sorter

task. The five-shape sorter task is reported as suitable for typically developing children aged 24 months or older (Atkinson et al., 2002). Atkinson et al. (2002) suggest that children beyond 24 months of age should be able to match at least 4/5 shapes correctly. In the present study, the majority of participants with SEN were able to complete both tasks with ‘no problems’ (89% for three-shape and 84.5% for five-shape). Twelve percent of participants had ‘major problems’ or were ‘unable to perform’ the task. Failure on this task is indicative of developmental delay or a specific impairment in spatial cognition which may account for the difference in performance between the population with SEN and the typically developing population (Atkinson et al., 2002).

In general, across all visual perceptual tasks, participants with SEN performed worse than typically developing children. Performance of participants with severe learning difficulties was significantly worse than that of participants with moderate or moderate/severe learning difficulties. Nielsen et al. (2007a) report that children with a more severe developmental disability are at a higher risk of vision problems, including cerebral visual impairment which arises as a result of damage to the brain. This can ultimately disrupt aspects of visual perception and normal visual processing which may account for these findings (Nielsen et al., 2007a). Chapter 7 of this thesis will determine whether the visual perceptual tasks selected for use in the present study were useful in differentiating between participants stratified into CVI and non-CVI groups.

Visual function characteristics had an effect on performance on the tests of visual perception. Participants with poorer contrast sensitivity and atypical vertical eye movements had more difficulty orientating the card through the slit

on the LEA mailbox task. These results are unsurprising as accurate eye movement control is required to navigate one's hand to locate and orientate the card through the mailbox opening. The card presented to participants was white in colour. While the mailbox itself was a vibrant yellow colour, participants with poor contrast sensitivity could have difficulty discriminating the difference in colour between the card and the mailbox, adding to the complexity of this task. Impaired contrast sensitivity and eye movement control can be indicative of deficits in higher visual processing which may also account for the poorer performance on the LEA mailbox task (Allen et al., 2010; Kung & Willcox, 2007).

Participants with atypical smooth pursuit eye movements were more likely to have difficulties with the LEA 'open pattern' rectangles task. No such relationship was found for the 'closed pattern' task. This difference in performance could be explained by the greater area across which the 'open pattern' task was displayed. Adjacent rectangles were touching in the 'closed pattern' whereas in the 'open pattern' they were spaced 1-2cm apart resulting in a larger area for participants to observe and scan; a task made more difficult in the presence of atypical smooth pursuit eye movements. The 'LEA method' rectangles task results exhibited the strongest associations with visual deficits. Participants with poorer contrast sensitivity, reduced stereopsis, near strabismus and/or atypical smooth pursuit eye movements were more likely to have problems with this task. These results make sense given that the task required the participant to set one set of the grey rectangles on top of the other set of grey rectangles. Presence of strabismus disrupts binocular vision and results in reduced or absent stereopsis (3D vision). If a participant has reduced

stereopsis they will find this a more challenging task as they are required to use 3D vision to grasp and navigate the rectangles and accurately judge the distance in order to place one set on top of the other set of rectangles. Both sets of rectangles are grey in colour, but of varying shades, meaning that the contrast between the two sets is poor. Thus, if a child has reduced contrast sensitivity they will find it more difficult to accurately discriminate between the two sets of rectangles and successfully complete the 'LEA method' task. Processing of stereopsis and contrast sensitivity both involve higher visual processing centres (Nishida et al., 2001; Allen et al., 2010). Stereopsis neural processing is thought to occur within the dorsal region of the parieto-occiptal cortex (Nishida et al., 2001), therefore, if defective, could imply a higher visual processing deficit and ultimately hinder performance on the LEA rectangles task. Abnormal smooth pursuit eye movements would also render this task more difficult as the participant is required to search along one set of rectangles to identify where to place each rectangle from the second set. In addition, atypical smooth pursuit eye movements are associated with deficits affecting the occipital, temporal and parietal lobes (Heide et al., 1996). As with stereopsis and contrast sensitivity function, defective smooth pursuits could indicate a higher visual processing deficit and thus affect performance on the LEA rectangles task.

Participants with poorer contrast sensitivity were more likely to have difficulties with the shape sorter tasks. When presented with a shape to insert into the corresponding well on the shape board, all other shapes were first removed, leaving the participants with a pale wooden board to navigate. While the shapes themselves are of high contrast, participants with poor contrast

sensitivity may find it difficult to discern where the shape should be correctly inserted. A contrast sensitivity impairment may indicate a deficit in higher visual processing centres, including those involved in the perception of motion (Allen et al., 2010). As such, in the current study, participants with reduced contrast sensitivity may also present with a reduced ability to accurately execute visually guided motion required by the shape sorter tasks.

While the acceptability of the tests of visual perception was generally good in the population with SEN, a major drawback in their use is that all tests included in the present study require motor function. This renders their use unsuitable for some children with physical impairments and SEN.

6.4.3. Visual behaviours

Roman-Lantzy describes characteristic behaviours with which children with CVI often present. Such behaviours include preference for strong coloured objects (e.g. red and yellow), attraction of moving objects, visual latency, visual field preferences, difficulty with complex visual scenes, gazing at light sources, non-purposeful gaze, difficulties with distance viewing, diminished visual reflex responses, poor response to novel visual objects and absence of visually guided reach (Roman-Lantzy, 2007a). These characteristic behaviours were first observed in children with CVI by Jan and Groenveld (1993). Due to the varying nature of CVI, the number and type of behaviours a child may present with is dependent on the location of damage to the brain. In the present study, presence of a number of these visual behaviours was assessed through direct observation during the in-school vision assessment. In general, participants

with SEN described in the current study exhibited typical visual behaviour responses, however, poor eye contact was the most commonly recorded atypical visual behaviour noted (14%). It is well established that children with autism spectrum disorder often demonstrate poor eye contact (Senju & Johnson, 2009). Over one third (35.7%) of participants in the present study had a diagnosis of autism spectrum disorder which may account for this finding. Philip and Dutton (2014) and Fazzi et al. (2019) have previously reported that children with ASD and those with CVI share similar behavioural traits. Considering this, evaluation of whether atypical eye contact is also more common in children who exhibit evidence of CVI is explored in Chapter 7.

6.4.4. Crowded visual acuity and crowding ratios

As with the typically developing control population discussed in Chapter 4, participants with SEN exhibited significantly better binocular single optotype acuity scores compared to crowded optotype acuity scores. Performance on both visual acuity charts (crowded and single optotypes) was significantly poorer for participants with SEN compared with typically developing control children. This is consistent with previous literature which reports that children with developmental disabilities exhibit poorer visual acuity compared with typically developing children, as has been discussed previously in Chapter 5 (Courage et al., 1994; Woodhouse et al., 1996; Nielsen et al., 2007a; Creavin & Brown, 2009; Little et al., 2013).

Despite a significant difference in both single and crowded optotype visual acuity between the population with SEN and typically developing controls,

crowding ratios failed to demonstrate a significant difference between the two groups (p=0.072). Optotypes on each line of the LEA crowded symbols chart are spaced one optotype width apart which may not produce a great enough crowding effect to elicit differences between the population with SEN and typically developing population (Gräf et al., 2000). Gräf et al. (2000) report that crowded LEA optotype acuity was equal to visual acuity measured using the single Landolt-C test in a population of children and adults with amblyopia and non-amblyopic controls. This indicates that the LEA symbols are a less complex test compared to the Landolt C which has smaller inter-optotype spacing. Huunerman et al. (2012) also report that symbol optotypes evoke less crowding than letter optotypes, and smaller inter-optotype spacing produces poorer acuity scores. Likewise, Lalor et al., (2016) report that the Cambridge Crowding Cards create more crowding effects compared with the LEA symbols in a population of normally-sighted adults. While the LEA symbols are advantageous for use in young children due to the acceptability of the symbols, it may not induce sufficient contour interaction to differentiate crowding ratios between typically developing participants and those with SEN. This drawback may ultimately eliminate the ability of crowding ratios measured using the LEA symbols to identify children with evidence of CVI, explored in Chapter 7.

A measure of both crowded and single optotype acuity using the LEA symbols (enabling calculation of a crowding ratio) was possible in just over 75% of participants in the population with SEN. The remaining 25% were unable to comply with testing procedures and were significantly more likely to have severe learning difficulties. Participants with SLD who were able to complete the crowded and single LEA symbol charts had significantly poorer visual

acuity compared to those with MLD/SLD or MLD. Nielsen et al. (2007a) also found that children with a greater level of learning disability demonstrated significantly poorer visual acuities compared with more moderate/mild learning difficulties (Nielsen et al., 2007a). This is in agreement with findings from participants in the present study population (Black, 2019). Therefore, if calculation of a crowding ratio was possible in more participants with SLD, greater disparity between the population with SEN and typically developing control population may have been apparent.

A further reason why differences in crowding ratios between participants with SEN and the typically developing control population could be that visual acuity was scored using a line-by-line scoring system rather than letter-by-letter. Perhaps if letter-by-letter scoring had been employed this would have highlighted more subtle differences in crowding ratios between both groups of participants, particularly as the difference between groups was close to significance based on line-by-line scoring (p=0.072).

6.4.5. Strengths and Difficulties Questionnaire

In the present study, significantly poorer scores were obtained for participants with SEN across all subsections of the SDQ compared with UK normative data. This finding was apparent with both teacher and parent scores and is consistent with findings by Kaptein et al. (2008) who report that children with intellectual disability in their study population scored significantly worse across all subsections of the SDQ compared to children without intellectual disability (Kaptein et al., 2008). Hysing et al. (2007) also report that in a sample of 7-9-

year-olds with chronic illness (including neurological disorders and learning disabilities), scores on all SDQ subsections were significantly worse compared with healthy control children, with the exception of the ‘behavioural problems’ subsection, in which there was no significant difference reported between groups (Hysing et al., 2007). Evaluation of whether differences in SDQ scores exist between participants who exhibit evidence of CVI and those who do not is considered in Chapter 7 in order to ascertain whether the SDQ has value in identifying children more at-risk of CVI.

Parent and teacher responses on both the VSI and SDQ differed significantly across all subsections of the questionnaires for participants with SEN. This is in agreement with findings by Cheng et al. (2018) who report differences in parent and teacher responses using the SDQ in children aged six to 11 years. Cheng et al. (2018) argue that this lack of agreement does not indicate lack of validity of responses from one group of respondents over the other, but rather both respondents experience the child in different environments, with both viewpoints providing unique and valid insight into the child’s behaviours (Cheng et al., 2018). On the contrary, O’Connor et al. (2004) report that parents know their children and behaviours well, and therefore information provided by them is likely to be a richer source of information (O’Connor et al., 2004). A school environment tends to be more structured, and as such, teachers may not experience the full range of difficulties a child may present with in each aspect of daily living explored by the SDQ and the VSI, which may further account for the difference in responses.

6.5. Conclusion

This chapter has presented results of the population with SEN for a number of assessments which have been proposed to have value in probing for evidence of potential CVI-related difficulties within an in-school setting. Success rates for each assessment were generally high, however participants with more severe learning difficulties were more likely to have difficulty complying with the assessment procedures. For the majority of assessment procedures, participants with SEN performed or were scored more poorly compared to typically developing children, with the exception of crowding ratios, where a significant difference in performance was not observed. Results of this chapter have profiled what constitutes ‘typical’ responses and performance for participants with SEN and will be used in Chapter 7 to compare performance on assessments between participants stratified according to whether or not they exhibit evidence of CVI.

Chapter 7

Investigating cerebral visual impairment (CVI) in a population with Special Educational Needs (SEN) as part of an in-school vision assessment service

7.0. Chapter overview

This chapter stratifies participants with SEN into two groups according to whether they do or do not exhibit evidence of CVI as determined using parental responses on the Visual Skills Inventory (VSI). Participant demographics, visual function characteristics and performance on other methods of assessment described in Chapter 6 are compared between the two groups to determine whether differences exist between the CVI and non-CVI groups. 'Key questions' on the VSI used by previous authors to screen for CVI are also evaluated in the current population with SEN.

7.1. Introduction

As evidenced through systematic review of the literature (Chapter 2), use of a variety of tests and assessments provide an optimal approach to investigating CVI in children. Chapter 3 discusses the rationale for selecting tests used in the present study to investigate CVI within a special school setting. Chapter 5 and 6 present the results, including success rates when applied in the population with SEN, for the selected assessments. In the present chapter, participants were stratified according to whether or not they exhibited evidence of CVI using the responses on the parent VSI to stratify participants into 'CVI' and 'non-CVI' groups. The characteristics of these two CVI groups were then

compared using the metrics and approaches described in Chapter 3.2.3. These comparisons were used to identify whether additional assessments add value in the identification of children with CVI in special school settings. It is worth acknowledging at the outset of this chapter that these results are framed by using the parent VSI scores to stratify participants into the CVI group. The strengths and limitations of this approach are addressed in the discussion.

7.2. Methods

7.2.1. Determination of CVI and Non-CVI groups

As mentioned previously, results of the parent VSI were used to stratify participants into two groups: those who exhibited signs of CVI and those who did not (herein called CVI and non-CVI groups respectively). The VSI and scoring have been described previously (Chapter 3.2.3.1.2). Participants were defined as having evidence of CVI if they had a mean score of ≥3 in each or any section of the VSI completed by the participants' parent; meaning that the majority of difficulties in that section were reported to occur 'sometimes', 'often' or 'always'. These criteria are the same as those utilised by Mitry et al. (2016) and Duke et al. (2019). Valid VSI responses were obtained for 150 participants; of which 75 participants were categorised into the CVI group and 75 into the non-CVI group using the aforementioned criteria.

7.3. Results

7.3.1. Parent Visual Skills Inventory responses

7.3.1.1. CVI Group responses

The majority of participants (45.3%) identified as having evidence of CVI had problems in only one section of the VSI (Table 7.1).

VSI problems identified (mean score ≥3)	Number of participants, n (%)
One section only	34 (45.3%)
Two sections	16 (21.3%)
Three sections	8 (10.7%)
Four sections	6 (8%)
Five sections	5 (6.7%)
Six sections	5 (6.7%)

Table 7.1: Number of participants with a score ≥3 in one or more sections of the VSI.

Table 7.2 shows the number of participants scoring ≥3 in each subsection of the VSI. Eighteen participants (24.0%) had a mean score ≥3 for the entire inventory. Section 5 (noticing multiple targets) was the most common section where participants were reported as having difficulties, with 54 participants scoring ≥3 in this section, representing 72.0% of those in the CVI group. The least common section to elicit a mean score ≥3 was Section 6 (recognition and navigation), where 17 participants (22.7%) were reported as having problems. As discussed previously (Chapter 3), Section 6 probes for evidence of ventral stream dysfunction. Four participants were reported as having ventral stream problems only (Section 6). The remaining 13 had problems in at least one section relating to dorsal stream dysfunction.

VSI Section	Number of participants with mean score ≥3 (%)
Total inventory mean score	18 (24.0%)
Section 1. Visual fields	26 (33.3%)
Section 2. Perception of movement	27 (36.0%)
Section 3. Visually guided movement	20 (26.7%)
Section 4. Searching for visual targets	30 (40.0%)
Section 5. Noticing multiple targets	54 (72.0%)
Section 6. Recognising target objects and navigating around	17 (22.7%)

Table 7.2: Number of participants per each VSI subsection with a mean score ≥3.

7.3.1.2. Comparison of CVI and non-CVI group responses

Figure 7.1 illustrates parent VSI responses for the CVI and non-CVI groups for the total inventory and each of the six subsections. Data from the typically developing control population discussed in Chapter 4 are also included for comparison.

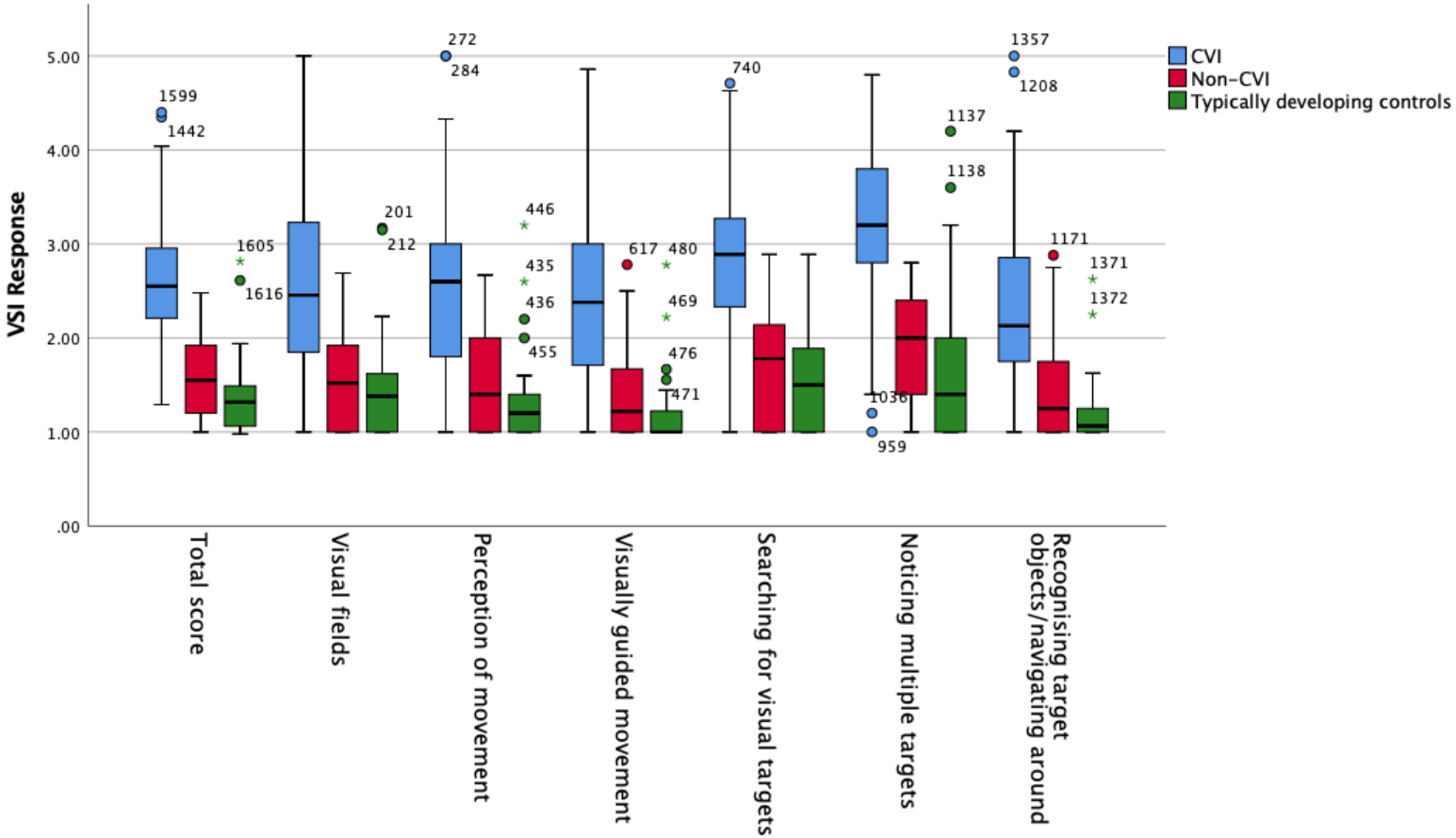


Figure 7.1: Box plots showing CVI, non-CVI group and typically developing control population (Chapter 4) responses for the total inventory and each VSI subsection. Y-axis scale 1, 2, 3, 4, 5 represents responses of 'never', 'rarely', 'sometimes', 'often' or 'always' respectively. The solid black line indicates the median and the box indicates the interquartile range. Whiskers indicate 5th and 95th centiles. Outliers are represented by coloured circles and asterisks extending beyond the whiskers.

7.3.1.3. Do parents and teachers identify the same CVI participants using the VSI?

A teacher-completed VSI was returned for 125 participants (62.5%). Both a parent and teacher VSI were returned for 100 participants (50.0%). Of these 100 participants, 52 were stratified into the CVI group and 48 into the non-CVI group according to parent VSI responses as discussed previously.

Application of the same criteria used to identify participants with evidence of CVI using the parent VSI to responses on the teacher VSI identified 29 participants who were reported as having a mean score ≥3 on each or any subsection of the VSI. Parents of four of these 29 participants did not return a VSI for their child. Of the remaining 25 participants for whom both a parent and teacher VSI were returned, 20 were included in the CVI group and five were in the non-CVI group (stratified using parent VSI responses). Thus, teacher responses on the VSI only identified 20/52 of participants in the CVI group (38.5% sensitivity; Figure 7.2).

Ninety-six participants were not identified as having evidence of CVI using the teacher VSI. Of these, 75 also had parent VSI responses available; 32 of whom were stratified into the CVI group and 43 were stratified into the non-CVI group (using parent VSI responses). Therefore, teachers identified 43/48 participants who were stratified into the non-CVI group (89.6% specificity; Figure 7.3).

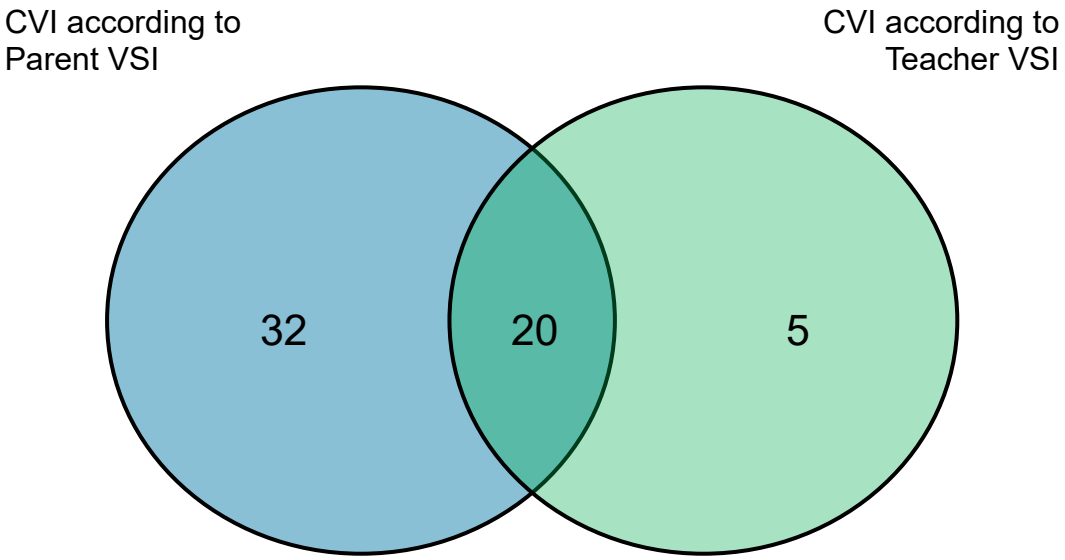


Figure 7.2: Venn diagram illustrating number of participants classified as having evidence of CVI according to parent and teacher VSI responses (only participants for whom parent and teacher VSI were available are included).

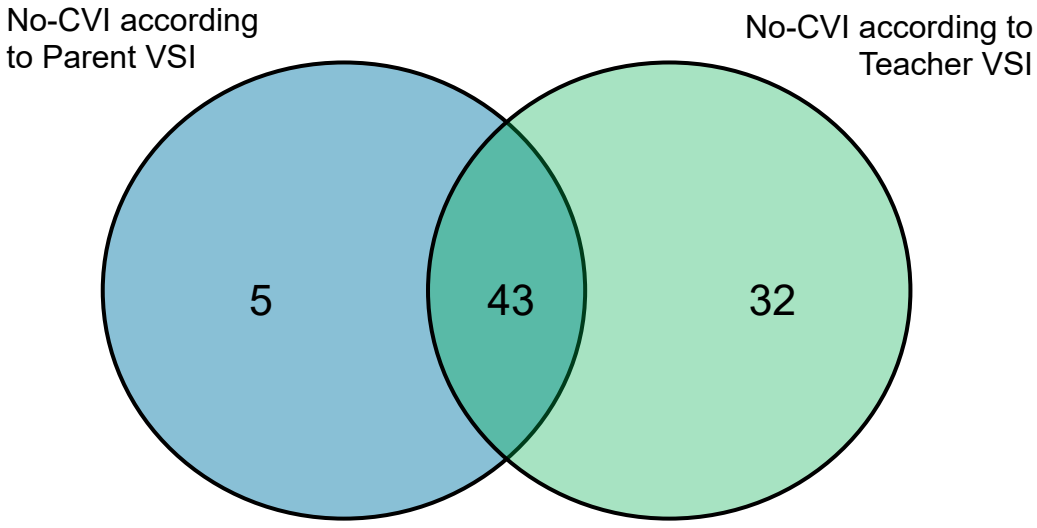


Figure 7.3: Venn diagram illustrating number of participants classified as having no evidence of CVI according to parent and teacher VSI responses (only participants for whom parent and teacher VSI were available are included).

7.3.2. Comparison of CVI and non-CVI group characteristics

7.3.2.1. Participant demographics

7.3.2.1.1. Age

Age distributions of participants in the CVI and non-CVI groups are shown in Table 7.3. A Mann-Whitney U test revealed a significant difference in age between the CVI and non-CVI group (U=2262, p=0.039), with younger children more likely to be classified as exhibiting evidence of CVI using the VSI, compared with older children.

	CVI Group (n=75)	**Non-CVI group (n=75)**
Median (years)	10.5	11.5
IQR (years)	6.5 to 13.5	9.25 to 13.7
Range (years)	3.75 to 19.25	4.50 to 19.33

Table 7.3: Age distribution of participants in CVI and non-CVI groups

7.3.2.1.2. Gender, Level of Learning Disability and Birth History

Gender distribution, level of learning disability and birth history of participants in the CVI and non-CVI group are shown in Table 7.4. Chi-square and Fisher's exact analysis revealed there was no significant associations in these demographics between the two groups (Table 7.4).

Demographic		CVI, n (%)	Non-CVI, n (%)	Chi-square analysis
Gender	Male	50 (33.3%)	52 (34.7%)	X^2=0.123, p=0.726
	Female	25 (16.7%)	23 (15.3%)	
Level of learning disability	PMLD	0 (0%)	0 (0%)	Fisher's exact test=6.383, p=0.549
	Severe	23 (15.3%)	25 (16.7%)	
	Moderate/ Severe	15 (10%)	8 (5.3%)	
	Moderate	29 (19.3%)	37 (24.7%)	
	Mild/MLD	0 (0%)	0 (0%)	
	Complex interaction of needs	1 (0.7%)	0 (0%)	
	Delayed learning	0 (0%)	1 (0.7%)	
	No permission to access / StEN not in file / information not present on StEN	3 / 3 / 1 (2 / 2 / 0.7%)	2 / 1 / 1 (1.3 / 0.7 / 0.7%)	
Birth History	Full term (GA ≥37 weeks)	58 (38.7%)	62 (41.3%)	Fisher's exact test=2.706, p=0.688
	Moderate to late preterm (GA ≥32 and < 37 weeks)	8 (5.3%)	8 (5.3%)	
	Very preterm (GA ≥18 and <32 weeks)	1 (0.7%)	2 (1.3%)	
	Extremely preterm (GA <28 weeks)	2 (1.3%)	0 (0%)	
	Unknown	5 (3.33%)	3 (2%)	

Table 7.4: Gender, birth history and level of learning disability of CVI and non-CVI groups. PMLD=profound and multiple learning difficulties, MLD=moderate learning difficulties, SLD=severe learning difficulties, StEN=statement of educational need, GA=gestational age.

7.3.2.1.3. Medical history

Participants were grouped according to whether they were diagnosed with a medical condition which affects brain development and/or function. This included participants with global developmental delay, epilepsy, cerebral palsy, dyspraxia, hydrocephalus, brain cyst, microcephaly, polymicrogyria, no nerve protection on left hand side of brain, kernicterus, holoprosencephaly and grey matter heterotopia (derived from parental report in Table 5.2). Chi-square analysis revealed participants with the aforementioned conditions were significantly more likely to have difficulties associated with CVI identified using the parent VSI compared to participants without these medical diagnoses (X^2=4.920, p=0.043; Table 7.5). There was no association between a diagnosis of autism spectrum disorder (ASD) or Asperger's and whether the participant was categorised into the CVI or non-CVI groups (n=35 and 24 respectively; X^2=3.381, p=0.094).

Medical diagnosis affecting brain development/function	**CVI, n (%)**	**Non-CVI, n (%)**
Yes, n (%)	21 (28.0%)	10 (13.3%)
No, n (%)	54 (72.0%)	65 (86.7%)

Table 7.5: Participants with a medical diagnosis affecting brain development and/or function according to CVI stratification.

7.3.2.2. Participant visual characteristics and function

7.3.2.2.1. Refractive error

Frequency of refractive error type (myopia, emmetropia, low or moderate hyperopia) for the CVI and non-CVI groups is shown in Table 7.6. A Mann-Whitney U test revealed no statistically significant difference in spherical equivalent refractive error (SER) between the CVI (Median, Mdn=+0.75) and non-CVI (Mdn=+0.75) groups (U=2791.5, p=0.937).

	CVI group				Non-CVI group			
	n (%)	**Mdn**	**IQR**	**Range**	**n (%)**	**Mdn**	**IQR**	**Range**
Myopia (≤-0.50D)	9 (12.0)	-0.75	-4.13 to -0.50	-6.50 to -0.50	10 (13.3)	-1.50	-5.81 to -0.69	-14.00 to -0.50
Emmetropia (>-0.50 to <+0.50)	20 (26.3)	0.00	-0.188 to +0.25	-0.25 to +0.25	18 (24.3)	0.00	-0.25 to -0.063	-0.25 to +0.25
Low hyperopia (≥+0.50 to <+2.00)	31 (40.8)	+1.00	+0.75 to +1.50	+0.50 to +1.75	26 (35.1)	+0.875	+0.50 to +1.25	+0.50 to +1.75
Moderate hyperopia (≥+2.00)	15 (19.7)	+3.50	+2.50 to +5.25	+2.00 to +6.75	21 (28.3)	+3.50	+2.25 to +5.00	+2.00 to +9.25

Table 7.6: Frequency of refractive error type for the CVI and non-CVI groups based on right SER.

7.3.2.2.2. Visual acuity

Descriptive statistics for binocular, best-corrected visual acuity (BCVA) measured at both distance and near for the CVI and non-CVI groups are shown in Table 7.7. These results are displayed graphically in Figure 7.4. A Mann-Whitney U test revealed there was a significant difference in distance BCVA, with participants in the CVI group exhibiting poorer visual acuity compared to the non-CVI group (U=2198.0, p=0.038). Best-corrected near

visual acuity did not differ significantly between groups (U=1414.0, p=0.279). Eight participants for whom a parent VSI was returned were identified as having a visual impairment (based on WHO criteria of visual acuity worse than 6/12 or 0.3logMAR equivalent; WHO, 2018b); of these seven (87.5%) were in the CVI group.

	CVI group			**Non-CVI group**		
	Median	**IQR**	**Range**	**Median**	**IQR**	**Range**
Distance acuity (logMAR)	0.000	-0.100 to 0.125	-0.300 to 0.600	-0.025	-0.150 to 0.086	-0.275 to 0.300
Near acuity (logMAR)	0.025	0.000 to 0.163	0.000 to 0.600	0.025	0.000 to 0.100	0.000 to 0.400

Table 7.7: Binocular, best-corrected distance and near visual acuity descriptive statistics for participants in the CVI and non-CVI group.

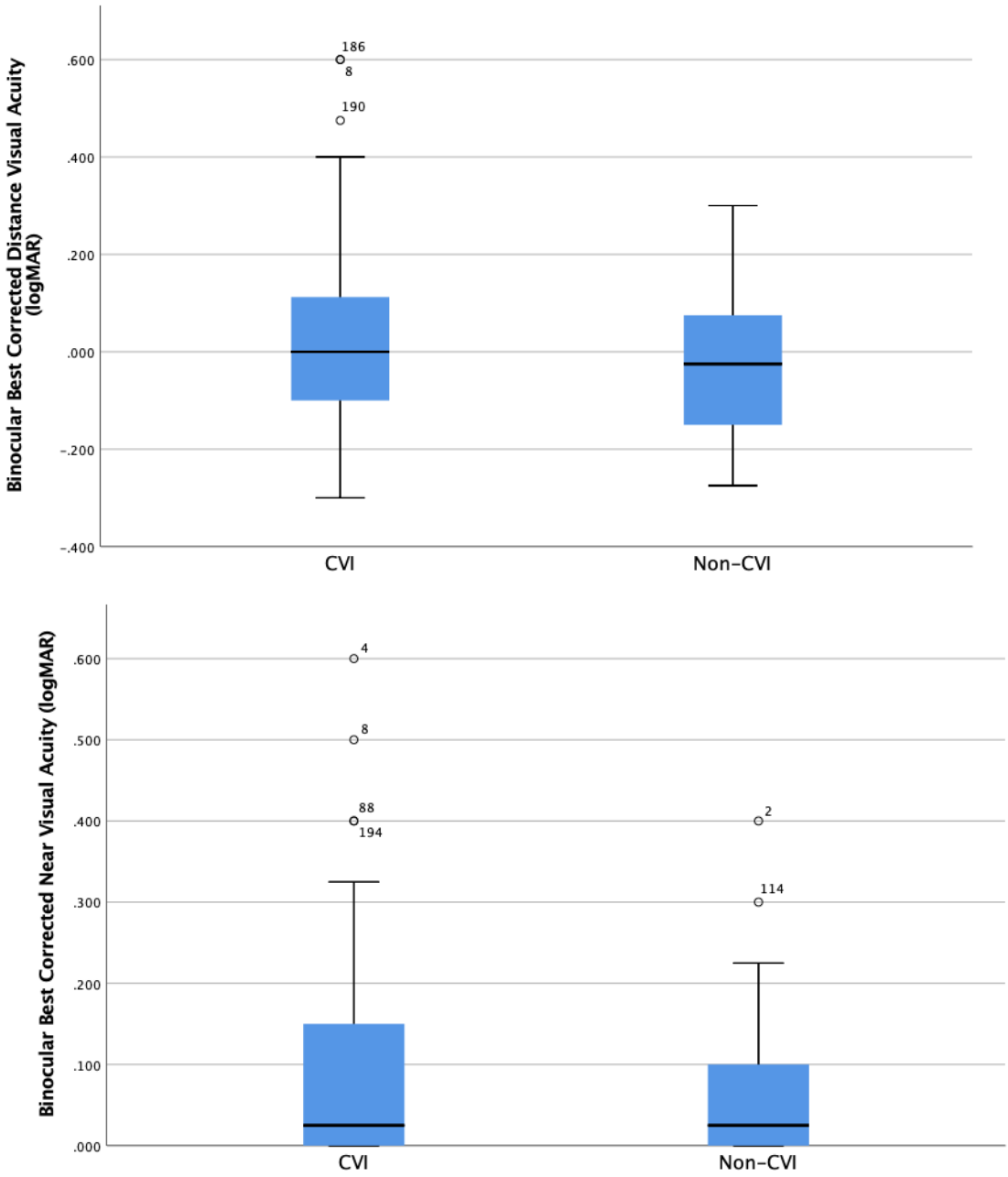


Figure 7.4: Binocular best-corrected distance (top) and near (bottom) visual acuity for the CVI and non-CVI groups. The solid black line indicates the median and the box indicates the interquartile range. Whiskers indicate 5th and 95th centiles. Outliers are represented by open circles extending beyond the whiskers.

7.3.2.2.3. Ocular movements and alignment

Data relating to presence of nystagmus, the quality of smooth pursuits, saccadic eye movements and ocular alignment with distance and near fixation are shown for both the CVI and non-CVI group in Table 7.8. Chi-square and Fisher's exact analysis revealed there was no significant association between the presence of abnormal ocular movements or alignment and the CVI/non-CVI groups (Table 7.8).

		CVI, n (%)	Non-CVI, n (%)	Chi-square analysis
Ocular movements	Normal vertical pursuits	60 (93.8%)	59 (8.4%)	X^2=3.012, p=0.103
	Abnormal vertical pursuits	4 (6.3%)	11 (15.7%)	
	Normal horizontal pursuits	60 (92.3%)	60 (85.7%)	X^2=1.484, p=0.279
	Abnormal horizontal pursuits	5 (7.7%)	10 (14.3%)	
	Normal vertical saccades	61 (95.3%)	67 (98.5%)	Fisher's exact test=1.161, p=0.354
	Abnormal vertical saccades	3 (4.7%)	1 (1.5%)	
	Normal horizontal saccades	65 (100%)	67 (98.5%)	Fisher's exact test=0.963, p=1.000
	Abnormal horizontal saccades	0	1 (1.5%)	
	Nystagmus	3 (4.0%)	2 (2.7%)	Fisher's exact, p=1.000
Ocular alignment with distance fixation	Orthophoria	57 (76.0%)	63 (84%)	Fisher's exact test=8.751, p=0.073
	Exotropia	8 (10.6%)	4 (5.3%)	
	Esotropia	8 (10.6%)	2 (2.6%)	
	Exophoria	2 (2.6%)	2 (2.6%)	
	Esophoria	0	3 (4.0%)	

	Eso- and hypertropia	0	1 (1.3%)	
Ocular alignment with near fixation	Orthophoria	51 (68.0%)	52 (69.3%)	Fisher's exact test=4.446, p=0.484
	Exotropia	6 (8.0%)	4 (5.3%)	
	Esotropia	5 (6.7%)	5 (6.7%)	
	Exophoria	7 (9.3%)	10 (13.3%)	
	Esophoria	1 (1.3%)	3 (4.0%)	
	Eso- and hypertropia	0 (0%)	1 (0.7%)	

Table 7.8: Ocular movements and alignment of CVI and non-CVI groups.

7.3.2.2.4. Ocular health

Results of ocular health assessments for participants in the CVI and non-CVI groups are shown in Table 7.9. Three participants presented with an ocular health abnormality which is known to occur in children with CVI (optic disc atrophy and optic nerve head pallor); all of whom were in the CVI group.

Ocular health details	**CVI, n**	**Non-CVI, n**
No ocular health abnormalities detected	60	65
Blepharitis	2	1
Blocked tear ducts	1	1
Lens opacity	1	1
Disc atrophy	2	0
Ptosis	1	0
Tortuous retinal blood vessels	1	0
Myelination of retinal nerve fibres	1	0
Pale fundus	0	1
Optic disc drusen	1	0
Posterior synechiae	1	0
Optic nerve head pallor	1	0
Intraocular lens	1	0
Ectopia lentis	0	1

Table 7.9: Results of ocular health assessment for the CVI and non-CVI groups.

7.3.2.2.5. Visual Fields

Of the total population with SEN, four participants presented with a visual field deficit. Of these four participants, only one parent returned a VSI questionnaire; this participant was in the non-CVI group.

7.3.2.2.6. Optokinetic (OKN) Response

Participants were classified as having 'typical' or 'atypical' binocular OKN responses assessed using an OKN drum. More participants in the CVI group had an atypical binocular OKN response compared to participants in the non-CVI group, however chi-square analysis revealed the association between groups did not reach statistical significance (Table 7.10).

OKN Response	CVI, n (%)	Non-CVI, n (%)	Chi-square analysis
Typical	58 (82.9%)	67 (91.7%)	χ^2=2.586, p=0.133
Atypical	12 (17.1%)	6 (8.2%)	

Table 7.10: OKN responses for participants in the CVI and non-CVI groups.

7.3.2.2.7. Contrast Sensitivity

Table 7.11 shows binocular contrast sensitivity results for the CVI and non-CVI groups, according to whether participants had a normal result or a result outside the normal range measured using the Cardiff Contrast Test. Chi-square analysis revealed there was no significant association in performance between performance of the two groups (Table 7.11).

Contrast sensitivity	CVI, n (%)	Non-CVI, n (%)	Chi-square analysis
Normal	57 (80.3%)	62 (87.3%)	X^2=1.297, p=0.363
Outside normal range	14 (19.7%)	9 (12.7%)	

Table 7.11: Contrast sensitivity for the CVI and non-CVI groups.

7.3.2.2.8. Stereopsis

Table 7.12 shows CVI and non-CVI group responses according to whether they had a normal result or result outside the normal range using the Frisby stereotest. Chi-square analysis revealed no significant association between performances of the two groups (Table 7.12).

Stereopsis	CVI, n (%)	Non-CVI, n (%)	Chi-square analysis
Normal	35 (60.3%)	38 (57.6%)	X^2=0.098, p=0.855
Outside normal range	23 (39.7%)	28 (42.4%)	

Table 7.12: Results of Frisby stereotest between CVI and non-CVI groups.

7.3.2.3. Visual behaviour observations

Results of direct observation of visual behaviour for the CVI and non-CVI groups are shown in Table 7.13; there were no significant associations of visual behaviour observations between the two groups. Definitions for each observed behaviour have been described previously (Chapter 3.2.3.4.). Eye contact was recorded as atypical in 13 participants in the CVI group compared with five participants in the non-CVI group. Six children with atypical eye contact behaviours did not make eye contact (4 CVI; 2 non-CVI) and 12 made inconsistent eye contact (9 CVI; 3 non-CVI).

Observed visual behaviour	**CVI, n**		**Non-CVI, n**		**Chi-square analysis**
	Typical	**Atypical**	**Typical**	**Atypical**	
Awareness of movement	75 (100%)	0	75 (100%)	0	Not possible
Blink reflex	75 (100%)	0	75 (100%)	0	Not possible
Head posture	71 (94.7%)	4 (5.3%)	71 (94.7%)	4 (5.3%)	Fisher's exact test, p=1.000
Eye contact	62 (82.7%)	13 (17.3%)	70 (97.2%)	5 (2.7%)	X^2=4.040, p=0.076
Visual latency	75 (100%)	0	75 (100%)	0	Not possible
Purposeful gaze	73 (97.3%)	2 (2.7%)	70 (97.2%)	5 (2.7%)	Fisher's exact test, p=0.442
Reaction to light	72 (96.0%)	3 (4.0%)	73 (97.3%)	2 (2.7%)	Fisher's exact test, p=1.000

Table 7.13: Results of visual behaviour observations for CVI and non-CVI groups.

7.3.2.4. Tests of visual perception

As the majority of participants with SEN performed 'normally' on the LEA mailbox and shape-sorter tasks (discussed in Chapter 6), these tests were not considered viable to accurately discriminate between CVI and non-CVI groups. Therefore, only results of the LEA rectangles tasks are considered here as they showed the most potential in discriminating between varying levels of performance across the population with SEN. Table 7.14 shows the performance on each of the LEA rectangles tasks for the CVI and non-CVI groups. Chi-square analysis revealed no statistically significant association in performance between the groups on any task ($p>0.05$ for all; Table 7.14).

Visual perception task	Score	CVI, n (%)	Non-CVI, n (%)	Chi-square analysis
LEA Rectangles: Open pattern	No problems	30 (40%)	35 (46.7%)	Fisher's exact test=0.645, p=0.793
	Minor/moderate problems	15 (20%)	16 (21.3%)	
	Major problems	3 (4.0%)	6 (8.0%)	
LEA Rectangles: Closed pattern	No problems	32 (42.7%)	33 (44%)	X^2=1.330, p=0.542
	Minor/moderate problems	11 (14.7%)	18 (24%)	
	Major problems	7 (9.3%)	6 (8.0%)	
LEA Rectangles: LEA method	No problems	38 (50.7%)	46 (61.3%)	Fisher's exact test=2.174, p=0.365
	Minor/moderate problems	10 (13.3%)	12 (16%)	
	Major problems	4 (5.3%)	1 (1.3%)	

Table 7.14: Performance on each LEA rectangles tasks for the CVI and non-CVI groups.

7.3.2.4.1 Comparison of parent VSI responses and visual perceptual test performance

To determine whether any subsection of the VSI correlated with performance on the LEA rectangles tests, scores on each task were coded as 'no problems' or 'problems' (minor/moderate or major problems). Similarly, responses for each section of the VSI were coded 'normal' or 'outside normal range'; If participants had a mean score of <3 this was considered 'normal', and a mean score ≥3 was considered 'outside normal range'. Chi-square analysis was then carried out to determine if there was a relationship between visual perceptual test results and parent-reported scores on the VSI. Using this analysis, no associations were found between VSI scores and LEA rectangles task performance (Table 7.15).

VSI Section	LEA Rectangles Task		
	Open pattern	**Closed pattern**	**LEA method**
Section 1. Visual fields	χ^2=0.135, p=0.812	χ^2=0.179, p=0.816	χ^2=0.040, p=1.000
Section 2. Perception of movement	χ^2=0.017, p=1.000	χ^2=0.009, p=1.000	χ^2=1.169, p=0.360
Section 3. Visually guided movement	χ^2=0.061, p=0.832	χ^2=0.167, p=0.831	χ^2=0.013, p=1.000
Section 4. Searching for visual targets	χ^2=0.299, p=0.639	χ^2=0.145, p=0.817	χ^2=2.326, p=0.180
Section 5. Noticing multiple targets	χ^2=0.056, p=0.826	χ^2=0.609, p=0.512	χ^2=1.502, p=0.320
Section 6. Recognising target objects and navigating around	χ^2=0.000, p=1.000	χ^2=1.274, p=0.292	χ^2=0.881, p=0.482

Table 7.15: Chi-square analysis of parent-reported problems on each section of VSI compared with performance on visual perception tests.

7.3.2.5. Visual acuity crowding ratios

One hundred and twenty-two participants (61%) both returned a parent VSI questionnaire and were able to successfully complete the high contrast crowded and single LEA optotype acuity tests, thus allowing calculation of a crowding ratio. Of these, 59 participants (49.4%) were in the CVI group and 63 participants (51.6%) were in the non-CVI group. Median visual acuity crowding ratios for both the CVI and non-CVI groups was 1.26 (IQR 1.26 to 1.58 for both). Figure 7.5 illustrates the crowding ratio results for CVI and non-CVI groups. Mann Whitney U analysis revealed no significant difference in crowding ratios between the two groups (U=1747.5, p=0.555).

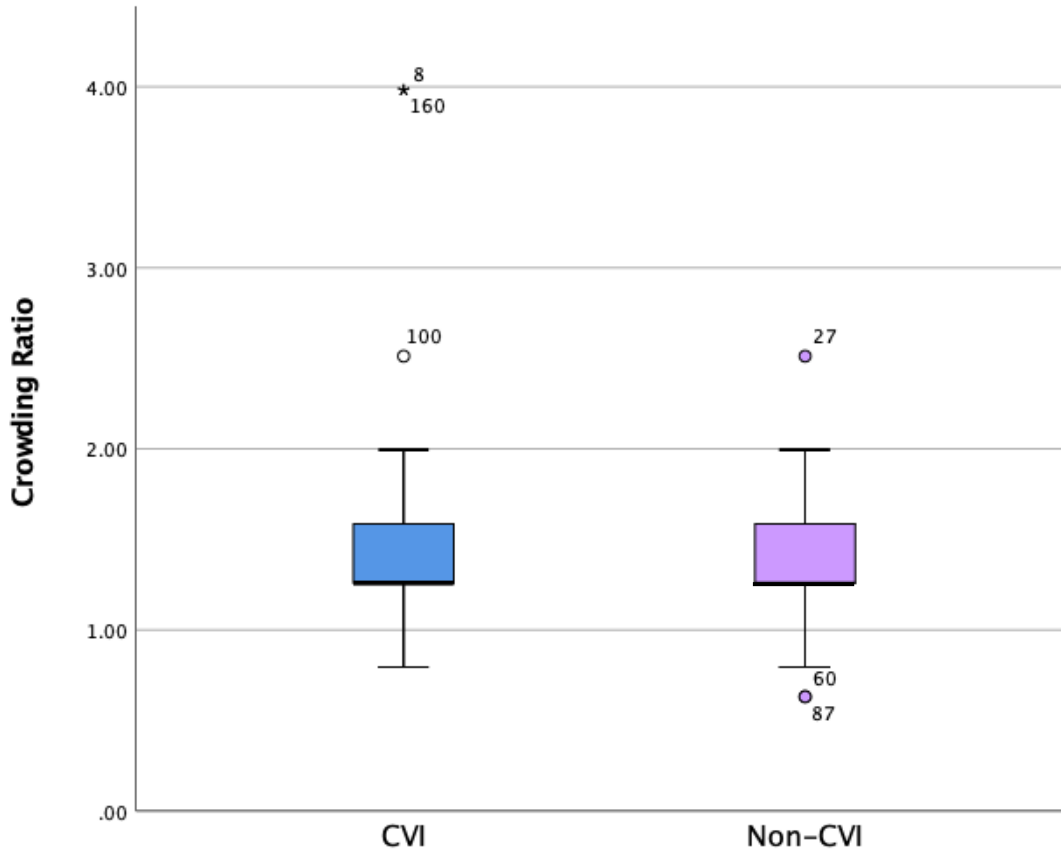


Figure 7.5: Box plots showing crowding ratios determined using the LEA symbols for the CVI and non-CVI group. The solid black line indicates the median and the box indicates the interquartile range. Whiskers indicate 5th and 95th centiles. Outliers are represented by circles extending beyond the whiskers.

7.3.2.5.1. CVI participants with a crowding ratio outside the normal range

As discussed previously, a crowding ratio measured using the LEA symbols exceeding 1.58 was considered outside the normal range (see Chapter 4). Applying this criterion to the population with SEN identified 22 participants with a crowding ratio outside the normal range (as discussed in Chapter 6). Of these, 19 parents returned a VSI questionnaire for their child. Ten participants in the CVI group and nine participants in the non-CVI group were considered to have a crowding ratio outside the normal range. Chi-square analysis revealed there was no significant association between normal/abnormal crowding ratios and CVI groups (X^2 =0.164, p=0.804).

7.3.2.5.2. Comparison of crowding ratios with VSI scores

'Normal' (mean score <3) or 'outside normal range' (mean score ≥3) parent VSI responses according to whether participants exhibited a 'normal' or 'outside normal range' crowding ratio are shown in Table 7.16. The two subsections in which parents reported the most problems for participants with a crowding ratio outside the normal range were in relation to difficulties with 'visual fields' (Section 1) and 'noticing multiple targets' (Section 5). Participants with a normal crowding ratio also exhibited the most difficulties in Section 5 'noticing multiple targets'.

VSI Section	Crowding ratio outside normal range		Normal crowding ratio	
	Parent VSI mean score <3	Parent VSI mean score ≥3	Parent VSI mean score <3	Parent VSI mean score ≥3
Section 1. Visual fields	13 (68.4%)	6 (31.6%)	87 (85.3%)	15 (14.7%)
Section 2. Perception of movement	14 (73.7%)	5 (76.3%)	85 (85.0%)	15 (15.0%)
Section 3. Visually guided movement	16 (84.2%)	3 (15.8%)	90 (87.4%)	13 (12.6%)
Section 4. Searching for visual targets	16 (84.2%)	3 (15.8%)	84 (81.6%)	19 (18.4%)
Section 5. Noticing multiple targets	13 (68.4%)	6 (31.6%)	61 (61.0%)	39 (39.0%)
Section 6. Recognising target objects and navigating around	18 (94.7%)	1 (5.3%)	94 (91.3%)	9 (8.7%)

Table 7.16: Participants with a crowding ratio outside the normal range (n=19) and a normal crowding ratio (n=103) according to difficulties on the VSI questionnaire.

7.3.2.5.3. Comparison of crowding ratios with performance on tests of visual perception

Chi-square analysis was carried out to determine if there was any association between participants with a normal/outside normal range crowding ratio and performance on the tests of visual perception. As discussed previously, only the LEA rectangles tasks were considered as they showed the most promise in identifying difference in performance between participants with SEN. Performance on each task was coded as ‘no problems’ or ‘problems’ as described in Section 7.3.2.4.1. Analysis revealed no significant association

between crowding ratios and performance on the LEA rectangles tasks ($p>0.284$ for all).

7.3.2.6. Strengths and Difficulties Questionnaire (SDQ)

7.3.2.6.1. Parent SDQ responses

A one-way between-groups analysis of covariance (ANCOVA) was conducted to compare parent responses on each subsection of the SDQ between the CVI and non-CVI groups. Age of participants was used as a covariate in the analysis. Results revealed that parents of participants in the CVI group scored their children significantly higher (indicating more problems) compared to parents of participants in the non-CVI group on all subsections of the SDQ, with the exception of the 'kind and helpful behaviour' section (Table 7.17; Figure 7.6).

SDQ Subsection	CVI (Mdn)	Non-CVI (Mdn)	One-Way ANCOVA
Overall stress	22.0	16.0	F=27.534, p<0.001
Emotional difficulties	6.0	4.0	F=23.124, p<0.001
Behavioural difficulties	3.0	2.0	F=23.124, p<0.001
Hyperactivity and concentration difficulties	9.0	7.0	F=9.188, p=0.003
Difficulties getting along with other children	5.0	3.0	F=16.293, p<0.001
Kind and helpful behaviour	7.0	7.0	F=0.002, p=0.961
Impact score	4.0	1.0	F=9.348, p=0.003

Table 7.17: Median responses for each parent SDQ subsection for CVI and non-CVI groups.

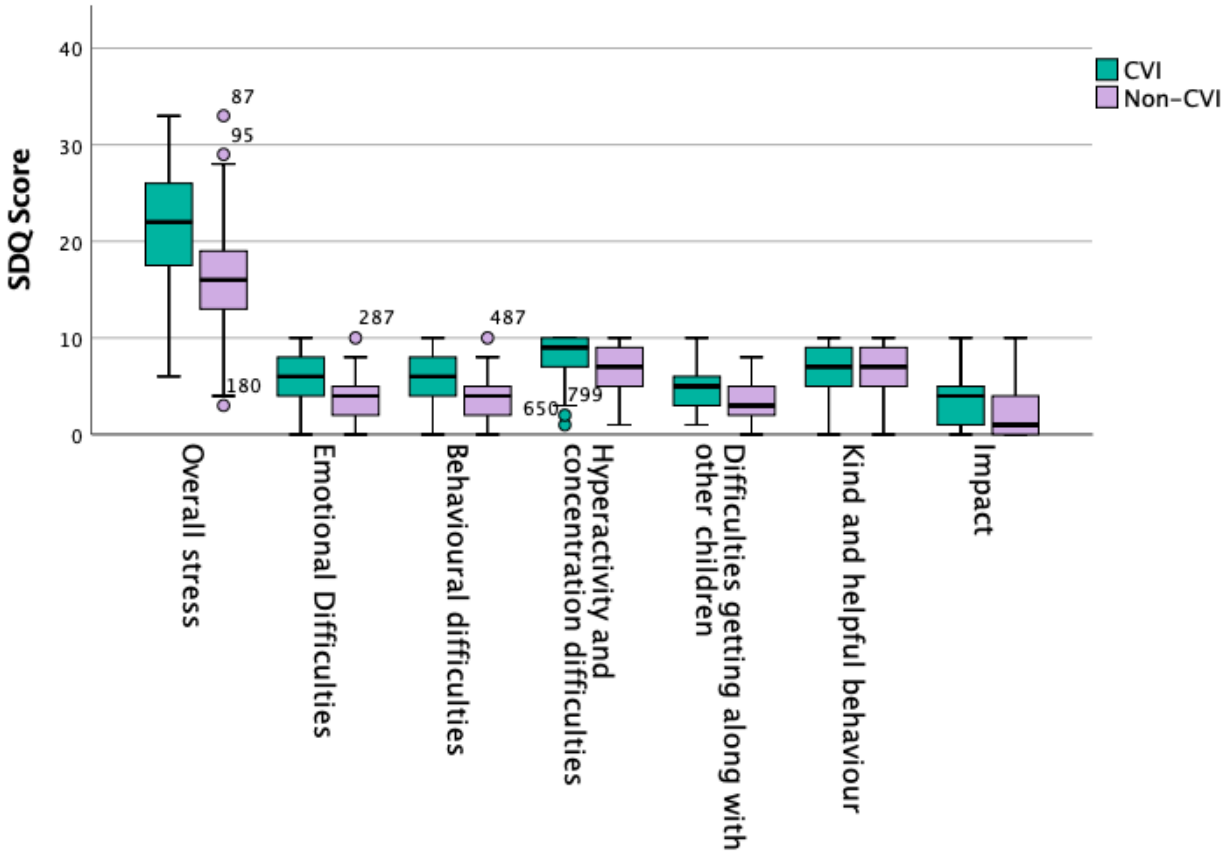


Figure 7.6: Box plots showing CVI and non-CVI group responses for each subsection of the parent SDQ. The solid black line indicates the median and the box indicates the interquartile range. Whiskers indicate 5th and 95th centiles. Outliers are represented by circles extending beyond the whiskers.

Participants were grouped according to whether they were reported as having 'difficulties' on the parent SDQ. Cut-off scores to facilitate grouping of participants are available on the SDQ website (Youth in Mind, 2016). Participants who scored 'high' or 'very high' on the 'overall stress' scoring were stratified into the 'difficulties' group (n=106). All other participants for whom a parent SDQ was available were stratified into a 'non-difficulties group' (n=73). Chi square analysis was then carried out to determine if participants with 'high' or 'very high' scores (indicating more difficulties) were more likely to have evidence of CVI identified using the parent VSI. This revealed a significant

difference, with the CVI group more likely to score ‘high’ or ‘very high’ on the parent SDQ ‘overall stress’ score (Table 7.18).

SDQ categorisation	CVI, n (%)	Non-CVI, n (%)	Chi-square analysis
Non-difficulties group	14 (20.6%)	39 (57.4%)	X^2=19.323, p<0.001
Difficulties group	54 (79.4%)	29 (42.6%)	

Table 7.18: Chi square analysis for participants in the CVI and non-CVI group according to whether they were defined as having ‘difficulties’ on the parent SDQ.

7.3.2.6.2. Teacher SDQ responses

Teacher responses on the SDQ did not differ significantly for participants in the CVI and non-CVI groups across all subsections of the SDQ (One-way ANCOVA with age as covariate, p>0.05 for all; Table 7.19).

SDQ Subsection	CVI (Mdn)	Non-CVI (Mdn)	One-way ANCOVA
Overall stress	11.5	11.0	F=0.003, p=0.953
Emotional difficulties	2.0	2.0	F=1.175, p=0.280
Behavioural difficulties	2.0	1.0	F=0.028, p=0.867
Hyperactivity and concentration difficulties	5.0	5.0	F=0.057, p=0.811
Difficulties getting along with other children	3.0	2.0	F=0.041, p=0.840
Kind and helpful behaviour	5.0	6.0	F=0.424, p=0.516
Impact score	1.0	0.0	F=0.255, p=0.615

Table 7.19: Median responses for each teacher SDQ subsection for CVI and non-CVI groups.

7.3.2.7. CVI group characteristic interactions

The preceding analyses have identified three characteristics which differed significantly between the CVI and non-CVI group; medical history affecting brain development/function (n=21 in CVI group), distance visual acuity (n=5 in CVI group with visual impairment) and 'high' or 'very high' parent SDQ overall stress score (n=54 in CVI group). Figure 7.7 illustrates how many participants in the CVI group had one or more of these characteristics. Sixty-one participants (81.3%) in the CVI group had at least one of these characteristics. Three participants (4.0%) were included in all three categories and 13 (17.3%) were in two categories. The majority of CVI participants (n=45) were included in one of these categories only (39 parent SDQ only, 1 distance visual acuity impairment only and 5 medical history affecting brain development/function only).

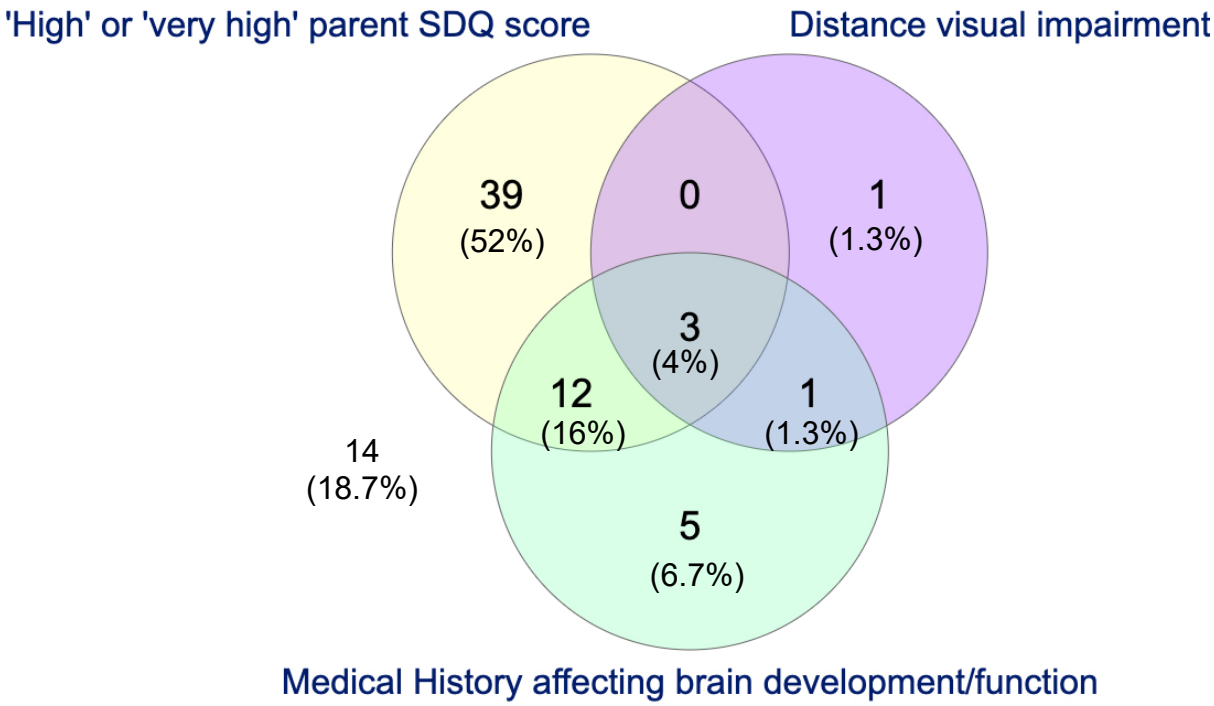


Figure 7.7: Venn diagram illustrating participants in the CVI group who were identified as having a medical history which affects brain development/function, distance visual acuity impairment and 'high' or 'very high' parent SDQ overall stress score.

7.3.2.8. Five Key Questions on the VSI

Rather than completing the full VSI, Dutton et al. (2010b) suggest that applying five key questions contained within the total VSI can identify children who require more detailed evaluation of CVI. The questions identified by Dutton and colleagues are reported to identify no false positive and no false negative results in a sample of 40 children with cognitive and perceptual visual impairment, and 150 control children (Dutton et al., 2010b). There is a limited amount of further information available on this sample in the literature, yet despite this, these five key questions are often used as a CVI screening tool in a clinical setting to identify children who may warrant more thorough investigation for CVI.

The ‘key questions’ are:

1. Does your child have difficulty walking down stairs? (Section 1 Visual Fields)
2. Does your child have difficulty seeing things which are moving quickly, such as small animals? (Section 2 Perception of Movement)
3. Does your child have difficulty seeing something which is pointed out in the distance? (Section 4 Searching for Visual Targets)
4. Does your child have difficulty locating an item of clothing in a pile of clothes? (Section 4 Searching for Visual Targets)
5. Does your child find copying words time consuming and difficult? (Section 4 Searching for Visual Targets)

If parents reported difficulties to occur ‘often’ or ‘always’ on at least three of these items, Dutton suggests further assessment for CVI is warranted (Dutton et al., 2010b).

In the present study, Binary Logistic Regression was carried out to determine whether the five key questions had acceptable criterion validity, i.e. how accurately the questions identified participants who were classified as having CVI according to the full VSI. The dependent variable was whether participants were identified on completion of the full VSI as having CVI or not, and the independent variable was whether the participants were identified as having CVI using the predefined criteria for the five key questions (i.e. scores of 'often' or 'always' on at least 3/5 of the key questions). Analysis revealed that the five key questions were significantly able to distinguish between those who did and did not have CVI (X^2=28.56, p<0.001). Specificity of the questions was high (100%), however sensitivity of the questions was low (25.3%; Table 7.20). This means that 75% of participants with SEN in the current population with evidence of difficulties relating to CVI would be missed if these five key questions were employed.

CVI group classification when full VSI applied	**Identified as requiring further investigation with five key questions**	
	Yes, n (%)	**No, n (%)**
CVI (n=75)	19 (25.3%)	56 (74.7%)
Non-CVI (n=75)	0 (0%)	75 (100%)

Table 7.20: CVI and non-CVI participants identified using the five key questions compared to application of the full VSI.

7.3.2.8.1. Are better key questions available for a population with SEN?

Several parents in the present study provided written comments on their returned VSI to state that a number of the key questions were not suitable for their child, for example if their child used a wheelchair, key question one was inappropriate. Many also commented that their child could not read or write, deeming key question five unsuitable.

To determine if a different subset of questions from the VSI could accurately predict which children were identified as having CVI in this population with SEN, responses for each question from the full inventory were initially coded as ‘normal’ (responses of ‘never’ or ‘rarely’) or ‘abnormal’ (responses of ‘sometimes’, ‘often’ or ‘always’). Binary Logistic Regression was then applied for each subsection of the questionnaire, with the dependent variable selected as participants who were or were not identified as having CVI through application of the full inventory. Independent variables were questions within each subsection of the VSI. Using this model, 12 questions were identified as contributing significantly to the CVI group prediction as shown in Table 7.21; two of these are included in the original five key questions – Question 19 and 24 (both part of Section 4).

Question	P value	Odds ratio	95% CI for Odds ratio
Section 1: Visual fields			
Question 6 Does your child look down when crossing floor boundaries?	0.035	5.254	1.123 – 24.573
Question12 Does your child bump into doorframes or partly open doors?	0.018	4.476	1.298 – 15.438
Section 2: Perception of movement			
Question 18 Does your child have difficulty catching a ball?	0.003	3.454	1.536 – 7.817
Section 3: Visually guided movement			
Question 30 Does your child bump into low furniture such as a coffee table?	0.004	20.315	2.572 – 160.441
Question 32 Does your child get angry if furniture is moved?	0.032	3.605	1.116 – 11.645
Section 4: Searching for visual targets			
Question 19 Does your child have difficulty seeing something which is pointed out in the distance?	0.023	3.447	1.185 – 10.027
Question 21 Does your child have difficulty finding an item they want if there is too much visual information?	0.017	4.375	1.306 – 14.656
Question 24 Does your child have difficulty locating an item of clothing in a pile of clothes?	0.007	5.574	1.585 – 19.474
Section 5: Noticing multiple targets			
Question 39 Does your child bump into things when walking and having a conversation?	0.043	2.813	1.036 – 7.642
Question 40 Does your child miss objects that are obvious to you because they are different to their background?	0.001	10.642	2.571 – 44.046
Question 41 Do rooms with a lot of clutter cause difficulty behaviour?	<0.001	8.032	2.670 - 24.164
Question 43 Is behaviour in a busy supermarket difficult?	0.017	4.289	1.301 – 14.137
Section 6: Recognising target objects and navigating around			
None identified			

Table 7.21: Twelve proposed new ‘key questions’ identified using binary logistic regression.

Considering whether respondents scored at least one of these 12 questions as occurring at least ‘sometimes’, identified all 75 children in the evidence of CVI group (100% sensitivity), however only 15 participants were correctly identified as not having CVI (20% specificity) indicating a high false positive rate.

Altering the criteria to include respondents who scored at least four of the 12 questions as occurring at least ‘sometimes’ identified 69 of the 75 CVI participants (92% sensitivity) and increased specificity to 74.7% by correctly identifying 56/75 participants who were not stratified as having CVI.

When selecting their key questions, Dutton et al. (2010) included responses of ‘often’ or ‘always’ only. Application of these same criteria for the 12 questions identified 69/75 participants who were identified as having CVI (92% sensitivity) and 48/75 participants who were not identified as having CVI (64% specificity) who reported responses of ‘often’ or ‘always’ on at least one question.

7.4. Discussion

7.4.1. Visual Skills Inventory

A limitation of the present analysis is that only responses from parents on the VSI were used to stratify participants into CVI and non-CVI groups. As discussed in Chapter 2, there is no consensus among professionals for a 'gold-standard' approach when assessing and diagnosing CVI in children. While other studies have used a multi-assessment approach, and this approach is recommended in Chapter 2, the VSI was used in the present study as it is a well-established and recognised tool commonly used in the assessment and diagnosis of CVI which could be applied to identify children with evidence of CVI as part of an in-school vision assessment. The VSI has also been shown to successfully distinguish presence/absence of CVI between groups of children both with and without intellectual disability (Geldof et al., 2015). Another advantage of the VSI when applied in an educational setting is that the design and grouping of the questions allows problematic areas associated with CVI to be easily identified and allows provision of specific management strategies to address these difficulties. Ultimately, this eases the translation of the findings of the VSI into strategies that parents and teachers can apply to alleviate CVI-related difficulties in the child's home and educational environment. This was an important consideration for the present study as parents and teachers were provided with a written report detailing the child's visual strengths and weaknesses after the in-school vision assessment. In addition, Hellgren et al. (2020) report that the VSI was equivalent to time-consuming cognitive and perceptual assessments when detecting CVI in children born extremely premature, further highlighting the viability of the VSI

at eliciting evidence of CVI. It is recognised, nonetheless, that identifying CVI through structured-history taking tools can yield a high false positive rate if used in isolation (van Genderen et al., 2012). The author also acknowledges that not all participants with SEN were included in the present chapter analysis because a VSI was not available for all participants. This excluded 25% of the study population with SEN (n=50) from analyses in this chapter.

The majority of participants with SEN identified in the CVI group had problems reported by parents in one section of the VSI only, indicating that participants in the current population may have exhibited a 'mild' form of CVI. Participants were most frequently reported as having difficulties in the 'noticing multiple targets' section of the VSI. Fifty-four (72.0%) participants were identified by parents as having difficulties in this section which relates to problems attending to more than one visual stimuli at a time. The second-highest scoring section which was the 'searching for visual targets' section which relates to interpreting visual information in a busy or crowded environment. This is a dorsal stream function which is commonly noted as problematic in children with CVI (Dutton et al., 2010; Ortibus et al., 2011; Macintyre-Beon et al., 2012; Dutton, 2013; Philip & Dutton, 2014). Problems in the 'recognition and navigation' section were least frequently reported by parents as problematic. This section relates to ventral stream dysfunction. Results from the present study agree with those of others who report ventral stream problems are less prevalent (Ortibus et al., 2011; van Genderen et al., 2012; Macintyre-Beon et al., 2013). Dutton (2009) also reports that ventral stream dysfunctions are less common, and when present, often occur concomitantly with dorsal stream dysfunction rather than

in isolation (Dutton, 2009). This was true in the present population; of the 17 who were identified as having problems associated with ventral stream dysfunction, 13 also had reported difficulties relating to dorsal stream dysfunction.

As discussed in Chapter 6, parents reported their children as having more problems on the VSI compared to teachers. Applying the same criteria to teacher VSI responses to identify participants who exhibit evidence of CVI identified a much smaller cohort of children compared to parents (n=25 vs n=75 respectively). A possible reason for this is that a number of questions in the VSI relate to activities which may occur less frequently in school than at home, for example ‘Does your child choose to watch slow moving TV?’ or ‘Does your child walk out in front of traffic?’ A teacher may not witness a child’s behaviour in such situations and their responses may therefore not truly reflect the child’s difficulties. Furthermore, it has been shown that teachers of children with learning disabilities have lower expectations in terms of their academic performance compared to typically developing children (Peeters et al., 2009). These findings could also be translated to factors outside academic performance, and as such teachers may have had lower expectations of performance in the tasks included in the VSI which could account for the lower scores attributed by them. A further explanation may be that teachers are likely to attribute their responses by comparing an individual child’s performance with other children with SEN in their class, whereas parents may compare their child’s performance with siblings who may be typically developing. As such, there is likely to be greater disparity in perceived difficulties for their child with

SEN compared with the typically developing child which may account for the higher degree of reported problems by parents.

7.4.2. Group demographics

It has been suggested that children with visual impairments should be provided with habilitation strategies as early as possible in order to maximise vision and developmental outcomes (Sonksen et al., 1991; Khetpal et al., 2007; Roman-Lantzy, 2007b; Ortibus et al., 2011; Lehman, 2013). Findings from the current study revealed that participants in the CVI group were significantly younger compared to those in the non-CVI group. While this may indicate that parents of younger children may be more sensitive or less accepting of the behaviours included in the VSI, or that older children may have developed their own 'coping mechanisms' to account for their visual difficulties, it also highlights the need to identify CVI early so that parents and teachers may be provided with management strategies to alleviate the impact of CVI on daily living activities and ultimately improve visual outcomes.

Birth history between groups did not differ significantly in the current population. Previous studies have reported that children born prematurely, either with or without intellectual disability, are at a higher risk of CVI (Khetpal et al., 2007; Macintyre-Beon et al., 2013; Geldof et al., 2015; Hellgren et al., 2020). However, the majority of participants in the current study were born full term (80.0%) with a low representation of children born very or extremely pre-term (n=5, 3.3%) which may account for the lack of difference between CVI and non-CVI groups.

Presence of a medical diagnosis affecting neurological function was significantly associated with a CVI diagnosis in the present study. This is in keeping with results from systematic review of the literature (Chapter 2) where consideration of a child's medical history was identified as an important factor in the assessment and diagnosis of CVI. CVI arises as a result of damage to, or underdevelopment of the brain (Philip & Dutton, 2014), as such it is expected that children with a medical diagnosis affecting neurological function would be more likely to be stratified into the CVI group.

Some studies and authors have suggested that there is an association between CVI behaviours and behaviours exhibited by children with ASD (Philip & Dutton, 2014; Fazzi et al., 2019), however there have been few published studies which have explored this finding specifically. Using the VSI in the present study, more participants with an ASD diagnosis were stratified into the evidence of CVI group compared to the non-CVI group indicating a potential association between the two conditions, however, this inter-group difference did not reach statistical significance ($p=0.094$). Some teachers in the present study provided written comment on the VSI stating that they considered some difficulties to be ASD related and as such rated the question 'not applicable'. This anecdotal evidence adds further weight to the suggestion that the relationship between ASD and CVI warrants more in-depth investigation on larger ASD populations in order understand the association between the two conditions. This can ultimately ensure that behaviours shared by the two conditions are appropriately identified, recognised and managed

where possible. The fact that some teachers attributed potential CVI behaviours to an ASD diagnosis may also account for the lower number of children identified as having CVI through teacher VSI responses.

7.4.3. Visual characteristics and visual behaviours

The majority of visual function measures/characteristics and observed visual behaviours did not differ significantly between the CVI and non-CVI groups in the current population, with the exception of distance visual acuity which was significantly poorer in the CVI group. While impairment of distance visual acuity in children with CVI is often reported in the literature, the majority of between-group comparisons of visual characteristics and observations in the present study are conflicting with previous literature where children with CVI, both with and without learning disability, have been described as having associated ocular abnormalities such as ocular movement disorders, strabismus, nystagmus, contrast sensitivity, significant refractive errors and optic nerve disorders, (e.g. Huo et al., 1998; Salati et al., 2002; Khetpal & Donahue, 2007; Fazzi et al., 2007; Macintyre-Beon et al., 2013; Pehere et al., 2018). Common aetiologies surrounding a CVI diagnosis include hydrocephalus, epilepsy, central nervous system infections and traumatic brain injury, with the most common cause reported as hypoxic-ischaemic encephalopathy; all of which are associated with co-existing ocular abnormalities (Good et al., 2001; Khetpal & Donahue, 2007; Boot et al., 2010; Philip & Dutton, 2014; Fazzi et al., 2007). However, only a small number of participants (5.0%) in the present study presented with these aforementioned conditions, according to parental report, which may account for the lack of

difference in ocular abnormalities and observed visual behaviours between the CVI and non-CVI groups. While the sample included in the present study was representative of the profile of the school in terms of level of learning disability, it was under-representative of the total NI special school population in that there was only a small proportion of pupils with profound and multiple learning difficulties. Perhaps if more pupils with PMLD participated, there may have been a greater representation of children with the aforementioned aetiologies surrounding a CVI diagnosis, and thus a greater number of visual function abnormalities in the CVI group. CVI groupings in the present study were also only reliant on parent VSI responses which may have miscategorised some participants, therefore masking any potential between-group differences in visual function characteristics.

Visual behaviours associated with CVI have been described previously (Roman-Lantzy, 2007a). Participants in the present study were only observed over a small time period throughout the vision assessment conducted on the school premises. This may not have provided sufficient time to gather a comprehensive picture of a child's visual behaviours. In fact, Roman-Lantzy (2007) advocates observing the child's visual behaviour in a variety of settings, for example, in home and educational environments, during quiet and noisy times, with familiar and novel objects, in both near and distance activities (Roman-Lantzy, 2007e). Roman-Lantzy (2007) reports that anomalous visual behaviours which are consistent with a CVI diagnosis are more often observed in children with severe forms of CVI. The lack of atypical visual behaviours noted in the current population may again indicate that participants with

evidence of CVI could be defined as more ‘mild’ compared to the severity of CVI described by Roman-Lantzy. This is consistent with previous discussion regarding the responses on the VSI and is in keeping with the suggestion by Hellgren et al. (2020) that the VSI is sensitive to mild visual impairments. Results of the present study indicate that inclusion of visual behaviour observation does not add great value if included as part of an in-school vision/CVI assessment in special schools with a similar learning disability profile to that of the current study. If observation of the child could be extended to include observation periods outside of the vision assessment, such as in the classroom or navigation between classes as advocated by Roman-Lantzy, perhaps this would provide more meaningful information. However, the practicalities of carrying this out on all children in a school setting is problematic. As an alternative, other methods, such as the VSI, could be applied to first identify ‘at-risk’ children on whom a detailed observation of visual behaviours could then be conducted.

7.4.4. Visual perception tests

Performance on the tests of visual perception which were selected for the present study did not differ between CVI and non-CVI groups. The selected tasks examined very specific aspects of the participants’ visual processing ability, primarily associated with ventral stream function. Using the VSI, ventral stream dysfunctions were least frequently reported by parents which may account for the lack of association between problems on the tests of visual perception and parent-reported evidence of CVI. This is consistent with findings by Ortibus et al. (2011) who report that despite children scoring

positively on the L94 visual perceptual battery (a task which mainly involves object recognition; a ventral stream function), parents infrequently reported difficulties with ventral stream functions using a questionnaire developed to screen children for CVI (Ortibus et al., 2011). Macintyre-Beon et al. (2013) report similar findings; performance on tests of visual perception used in their study population did not correlate well with parent-reported problems on the VSI. Macintyre-Beon et al. (2013) report that the lack of agreement between parental VSI responses and visual perceptual test performance is more likely due to failure of the visual perception tests to identify CVI. They argue that tests of visual perception are not designed to specifically elicit deficits associated with CVI, whereas the VSI was designed for this purpose (Macintyre-Beon et al., 2013).

7.4.5. Visual acuity crowding ratios

Van der Zee et al. (2017) explored whether binocular visual acuity crowding ratios could distinguish between three groups of children: i) healthy, typically developing children, ii) children with ocular abnormalities and iii) children with indications of neurological damage. Van der Zee et al. (2017) report that using the Cambridge Crowding Cards and Cambridge Single Cards (letter optotype visual acuity charts), children with indications of neurological damage (group iii) exhibited higher visual acuity crowding ratios compared with the other two groups of children. Van Genderen et al. also report that over 40% of their sample of children with CVI had a binocular crowding ratio ≥2. Only one child without CVI in their study population had a crowding ratio outside the normal range. The acuity test used to obtain a crowding ratio in van Genderen’s

population is not reported and results were recorded retrospectively from medical records, therefore direct comparisons in test parameters cannot be conducted. As discussed previously, the Cambridge Crowding Cards have been shown to induce more crowding effects compared with the LEA symbols in a population of normally sighted adults (Lalor et al., 2016). This may account for the lack of difference found between the CVI and non-CVI groups in the current study compared with the findings from van der Zee et al. (2017).

Van Genderen et al. (2012) report that, in their study population, a crowding ratio outside the normal range occurred more commonly in prematurely-born children with periventricular leukomalacia (van Genderen et al., 2012). In the present study the majority of participants were born full term and none were reported by their parents as having periventricular leukomalacia. The differences in birth history between the current study participants and van Genderen et al.'s cohort may partially explain why differences in crowding ratios were not observed between the CVI and non-CVI group in the present study. Twenty-eight participants (37.3%) for whom a VSI was returned by their parent were unable to comply with both a crowded and single optotype visual acuity measure (16 were stratified into the CVI group and 12 were in the non-CVI group). If these 28 participants were able to complete the LEA symbol acuity tests, perhaps between-group differences in crowding ratio may have been observed. These missing data highlight a considerable drawback in using crowding ratios to indicate potential CVI as the method relies on the child's ability to undertake optotype acuity testing. Further work is required to determine if application of the crowding ratio may be more suitable when

applied to specific subgroups of patients who are at a higher risk of CVI, for example children with Down syndrome or cerebral palsy.

Only 15.3% of participants with a crowding ratio outside the normal range were identified as having problems on the ‘searching for visual targets’ section of the VSI. This section relates to the interpretation of visual information in a crowded environment. This lack of agreement indicates that crowding ratios determined through comparison of binocular crowded and single visual optotype acuity do not correlate well with parent-reported difficulties on the VSI. This finding resonates with data from typically developing children discussed in Chapter 4.

7.4.6. Strengths and Difficulties Questionnaire

Parent SDQ scores for participants in the CVI group were significantly worse compared to participants in the non-CVI group. This indicates that, according to parental report, children with evidence of CVI have more perceived behavioural and emotional difficulties than those without evidence of CVI. This is consistent with work undertaken by Geldof et al. (2015) who reported that parent SDQ scores were significantly poorer for very preterm/very-low-birth-weight children with CVI compared to control children born at full term and very preterm/very-low-birth-weight children without CVI (Geldof et al., 2015). The differences in parent responses found between CVI and non-CVI groups indicate that the SDQ could be used as an additional tool in the identification and diagnosis of children with CVI. However, it is worth noting that children were stratified into CVI and non-CVI groups based on parental report using

the VSI, so this finding may simply reflect a tendency for parents of the CVI group to score their children less positively on behaviour-type questionnaires.

Responses on the teacher SDQ did not discriminate between CVI and non-CVI groups. Teacher responses could be considered less biased compared to those of parents, however, as discussed previously, Cheng et al. (2018) report that teachers observe children in a very different environment and as such may not experience the true extent of their difficulties (Cheng et al., 2018). Perhaps in the more structured educational environment, teachers may be less aware of a child's emotional and behavioural difficulties which could account for the overall more positive scoring of participants compared to parents and the lack of difference between CVI and non-CVI groups. Teachers also spend less time with a child on a one-to-one basis compared with parents, which could indicate that they may not be as aware of the child's strengths and difficulties.

7.4.7. Five Key Questions

When applied to the population with SEN included in the present study, the five key questions identified by Dutton et al. (2010) had good specificity (100%), but very low sensitivity (25.3%) when compared with application of the full VSI. The low sensitivity value indicates that many children with potential CVI risk being overlooked if screening for CVI was carried out using these five key questions in a population with SEN. It is generally accepted that screening questionnaires should have at least 70-80% sensitivity and a specificity close to 80% to reduce misidentification of patients and minimise over-referrals

(Glascoe, 2005). Gorrie et al. (2019) applied the five-key questions for CVI in a sample of 535 children (either typically developing or with additional support needs) and reported good sensitivity (81.7%) and good specificity (87.2%; Gorrie et al., 2019). However, CVI status was available only through parental report in response to the question ‘Does your child have CVI?’ which has been identified as a potential limitation in the study discussion (Gorrie et al., 2019).

The five key questions suggested by Dutton et al. (2010) may also be unsuitable for children with mobility or motor impairment, for example cerebral palsy, a population known to be associated with CVI (Mitry et al., 2016). In their population of children with cerebral palsy, Mitry et al. (2016) excluded questions from the VSI which were reported as ‘not applicable’ by more than 50% of respondents. Two such excluded questions were ‘Does your child have difficulty walking down stairs?’ and ‘Does your child find copying words or drawings time consuming and difficult?’; both of these questions form part of the five key questions and the tasks they relate to require adequate motor function, thus further highlighting the need to develop more suitable questions for individuals or groups with physical disabilities.

In the current study, a reduced inventory formed of 12 questions was identified which distinguished between participants in the CVI and non-CVI group stratified through application of the full parent VSI. These 12 questions yielded a specificity of 74.7% and sensitivity of 92.0% if parents reported positively (‘sometimes’, ‘often’ or ‘always’) on at least one third of questions (4/12). The 12 identified questions are less influenced by a child’s mobility or ability to read

or write, and may therefore be more suitable to apply to children at risk of CVI who often present with additional physical and educational needs. ‘The CVI Questionnaire’ is another screening tool used in the investigation of CVI developed by Ortibus and colleagues (Ortibus et al., 2011). Ortibus reports a sensitivity of 80% and specificity of 60% when applied to a heterogeneous group of 91 children, which is reported by the authors as having acceptable screening validity (Ortibus et al., 2011). Therefore, the 12 questions identified in the present study have value as an effective screening tool to identify children who warrant further investigation of CVI. Future studies are required to further investigate the value and utility of these 12 questions as a screening tool for CVI in more at-risk populations. Neither Dutton’s five key questions, nor the 12 identified through the current study contain questions relating to ventral stream dysfunction. As discussed previously, ventral stream dysfunction rarely occurs in isolation (Dutton, 2009), therefore the majority of children with potential CVI should be identified using these dorsal-only screening questions (Gorrie et al., 2019).

7.5. Conclusion

The present chapter stratified participants into a CVI and non-CVI group determined by responses on the parent VSI. Characteristics between the two groups were then compared to determine which characteristics may be important to consider when identifying children with/at-risk of CVI as part of an in-school vision and CVI assessment. Analysis revealed that important factors to consider are a positive medical history of any abnormality which may affect brain development or function, reduced distance visual acuity and a ‘high’ or

‘very high’ overall stress score on the parental Strengths and Difficulties Questionnaire. Tests of visual perception, observation of visual behaviours, crowding ratios and the majority of tested visual functions did not show significant associations between CVI group classifications, and as such may play a less important role in identifying children in special schools as part of an in-school eyecare programme (in schools with a similar demographic to that included in the present study). Determination of more suitable ‘key questions’ within the VSI which could be applied to screen for CVI was also conducted. This revealed a reduced inventory of 12 questions which are more suitable for children with motor impairments and those who are unable to read or write.

Chapter 8

Parent and teacher evaluation of an in-school vision assessment and provision of written report of visual status for children in special schools

8.0. Chapter overview

This chapter evaluates the parent and teacher opinion of in-school vision assessment and provision of written Vision Reports of visual and cerebral visual impairment (CVI) status for children in special schools. A version of this chapter has been submitted for publication in PLOS One and is under review at the time of submission.

8.1. Introduction

Outcomes of a child's visual assessment are often communicated verbally to parents which may result in key information being forgotten or misunderstood (Thomson et al., 2001; Kessels, 2003). If a parent has been provided with advice to ameliorate the impact of a visual deficit on the child's daily living, they may be unable to retain all of the information which has been supplied verbally, which ultimately reduces the likelihood of appropriate management strategies being implemented in the child's home environment. Implementation of such strategies are even less likely to be instigated in the child's educational environment if information is not shared with teachers or educators. Impaired academic performance has been associated with visual deficits, in both mainstream and special school settings (Dudovitz et al., 2016) and correction of visual deficits has a positive impact on classroom behaviour

(Black et al., 2019, McKerr et al., 2020). It is therefore important that meaningful information on visual status and visual deficits is effectively translated and delivered to all stakeholders involved in a child's care, including teachers (Lehman, 2013)

As discussed previously, the methods and results of this thesis formed part of the larger Special Education Eyecare (SEE) project which evaluated whether application of a sector-agreed Eyecare in Special Schools Framework reduced unmet visual need and increased classroom engagement and behaviour (see Chapter 1 for more information; The Royal College of Ophthalmologists, 2016). The purpose of this chapter was to evaluate the benefit to parents and teachers, of (i) providing children attending special schools with a comprehensive in-school vision assessment and (ii) providing a lay-language 'Vision Report' to stakeholders involved in the child's care.

8.2. Methods

8.2.1. Vision Report

Following the vision and CVI assessment detailed in Chapter 5 and 6, parents and teachers were provided with a semi-standardised 'Vision Report' (Appendix 12). This report was written by the optometrists undertaking the visual assessment (author ELM and SAB). Vision Reports offered practical advice, written in lay-language, on how to account for any vision difficulties the participant presented with. Technical information regarding visual and CVI status suitable for sharing with other eye/healthcare professionals was provided at the end of the report. The Vision Report proforma used in the

present study was developed by Ulster University and SeeAbility (Optometry and Vision Science Research group, 2019). This was utilised and refined during a pilot of the SEE Project at a different special school from March to June 2016. Figure 8.1 details the information included in the Vision Report.

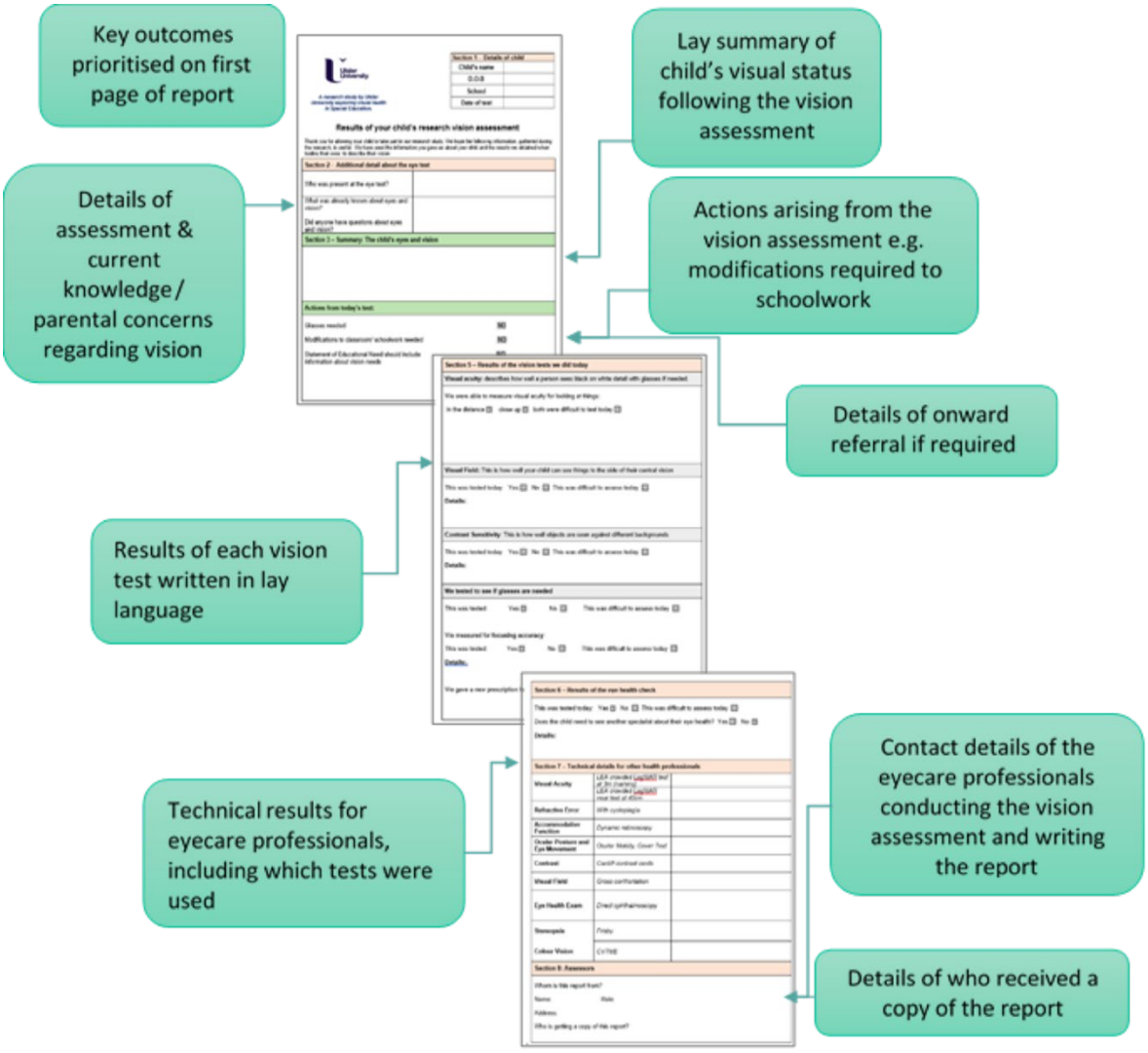


Figure 8.1: Information detailed in the Vision Report provided to parents and teachers following in-school vision assessment.

Within each section, if a participant had a 'normal for age' result, parents were informed of this positive finding. Normal results were defined using previously

published normative data for each test used (Black et al., 2019). Where reduced function was identified, this was communicated and practical advice provided to mediate the impact of this deficit, if appropriate. For example, if the participant had a restriction of their visual field on their right-hand side, advice regarding seating position, placement of school work, food etc. was provided to maximise use of the participant's available vision. If a participant demonstrated evidence of difficulties relating to CVI, practical strategies were provided to minimize the impact of the difficulties at home and at school (see Table 1.5 for examples). If a participant had an accommodative deficit, bifocals or near work spectacles were provided along with detailed advice on when these spectacles should be worn. Where a child was under the care of another eyecare provider, written information was provided to this individual regarding the findings and outcomes of the in-school vision assessment.

Where appropriate, the Vision Report was complemented with additional information from the Ulster Vision Resources (UVR; Optometry and Vision Science Research Group, 2020). The UVR is an online tool previously developed by eyecare clinicians and researchers at Ulster University to aid parent and professional understanding of a child's vision difficulties. Amongst other resources, the UVR provides downloadable examples of suitable images and font sizes for children and adults with reduced visual acuity at distance or near. The UVR also contains advice for parents on how to encourage children to wear their spectacles, as compliance was often reported by parents to have been an issue in previous or current spectacle wear; these resources were developed by the author as part of the current project.

8.2.2. Parent and teacher feedback

A feedback questionnaire was developed to determine the value to parents and teachers of the in-school vision assessment and Vision Report. Two versions of the questionnaire were developed after the pilot study carried out at an additional special school from March to June 2016; one for parents and one for teachers (Appendix 15). Both questionnaires included a variety of 5-point Likert scale questions, yes/no and free-text responses. As the current study was completed across two academic years (2016/17 and 2017/18), feedback questionnaires were distributed to all teachers upon completion of the study at the end of the second year. Some teachers had more than one pupil in their class who participated in the study, however they completed only one questionnaire to cover their experience of the in-school eyecare. Parents were provided with a single questionnaire at the end of the academic year during which their child received the in-school vision assessment. Parent and teacher questionnaires contained 16 and 13 items respectively to identify benefits and limitations of the in-school vision assessment and their perception of the utility of the vision assessment and Vision Report for parents, school staff and pupils.

8.3. Results

8.3.1. Feedback questionnaire return rates

8.3.1.1. Parent questionnaire

Parents of 196 participants consented to receive a feedback questionnaire; 123 (62.8%) were returned to the research team. The profile of participants for whom a questionnaire was returned was comparable with those for whom a questionnaire was not returned in terms of level of learning disability and age (Fisher's exact test, p=0.110 and Mann Whitney U=4040.50, p=0.242 respectively). Subsequent results included in this chapter are representative of the 123 participants for whom a questionnaire was returned, rather than the entire study population.

8.3.1.2. Teacher questionnaire

Forty teachers were invited to complete a feedback questionnaire; 23 were returned (57.5%). A total of 88 pupils were represented by the teacher's responses (44.0%).

8.3.2. In-school eyecare service feedback

8.3.2.1. Usefulness of the in-school vision assessment

Both parents and teachers were questioned on the utility of the in-school vision assessment for themselves and for the children (Figure 8.2). Most parents and teachers reported positively; 84.6% of parents (n=104) rated the in-school vision assessment as 'very useful' or 'useful' for themselves, and 84.2% reported the same for their child's teacher. Two parents (1.6%) reported the vision assessment was 'not at all useful' for them. From the teacher

perspective, 77.3% of teachers reported the vision assessment as ‘useful/very useful’ for themselves, and 80.0% felt it was ‘useful/very useful’ for parents. One teacher and one parent rated the eye exam as ‘not at all useful’ for school staff. With regard to the utility of the in-school vision assessment for the children, 82.4% of parents and 80.9% of teachers reported it was ‘useful’ or ‘very useful’. All staff reported positively (i.e. responses of ‘very useful’, ‘useful’ or ‘somewhat useful’) on the usefulness of the in-school eye examination for the children, whereas two parents rated it as ‘not at all useful’ for their child.

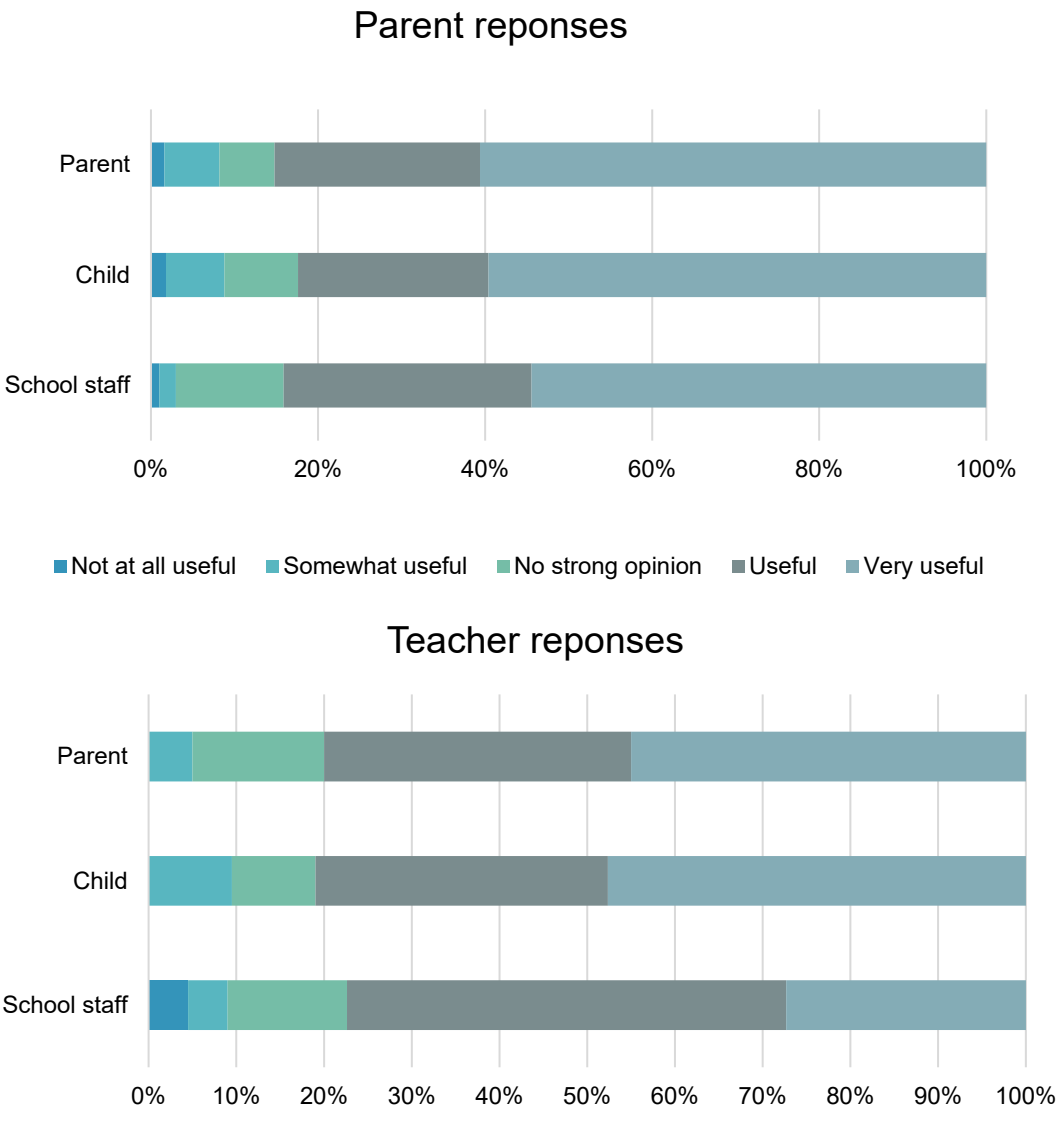


Figure 8.2: Parent and teacher opinion on the usefulness of the in-school vision assessment for themselves and for the children.

8.3.2.2. Benefits and limitations of the in-school vision assessment

Parents and teachers were asked to identify, from a selection of offered statements, the benefits and limitations they perceived of the in-school vision assessment service. Several statements could be selected and there was opportunity to provide additional free-text responses. Responses are shown in Figure 8.3a and Figure 8.3b. For parents, the most commonly reported benefits were the familiarity of the school setting (81.3%), the convenience of having the vision assessment completed in school (74.0%) and that the assessment could be carried out over multiple short visits if the child required, for example due to challenges in compliance or attention (65.0%). All teachers responded that the familiarity and convenience for parents were of benefit, while 82.6% reported that being able to speak directly to the eyecare providers regarding a pupil's vision and visual needs was beneficial. Free-text responses from parents centred around the benefit of the in-school setting in minimising time away from school to attend external appointments, and the added convenience this has for working parents. Seventeen teachers (73.9%) reported the vision assessment did not disrupt the pupils' other school activities.

Limitations were reported less frequently. For parents, the most commonly identified limitation (reported by 15.4%) was the inability to speak to the eyecare provider directly at the time of testing. Similarly, the most common limitation reported by teachers (34.8%) was that the parents may not be present at the vision assessment, however, nine teachers (39.1%) considered this beneficial. Other limitations reported by teachers related to the child

missing class activities to attend the vision assessment and staff shortages to accompany the child to their assessment (both 26.1%).

8.3.2.3. Provision of spectacles

In line with the Eyecare in Special Schools Framework under test in the SEE Project, where new or updated spectacles were required after the vision assessment, in-school dispensing of spectacles was offered. Parents were asked whether, if their child required spectacles, they had a preference on how these were dispensed. A total of 116 parents responded to this question, with some parents choosing more than one option. The majority of parents (56.9%, n=66) reported they would be happy for their child to have spectacles chosen, dispensed and fitted at school. Of these, 52 (78.8%) reported they would like to be involved in choosing the frames, while the remaining 14 (21.2%) reported they were comfortable not being involved in frame choice. Thirty-three parents (28.4%) reported they would prefer to get their child's spectacle prescription dispensed in their local opticians/optometrists, and 22 parents (19%) reported they had no preference for where spectacles were dispensed.

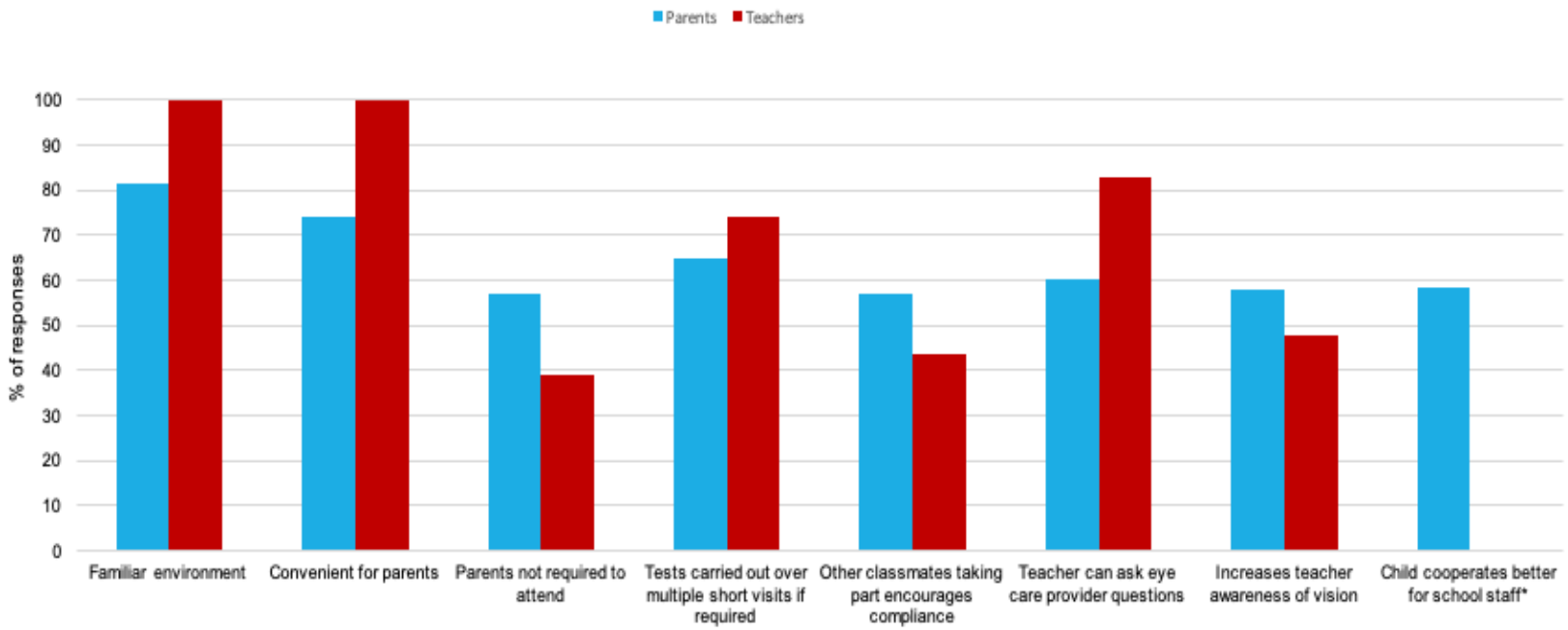


Figure 8.3a: In-school vision assessment benefits reported by parents and teachers. *Question asked to parents only. Blue bars represent parent responses and red bars represent teacher responses.

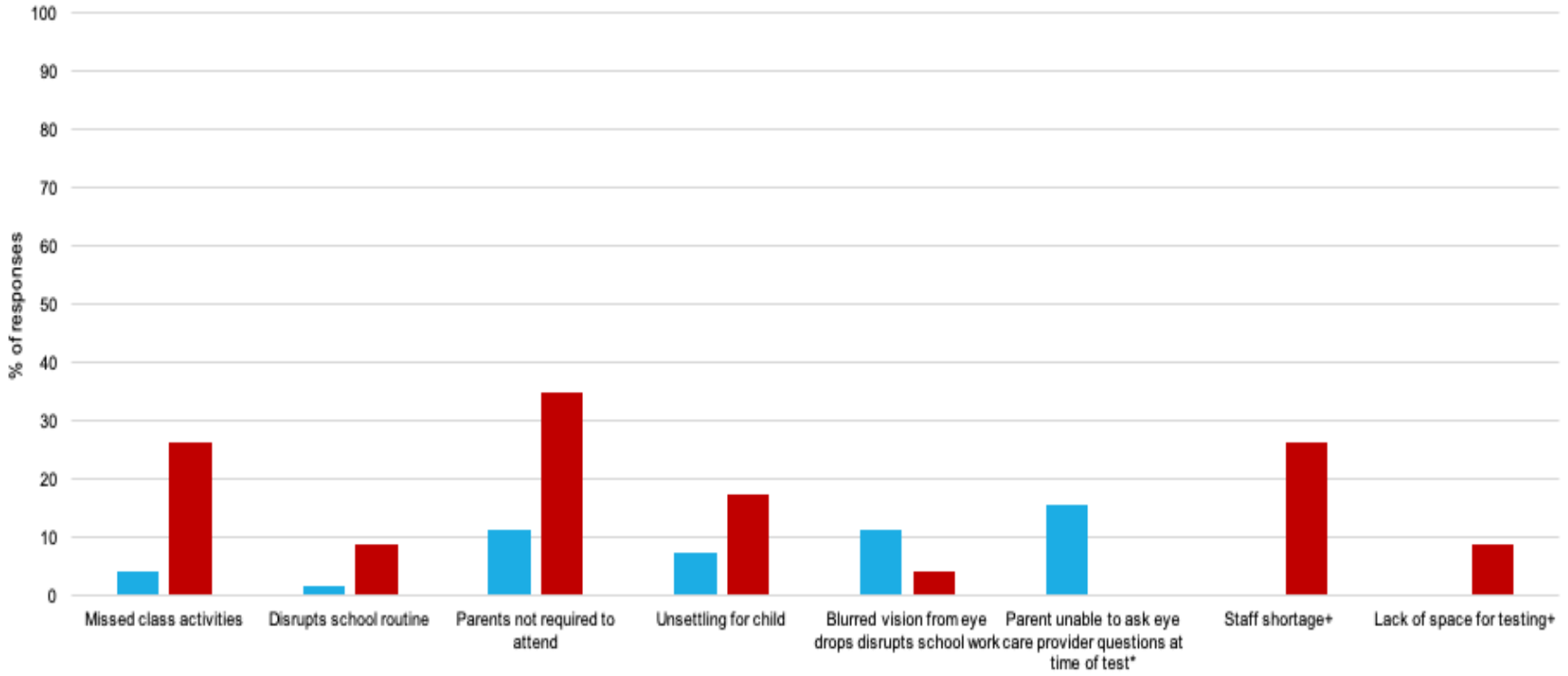
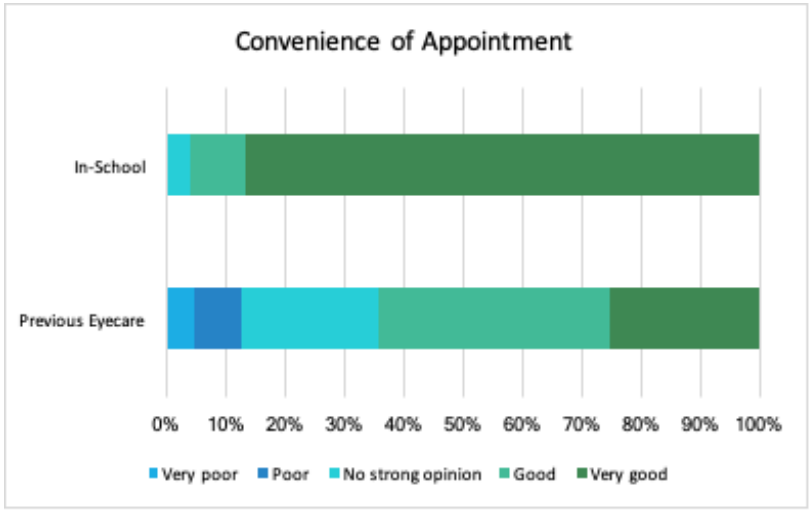
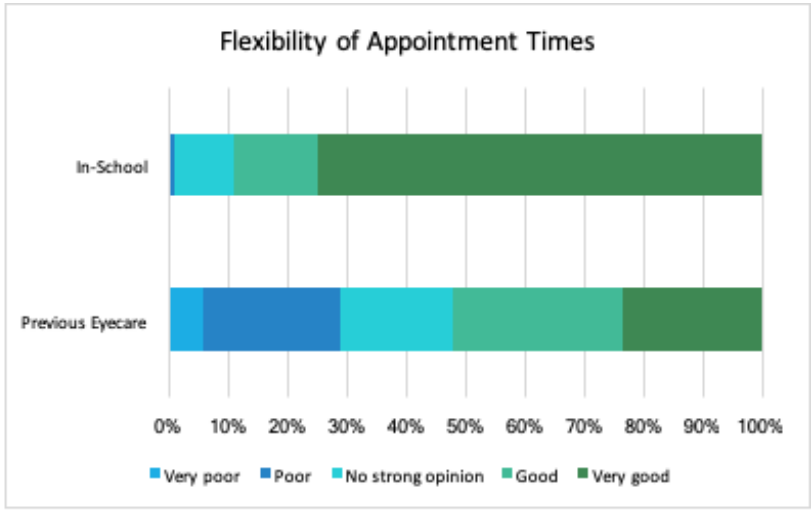


Figure 8.3b: In-school vision assessment limitations reported by parents and teachers. *Question asked to parents only, +question asked to teachers only. Blue bars represent parent responses and red bars represent teacher responses.

8.3.2.4. Parent opinion regarding in-school eyecare compared with previous eyecare services

Parents were asked to rate their experience (see Figure 8.4) of the in-school eyecare and eyecare services their children had previously accessed i.e. hospital eye service and/or community eyecare at local optometrists/opticians. Three items were explored using a five-point Likert scale with options ranging from ‘very poor’ to ‘very good’. Not all children had previous history of eyecare, therefore results are representative of parents who answered each question (at least n=118 for in-school eyecare, n=61 for previous eyecare services). To determine whether responses differed significantly, Mann-Whitney U tests were carried out. There was a statistically significant difference between responses for all items, with in-school eyecare ranking more positively for experience across all aspects ($p<0.001$ for all).





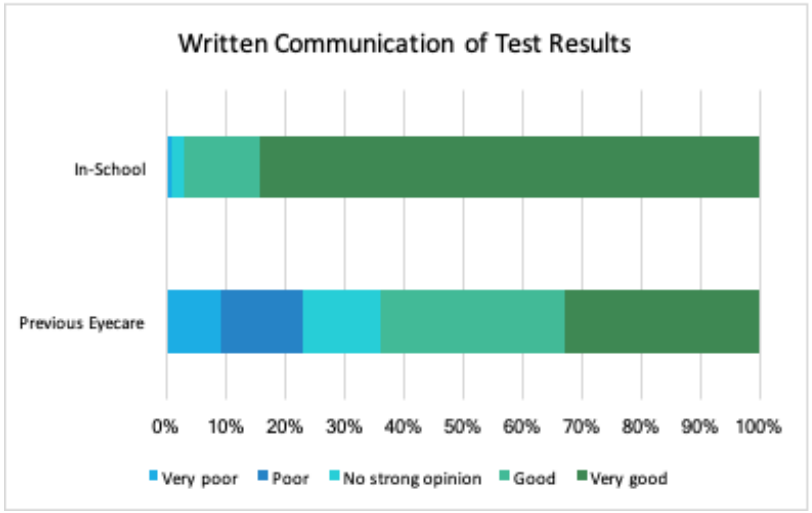


Figure 8.4: Responses from parents regarding their experience of various aspects of in-school eyecare and previously accessed eyecare services (hospital or community based).

8.3.3. Vision Report Feedback

8.3.3.1. Parent feedback on the Vision Report

8.3.3.1.1. Actions provided requiring parental input

Of the 123 parents who returned a questionnaire, an action which required parental input was recommended for 71 participants (57.7%). The number and type of these actions are shown in Table 8.1. More than one action was recommended for some children. The most common reason for advice provided was to account for difficulties associated with CVI (n=41). Provision of new/updated spectacles was the second most common action recommended (n=20).

Interventions/actions	Requiring parent action, n (% of those provided with actions in report)	Requiring teacher action, n (% of those provided with actions in report)
Advice to account for difficulties associated with CVI	41 (57.7)	40 (57.1)
Implementing new/updated spectacle wear	20 (28.2)	20 (28.6)
Enlarge print size of written material recommended	13 (18.3)	13 (18.6)
Recommend increase contrast of written/play material	12 (16.9)	12 (17.1)
Strategies provided to encourage spectacle wear	12 (16.9)	12 (17.1)
Advice to account for visual field deficit	2 (2.8)	2 (2.9)
Additional assistance when reading due to eye tracking problems	1 (1.4)	1 (1.4)
Referral to GP (n=2) or hospital eye service (n=4)	6 (8.5)	Teacher input not required
Convergence exercises prescribed	3 (4.2)	Teacher input not required
Blepharitis management implemented	1 (1.4)	Teacher input not required
Advice to account for colour vision deficit in class provided	Parent input not required	5 (7.1)

Table 8.1: Number and type of actions provided to parents and teachers in Vision Report (only includes children represented by parents who returned a feedback questionnaire (n=123)).

8.3.3.1.2. Implementation of suggested actions at home

Where an action had been suggested in the Vision Report, parents were asked to feedback whether they had implemented, or planned to implement, these modifications in the child's home environment. Of the 71 parents who were provided with an action requiring parental input, 34 (47.9%) reported they had implemented the necessary modifications at home, 11 (15.5%) reported they had not, three (4.2%) answered that they did not know and 15 (21.1%) reported that this question was not applicable despite having been provided with actions in the report. Eight parents (11.3%) did not respond to the question. The number and type of actions suggested to parents along with their response to whether this had been implemented or not are shown in Table 8.2. Aside from management of blepharitis (recommended for one child), the most commonly implemented action (70%, n=14) related to new or updated spectacle prescription. Strategies to encourage spectacle compliance were implemented by 58.3% of parents (n=7) for whom this was suggested. Actions which required environmental modifications to the child's home environment, work or play material were less frequently implemented; for example, increasing print size (46.2%) or contrast (50.0%) of written material, or practical strategies to account for CVI-related difficulties (48.8%).

Interventions/ Actions	Action implemented at home						
	Yes	No	Don't know	Not applicable	Total not implemented	Not answered	Total
Advice to account for difficulties associated with CVI	20 (48.8%)	7	0	10	17 (41.5%)	4	41
Implementing new/updated spectacle wear	14 (70%)	3	1	1	5 (25%)	1	20
Enlarge print size of written material	6 (46.2%)	2	1	1	4 (30.8%)	3	13
Increase contrast of written/play material	6 (50%)	0	2	4	6 (50%)	0	12
Provided strategies to encourage spectacle wear	7 (58.3%)	1	1	1	3 (25%)	2	12
Referral to GP (n=2) or hospital eye service (n=4)	0	1	0	2	3 (50%)	3	6
Convergence exercises prescribed	1 (33.3%)	0	0	1	1 (33.3%)	1	3
Advice to account for visual field deficit	0	1	0	0	1 (50%)	1	2
Blepharitis management	1 (100%)	0	0	0	0	0	1
Additional assistance when reading due to eye tracking problems	0	0	1	0	1 (100%)	0	1

Table 8.2: Responses to parent implementation of suggested actions in Vision Report.

Of the 34 parents who reported implementation of suggested actions, 23 (67.6%) specified what modifications they had made. Nine parents reduced clutter in the child's home, nine reported their child had increased compliance with spectacles, two children were provided with enlarged print material and one parent reported changing the home environment to reduce the impact of

CVI-related difficulties. One parent reported that her child already makes the suggested modifications herself by moving closer to objects to account for reduced vision. Another stated that, while they haven't currently acted to modify their child's environment, the Vision Report has made them aware of the child's vision needs and they plan to make adaptations as the need arises. Of the parents who had not implemented suggested actions, two provided additional comment relating to spectacle compliance; *"my daughter is non-compliant with wearing glasses*" and *"my son refuses to wear his glasses at school and home."*

8.3.3.1.3. Actions provided requiring teacher input

Of the 123 parents who returned a feedback questionnaire, 70 were provided with advice in the report which required action at school. The type and number of these actions are provided in Table 8.1.

8.3.3.1.4. Parental awareness of implementation of suggested actions at school

Parents were asked whether suggested actions had been implemented at school. Fifteen parents (21.4%) reported these had been implemented at school. Most parents (n=34, 48.6%) reported that suggested actions had not been made, or they were unaware whether actions had been implemented. The remaining parents felt this question wasn't applicable to them (n=12, 17.1%) or did not respond (n=9, 12.9%) to this question.

8.3.3.1.5. New information provided to parents

Parents were asked whether the Vision Report contained any information regarding their child's eyes and vision which was previously unknown to them. Thirty-six (31.6%) reported they received new information, 64 (56.1%) reported no new information was received and 14 (12.3%) were unsure whether the report provided them with new information. Of the 36 parents who received new information regarding their child's vision, 31 (86.1%) had a previous history of eyecare. Thirty-three parents provided written comment regarding what information was previously unknown to them. Information regarding refractive error status was the most commonly reported 'new information' (n=8; spectacles provided for the first time in four of these cases), closely followed by knowledge of what level of vision their child had (n=6). The latter was not always in relation to a reduced visual acuity as some parents commented that it was reassuring to know their child had a good level of vision. Five children were identified as having a colour vision defect in the study population. Parents of four of these children reported that they were previously unaware of their child's colour vision problem; all had a previous history of eyecare. Three parents provided more general comments on the information contained in the report: one commented that their child had never had a conclusive eye test before indicating that all of the information contained in the report was new to them; one remarked that they appreciated that the report *"gave specific findings*"; and one parent was aware of new information which resulted in changes to the child's classroom environment.

8.3.3.1.6. Parent-reported usefulness of written reports

Parents were asked whether they found the information contained in the Vision Report useful on a day-to-day basis using a Likert scale of responses ranging from ‘not at all useful’ to ‘very useful’. Of the 123 parents who returned the questionnaire, 115 responded to this question. Most of these parents (78.3%) found the information in the Vision Report either ‘very useful’ or ‘quite useful’ on a day-to-day basis. To determine if parents who found the information contained in the report useful on a day-to-day basis were more likely to have implemented actions suggested in the Vision Report, responses were grouped into positive and negative response categories. Responses of ‘very useful’, ‘quite useful’ or ‘parts are useful’ were ranked as positive while responses of ‘no strong opinion’ or ‘not at all useful’ were ranked as negative. Parent report of actions implemented at home were also assigned into two groups; ‘yes’ or ‘no’. The latter included responses of ‘no’, ‘don’t know’ or ‘not applicable’. Of the 71 parents who received an action for their child, 62 answered both of these questions and were included in this analysis. Fifty-five parents had a positive response to the utility of the report; thirty-three (53.2%) had implemented the suggested actions at home, compared with 22 parents who had not yet implemented these. Six parents (9.7%) who had a negative response to the usefulness of the Vision Report had not implemented suggested actions, while one other parent in this category (1.6%), despite reporting that the Vision Report was not useful had implemented the actions the Report had recommended. Fisher’s exact test showed that parents who found the report useful were significantly more likely to have implemented the suggested actions ($p=0.039$).

8.3.3.2. Teacher feedback on Vision Report

Of the 23 teachers who returned a feedback questionnaire, 15 (65.2%) reported they received a Vision Report for pupil(s) in their class; thirteen of whom read the reports immediately upon receipt, and two reported reading the report several weeks later.

8.3.3.2.1. Actions requiring teacher input

Of the 88 pupils represented by the teachers who returned a questionnaire and had participating pupils in their form class, 46 (52.3%) Vision Reports recommended a vision-related action from their teacher. The number and type of actions provided for the entire pupil population represented by returned teacher questionnaires are shown in Table 8.3. In addition, this table shows the number and type of actions recommended to the 15 teachers who reported receiving the Vision Report, and thus had a chance of being implemented. Of the 77 pupils represented by the teachers who received the reports, 41 (53.2%) required a teacher action.

Interventions/ actions	Number of actions recommended to teachers with participating children in class (n=18)	Number of actions recommended to teachers with children in class who received report (n=15)	Actions reported as implemented by teachers
Advice to account for difficulties associated with CVI	27	25	22
Implementing new/updated spectacle wear	10	9	7
Enlarge print of written material	8	7	7
Increase contrast of written/play material	10	8	7
Provided strategies to encourage spectacle wear	7	5	4
Account for colour vision deficit in class	2	2	2
Advice to account for visual field deficit	3	2	2
Additional assistance when reading due to eye tracking problems	2	2	2

Table 8.3: Number and type of interventions represented by teacher feedback questionnaires grouped by total provided and teachers who reported receipt of the Vision Report.

8.3.3.2.2. Implementation of suggested actions at school

Of the 15 teachers who reported receiving and reading the Vision Report, 12 (80%) had implemented the suggested actions in the report to account for the pupil's visual deficit in the classroom. Two teachers reported that they were unsure if modifications had been made; one of these teachers no longer taught the pupils for whom they had received the Vision Reports and the other had received Reports that did not recommend any actions.

Three teachers provided written comments on the modifications they had instigated for pupils in their class. One reported that the Vision Report drew attention to a pupil's need for high contrast print/written material, and their difficulty discriminating pictures and words if they were a similar colour to the background. In response, the teacher had made adjustments for this; ensuring the child uses a thick, dark pen when writing, and that reading material is presented in a clear, uncluttered manner. Another teacher commented that the child's *"desk is less cluttered and larger font is used."* One teacher commented that they had introduced a modified *"seating position for the child"* and altered *"font size and type for worksheets"* following receipt of the Vision Report.

8.3.3.2.3. Teacher-reported usefulness of written reports

Teachers were asked whether they considered the information contained in the Vision Reports useful and relevant to their work with the pupils; 100% responded positively to this question. Four (26.7%) rated the information as 'very useful', six (40.0%) 'quite useful' and five (33.3%) thought 'parts were useful'. While most teachers (80.0%) reported they felt confident implementing actions suggested in the report, 60.0% reported they were interested in further training on how to adapt a child's environment if they presented with a vision deficit.

8.3.3.2. Was the information in the Vision Report truly 'jargon-free'?

A key aim of the Vision Reports was to ensure they were written in layman's terms, avoiding technical jargon and providing meaningful, actionable

information to non-professional readers. In order to ascertain whether this aim was successfully achieved, we asked parents and teachers to rate whether the reports were written in a way they could understand using a five-point Likert scale ranging from ‘difficult to understand’ to ‘easy to understand’. The majority of parents (80.4%) found the information in the report either ‘easy’ or ‘fairly easy’ to understand (n=60 and 39 respectively). Ten parents had no strong opinion and four reported the language used was ‘somewhat difficult’ to understand. Likewise, most teachers (93.3% of those who received and read the reports) found the information contained in the report ‘easy’ or ‘fairly easy’ to understand (n=10 and 4 respectively). One teacher had no strong opinion. Neither parents nor teachers reported that the information in the report was ‘difficult’ to understand.

8.4. Discussion

An Eyecare in Special Schools Framework published by the Royal College of Ophthalmologists and other professional eyecare bodies in the UK recommends that children attending special schools should receive a full in-school vision assessment, as traditional vision screening is inadequate and unsuitable for this population (The Royal College of Ophthalmologists, 2016; Donaldson et al., 2019) Application of this Framework has been shown to have measurable benefits in terms of reducing a child’s unmet visual needs and increasing classroom engagement (Black et al., 2019). The current chapter reports that parents and teachers are strongly in favour of comprehensive in-school eyecare provision, further supporting the value of such services for this vulnerable group.

8.4.1. In-school vision assessment service feedback

Parents reported preference for in-school eyecare compared with previously accessed eyecare services. A key benefit of in-school eyecare which was repeatedly reported by parents and teachers was the familiarity of this setting for the children. It is well recognised that children with developmental disability, particularly those with autism spectrum disorder, prefer routine and familiarity (Szarko et al., 2013). Attending clinical appointments in unfamiliar environments can cause increased anxiety and behavioural difficulties in children with developmental disability (Evenhuis et al., 2000; Stein et al., 2012). In the present study, with regard to previously accessed eyecare services, one parent commented that the *"very clinical and new surroundings instantly puts my son on edge,"* while another stated *"the clinic environment was daunting for my son.*" Providing eyecare in a familiar environment, is likely to reduce stress and anxiety, therefore increasing the likelihood of compliance with testing procedures, ultimately providing more meaningful results. This benefit was frequently voiced by parents; e.g. *"it is very useful when all happens in a friendly environment like school", "my son was settled in a familiar place and cooperated well."* One parent commented that she was "*always reluctant to take my son to the opticians,"* indicating perceived barriers to accessing traditional eyecare services. When a child's compliance at an examination is poor, more frequent review appointments are required to allow completion of a conclusive eye examination. This creates a compounding burden on already strained NHS services by increasing clinic waiting times and reducing the number of appointments available for new patients. Furthermore, it has been shown that children often have a high 'did not attend' rate at hospital clinics. (Hirani et al., 2016; Pilling & Outhwaite, 2017).

Provision of eyecare in-school allows for another child to be examined in lieu of any absentees, reducing the financial impact of missed appointments (Department of Health, 2014).

Alongside this, children with developmental disability are likely to have ongoing health-related issues which require them to attend multiple clinical appointments. Providing eyecare in-school removes the organisational burden of arranging this appointment, something which was reported as an additional benefit by parents; *"it is helpful for parents to have this in school as many parents have a lot of appointments to attend," "providing this test within school saves my time and hassle making appointments outside," "one less appointment for parents to chase after."* The convenience for parents of providing eyecare in-school was one of the top-rated benefits reported by both parents and teachers, with two parents commenting *"very beneficial as I am a working mum*" and *"very convenient for working parents".*

Compliance with assessments was high during the in-school eye examination, with over 90% success rate achieved for the majority of tests (Black et al., 2019). In contrast, parents reported limited compliance with assessments at previously accessed eyecare services; *"my son tends to get very stressed as he is asked to do a lot in a short space of time. Tests tend to be inconclusive due to lack of cooperation."* The added benefit of providing eyecare in-school allows the examination to be carried out over multiple, shorter visits if necessary to complete a conclusive eye examination. In the present study almost one third of participants required at least two visits to complete the testing procedures (Black et al., 2019). These 'mop up' visits fitted easily into

the in-school testing schedule; a finding which is echoed in previous work (Donaldson et al., 2019). The in-school setting also allowed the clinicians to collaborate with teaching staff to identify the most appropriate time to examine pupils based on their behavioural and emotional needs.

Disruption of class activities due to attending the eye examination was not considered problematic, with majority of teachers reporting that the eyecare appointments were not disruptive to routine class activities. In fact, several parents commented that provision of eyecare at school resulted in the child having less time out of school to attend external appointments; *"it was beneficial to receive this eye examination at school rather than being removed from school and going to the hospital environment,"* and *"it is a good idea to have this done in school – no hassle, no change of environment and less time away from school for appointments."*

8.4.2. Vision Report feedback

Both parents and teachers reported positively on the value and usefulness of the Vision Reports. Most parents reported that the information contained in the Report was easy to understand. This is an important consideration as parents of children with SEN have previously reported that, with reference to the statutory assessment process for their child, use of professional jargon is confusing and hinders their contribution to the process (O'Connor et al., 2005; O'Connor et al., 2007). Given that jargon-free reporting of visual status is valued and used by recipients and verbal information has been shown to be poorly retained at clinic appointments (Thomson et al., 2001; Kessels, 2003), meaningful reporting of visual status should be integral to in-school eyecare

services. Without this component, services will fail to impact optimally on children's visual and educational outcomes. This has been evidenced through the overarching SEE Project; 27.5% of children (n=55) had at least one unmet visual need at baseline which required environmental modifications and advice only, which was detailed in the Vision Report (i.e. unmet needs were not due to lack of refractive correction). At follow-up, this number reduced to 9.0% (n=18; Black et al., 2019). Without provision of the written Vision Report, parents and teachers would have been unable to implement the required modifications to address these children's visual needs.

Teachers valued and acted on information regarding their pupil's vision and visual needs. One teacher commented that the Vision Report *"can impart information relating to environmental factors that can influence work/activities relating to pupils."* Donaldson et al. (2019) report that the regular presence of eyecare professionals in special school settings allows for more effective dissemination of relevant information to teaching staff and has the added benefit of raising awareness of vision among staff. In the present study, 83% of teachers valued the opportunity to speak directly to the eyecare provider regarding a child's vision, further highlighting the importance of increased communication between educators and clinicians.

Parents found the Vision Report useful and valued the information and advice provided in the report. Two parents provided written comment stating that discovering that their child had evidence of CVI was new information for them. One commented that she had implemented strategies suggested in the report to account fo CVI-related difficulties, such as removing patterned wallpaper

and duvet covers, storing toys in storage boxes, and reported that she has *"a better understanding of her child's vision and ways to help with her vision at home and outside."* In general, parents often implemented advice regarding spectacle wear. However, many failed to implement environmental modifications recommended in the report, indicating that parents may require further support to appropriately adapt the child's environment to compensate for visual deficits. This is reflected in feedback provided by one parent who, while she valued the information provided in the report, commented that she *"would like some more information on how to help her child with regards to CVI or understand more about it."* As such, to further enhance the advice provided in a written report, it would be beneficial to liaise with vision support and habilitation services, Qualified Teachers of the Visually Impaired and third-sector organisations who can bridge the gap between receiving information and practically implementing it in the child's home or educational environment. This is particularly important as Chadha and Subramanian (2010) have shown that children aged 3 to 16 years with a visual impairment have significantly poorer self-reported quality of life compared to age-matched, normally sighted peers. In their study, surveyed children were known to the eye clinic and were in receipt of habilitational support, yet they still exhibited poorer quality of life. If children have a visual impairment coupled with a lack of habilitation support, it is highly likely that reported quality of life scores would be even poorer. It is therefore of great importance that children receive optimum vision support.

Parents were generally unsure whether teachers had implemented modifications to the school environment as suggested in the Vision Reports despite 80% of teachers reporting they had implemented the suggested

actions in the report. This finding suggests that communication between parents and teachers was not optimal. O'Connor (2006) echoes this sentiment and reports that parents of children with SEN do not feel included in decisions made regarding their child's education, indicating a lack of communication and collaboration between parents and educators. Lehman (2013) highlights the importance of good communication between stakeholders involved in the child's care and notes that specific advice, including adjustments to the child's environment and visual materials, should be well documented and made available to educators to allow incorporation into the child's Individual Educational Plan (IEP). O'Connor-Bones et al., (2017) also advocate for a collaborative practice between health and teaching professionals. In an interview with classroom assistants for pupil's with SEN, with regard to working with healthcare professionals one assistant commented that *"everybody is working for the same goal, and that's to meet that child's individuals needs and to try and progress them as far as they can go."* This highlights how crucial a joined-up approach between parents, educators and healthcare professionals is in order to ensure the child's vision (and other) needs are optimally met to maximise their access to the curriculum. These sentiments are echoed by teachers in the present study with one commenting, *"it is a worthwhile idea to make teachers/parents aware of visual problems of the children and how to provide a better environment for them,"* while another stated *"information gathered can be shared with the teacher for the benefit of the child."*

8.5. Conclusion

Parents and teachers reported positively on the provision of comprehensive in-school eyecare for children in special schools, with parents showing preference for this service compared to previously accessed eyecare services. Jargon-free, written reports of visual status are valued and utilised by both parents and teachers. Parents and teachers may benefit from further support in making vision-related adjustments for the children in their care, particularly environmental modifications arising due to difficulties associated with CVI. Increased communication between parents and school is warranted to ensure a joined-up approach in actions implemented in the child's environment.

At the end of The SEE Project, a video was produced to highlight the outcomes of the project which includes experiences of children, parents and teachers who participated in the project. This is available to view by scanning the QR code found in Appendix 16.

Chapter 9

Thesis discussion and conclusions

9.0. Chapter overview

This chapter summarises the main findings arising from the work presented in this thesis. The original aims of the work are considered and in response to this, the key findings from the investigation into whether assessment of cerebral visual impairment (CVI) is feasible as part of a comprehensive in-school eyecare service for children attending special schools are summarised. This chapter also discusses the limitations of the current research and identifies areas of future work.

9.1. Original aims and objectives

The original overarching aims of the current project were to determine;

1. which methods of assessment are currently used in the investigation and diagnosis of CVI in children,
2. whether identification of CVI-related difficulties was feasible as part of a comprehensive in-school vision assessment for children in special schools,
3. whether parents and teachers of children in special schools value comprehensive in-school eyecare and provision of written reports of visual and CVI status.

In order to address these aims the following objectives were established;

- review the scientific literature to identify methods currently used to investigate and diagnose CVI in children
- determine the acceptability and suitability of selected CVI assessment methods when applied to a population of children with special educational needs (SEN) in an in-school setting
- evaluate parent and teacher opinion of in-school vision assessments and written Vision Reports through completion of a feedback survey.

9.2. Summary of key findings

The systematic literature review undertaken as part of this study has identified that there is a lack of consensus in the approach used to investigate and diagnose CVI in children. A multi-assessment approach is often employed; this has advantages in that children may be able to comply with at least some aspects of testing, especially if they have intellectual disability or additional complex needs. However, a lack of consensus with regard to an assessment framework or agreed diagnostic guidelines is likely to lead to an under-diagnosis of CVI in children. Without a formal diagnosis and recognition, statutory bodies are unlikely to resource support services for children and their families, which will ultimately have a negative impact on the child's educational and personal development.

The visual profile of the population with SEN included in the present study was similar to previously reported scientific literature, particularly among studies

which conducted in-school vision assessment in other parts of the UK (Das et al., 2010; Woodhouse et al., 2014; Donaldson et al., 2019).

The Visual Skills Inventory (VSI) was a useful tool for identifying children with evidence of CVI in the majority of participants. Identified difficulties could be mapped easily to practical management strategies designed to alleviate the impact of CVI-related difficulties at home and in school through provision of written Vision Reports. However, the VSI also presented several limitations, discussed later in Section 9.3.

The tests of visual perception selected for use in the present study (LEA mailbox, LEA rectangles and shape sorter tasks) were generally well accepted by participants with SEN, however they were not useful at discriminating between groups of participants with and without evidence of CVI in this population. A main disadvantage in their use is that they primarily test visual perceptual functions served by the ventral steam which are least commonly affected in children with CVI (Dutton, 2009; Ortibus et al., 2011; Macintyre-Beon et al., 2012). As such, their use is of limited value in an in-school vision assessment. Alternative tests which assess a broader spectrum of visual processing components were considered (e.g. TVPS), however, these are more intellectually challenging and significantly more time consuming to administer (especially as part of a suite of other assessments), and were therefore not deemed appropriate for an in-school vision assessment in a special school setting.

Direct observation of visual behaviours throughout the in-school vision assessment also proved futile at distinguishing between participants categorised into CVI and non-CVI groups. This was likely due to the limited period of observation throughout the vision assessment. A more suitable approach may be to observe the child's behaviour in a variety of habitual settings, for example in the classroom or during play/meal times, to provide a more comprehensive overview of the child's visual behaviour.

A surprising finding in the current work is that crowding ratios, measured using the LEA symbols, did not differ significantly between participants categorised into the CVI and non-CVI groups. This is a disappointing finding as other studies have concluded that crowding ratios have potential in identifying children with possible CVI (van Genderen et al., 2012; van der Zee et al., 2017). However, van Genderen et al. (2012) did not state which visual acuity tests were used in their study. Van der Zee et al. (2017) used the Cambridge Crowding Cards, which have been shown to have greater crowding effects than the LEA symbols (Lalor et al., 2016). The LEA symbols are well accepted among children with SEN making them a suitable test in the assessment of visual acuity (Little et al., 2013), however, the design may not induce sufficient contour interaction to produce enough crowding to elicit subtle deficits in visual processing. This ultimately reduces the viability for using this chart to effectively measure crowding ratios in children potentially at-risk of CVI (Gräf et al., 2000; Huunerman et al., 2012).

The group who exhibited evidence of CVI in the present study were significantly more likely to have parent-reported problems on the strengths and

difficulties questionnaire (SDQ). It could therefore be argued that information gained from this tool could be a useful addition to aid in the assessment of CVI. However, results must be interpreted with caution as CVI groups were determined based on parent-report. Parents of children in the CVI group may have a generally more negative view of behaviours compared to parents of children in the non-CVI group.

The presence of co-existing visual anomalies in children with CVI has been described extensively in the literature. Affected children are often described as having oculomotor deficits, reduced visual acuity, optic nerve abnormalities and significant refractive errors (Cioni et al., 1997; Huo et al., 1999; Matsuba & Jan, 2006; Khetpal & Donahue, 2007; Bosch et al., 2014; Geldof et al., 2015; Pehere et al., 2018). While the group who exhibited evidence of CVI in the current study did show some consistency with the reported literature in this regard (i.e. poorer distance visual acuity and higher prevalence of medical diagnoses affecting neurological function), there were many disagreements. CVI is an umbrella term covering a range of impairments which affect individuals' function in different ways dependent on the affected site or processing pathway within the brain. As such, not all affected individuals will present with the same type or severity of visual dysfunction. The similarity in visual function characteristics between the CVI and non-CVI groups may be attributed to the potentially mild CVI identified in the current population. In addition, the VSI may have been a suboptimal tool to use in isolation when stratifying participants into CVI and non-CVI groups.

Three key features were identified which differentiated between the CVI and non-CVI group; a medical history affecting neurological development/function, impaired distance visual acuity and a ‘high’ or ‘very high’ overall stress score on the parent SDQ. Therefore, presence of one of these key features alongside difficulties identified on the VSI may constitute a ‘red flag’ which warrants further investigation.

The present study has identified an alternative set of ‘key-questions’ which could be used to screen for evidence of CVI in a population with SEN. The chosen questions differ to those originally suggested by Dutton et al. (2010); the new questions being more appropriate for cohorts of children with physical and intellectual impairments.

Parents and teachers of children with SEN reported very positively on the benefits of in-school eyecare. Parents expressed preference for in-school eye examinations over community optometry and hospital eye services, citing that the familiarity of the school setting was beneficial and helped improve cooperation. While written reports of visual and CVI status are time-consuming to construct, parents and teachers report very positively on the information supplied by such reports and the majority of actions recommended in the report were implemented by teachers. While parents generally reported taking action on the implementation of spectacle wear as recommended in the reports, environmental modifications were less frequently implemented.

9.3. Limitations and challenges

The main challenge faced in the present work was determining how to stratify participants into CVI and non-CVI groups. At present, diagnostic criteria for CVI do not exist. As highlighted in Chapter 2 of this thesis, there is a lack of consensus regarding how to assess and diagnose CVI. Options were considered and a decision was made to base CVI stratifications on parent responses to the VSI. The developers of the VSI do not report specific criteria for scoring responses, however two studies explicitly report defining participants as having perceptual visual dysfunction if scores were, on average, greater than or equal to 3 in each or any section of the VSI. (Mitry et al., 2016; Duke et al., 2019). These clear criteria, having been twice utilised in the literature, were applied in the current study. Another reason for selecting the VSI as the means by which to stratify participants into those with or without CVI was the fact that the VSI did not rely on the participants' ability to comply with test procedures. This is advantageous given that participants with severe learning difficulties were less like to comply with the assessments, yet this is the group who are most likely to exhibit problems associated with CVI (Fazzi et al., 2007; Bosch et al., 2014).

Nonetheless, a major limitation of this approach is that participants for whom a VSI was not returned were excluded from the CVI analysis presented in Chapter 7. This resulted in exclusion of 25% of the total study population. Although the characteristics, in terms of age, gender and level of learning disability of the included and excluded groups were comparable, the inclusion of these additional 50 participants would have been desirable. Included in the excluded group were participants with moderate and severe physical

disabilities and profound and multiple learning difficulties (PMLD); individuals for whom the majority of the VSI questions were not applicable. Most participants with cerebral palsy in the study population were included in this group for whom VSI responses were excluded. This is a subgroup of children who are known to be affected by CVI (Dutton et al., 2012; Fazzi et al., 2012; Mitry et al., 2016). Therefore, by using only the VSI to identify CVI, visual difficulties experienced by these participants are likely to go unrecognised.

If including the VSI in future research studies, it may be advisable to complete this via telephone call to increase the number of valid responses. This method was employed when conducting the parental SDQs, which resulted in a higher completion rate of SDQ compared to the VSI (90.5% vs 75.0% respectively). Completion of the VSI via telephone also aligns better with how it was originally intended to be used; as a structured history-taking tool in clinical settings, rather than a questionnaire completed independently by parents (Dutton et al., 2010). The independent completion of the VSI by parents and teachers in the present study precluded the opportunity for parents and teachers to seek clarification regarding certain questions and/or answers. While parents were provided with contact details for the research team in order that they could discuss completion of the VSI if required, no parent availed of this option. The decision to issue the VSI to parents and teachers for independent completion was made based on the time constraints and demands of the project, but can be considered a limitation of the present research.

The author acknowledges that there is much controversy regarding the handling/interpretation of ordinal data obtained using a Likert scale in a

continuous manner, particularly when using parametric tests which assume normality. However, Sullivan and Artino (2013), who discuss the interpretation of ordinal data in medical education research, conclude by stating that parametric tests can be used to analyse Likert scale responses. Similar conclusions are drawn from Norman (2010) who summarises his discussion on the statistical controversies when analysing Likert data article by stating that “parametric statistics can be used with Likert data…with no fear of “coming to the wrong conclusion” ” and argues that the robust nature of parametric tests renders them suitable for analysing ordinal Likert data. A further reason why data from the VSI was handled in a continuous manner is that this approach has been utilised by Mitry et al. (2016) who report mean scores for each section of the VSI. They also report that participants with cerebral palsy in their study cohort were identified as having evidence of perceptual visual dysfunction based on a mean score of ≥3 on each or any subsection of the VSI, again highlighting that data obtained using the Likert scale VSI was interpreted in a continuous manner.

Another limitation of the current study is that only one special school was recruited to the main study. Participants included in the study were representative of the total school population in terms of age, gender and level of learning disability. However, participants were not representative of the learning disability profile of children in the whole of Northern Ireland. As such, children with profound and multiple learning difficulties (PMLD) were under-represented.

As highlighted in Chapter 8, environmental modifications to account for visual deficits were less well implemented by parents compared with modifications

relating to, for example, spectacle wear or referral to secondary care. Parents were seldom provided with additional verbal or practical support following receipt of the written Vision Report unless this was specifically requested. It may have been more appropriate to underpin and facilitate the implementation of environmental modifications by directing parents to vision support services such as the Qualified Teachers of the Visually Impaired (QTVIs) or third sector support organisations such as Guide Dogs Movement Matters or the RNIB (Guide Dogs, 2020; RNIB, 2020). It is acknowledged that the practicalities of implementing this suggestion may not be straightforward. While a child may greatly benefit from environmental modifications following detection of evidence of CVI, they may not qualify for vision support services as their visual deficit may not be significant enough to meet the criteria for such provision. This may be particularly true for QTVI support for which, in Northern Ireland, a child is required to have a visual impairment registration to qualify and where resources are limited. Report from North America also echoes similar challenges (Kran et al., 2019)

The author would like to briefly acknowledge some of the challenges, difficulties and lessons learned from conducting this work. Firstly, while the in-school environment was tremendously advantageous in many respects, it also presented some challenges in terms of planning and scheduling the vision assessments. An approximate timetable for assessing the children was made for each day, however this did not always come to fruition as often when seeking a child from their class they may have been absent due to a school trip or other school-related activity. The author also had to plan assessment times around the school timetable which proved challenging at times as for

some younger pupils the school day terminated at 1pm. It was important to prioritise these children throughout the morning. In addition, after discussion with the class teachers it was evident that some children were more likely to comply best at certain times of the day. It was important to consider this information and prioritise these children at a time which best suited their needs. Staff shortages also proved challenging at times throughout the study. Depending on the child's underlying medical diagnoses (e.g. epilepsy) it was sometimes essential for a teacher or classroom assistant to attend the assessment with the child. This could prove problematic if another staff member in that particular class was on a break and an additional staff member could not be released to attend the assessment with the child.

Despite these logistical considerations the in-school environment was pivotal to the success of assessing some children. For example, one child became very upset when they attempted to cross the threshold into the testing room; it was not possible to conduct the assessment on this day. After discussion with the child's teacher it was instead possible to conduct the assessment in the child's classroom where she felt entirely relaxed and comfortable. She ultimately cooperated very well with all assessment procedures and was a pleasure to examine in this familiar environment.

Throughout the assessment, it was often necessary to adapt the examination style to suit the needs of the child. For example, it was not uncommon to determine the child's cycloplegic refractive error whilst sitting on the floor if a child felt more comfortable in this position. Due to fleeting attention and it was often necessary to conduct assessments promptly and to vary the activity to

increase engagement with assessment procedures. Implementation of visual and auditory aids were also often employed to engage the child and maintain their attention, for example through singing or use of videos. The author has also learnt valuable lessons in adapting a vision assessment to suit children with different special educational needs. For example, often children with autism spectrum disorder responded best when spoken to in a calm, matter-of-fact manner with explicit detail provided when explaining each assessment procedure and outcome. On the contrary some children with Down syndrome preferred if the assessments were made into ‘games’ where auditory rewards were provided upon completion of an assessment. Adapting communication style was necessary throughout the study as many participants were non-verbal. In attempt to suit the communication needs for as many participants as possible, the author completed a Makaton sign language course which proved invaluable in communicating with some children.

Despite these challenges, the author feels immensely privileged to have been part of such a worthwhile project which helped to address and meet the needs of children with previously unrecognized vision deficits.

9.4. Implications and recommendations of this thesis

9.4.1. Recommendation to include CVI assessment and/or screening as part of an in-school vision assessment for children in special schools

The landscape for the provision of eyecare in special schools is changing. Public Health England recognise that traditional vision screening is unsuitable

for this population and as such, more comprehensive models of eyecare are being introduced (Public Health England, 2019). CVI is the leading cause of childhood visual impairment in developed countries and is likely to affect a large number of children with learning disabilities attending special schools due to the aetiologies surrounding the condition (Rahi & Cable, 2003; Boonstra et al., 2012). Special school eyecare models, therefore, provide a prime opportunity and an ideal vehicle in which to include CVI assessment and/or screening. At least 38% of participants in the current study exhibited evidence of CVI using the VSI; a statistic that highlights the need to seek and address CVI-related difficulties.

9.4.2. Recommendation to include written reporting of visual and CVI status as part of an eyecare model for children in special schools

As discussed previously (Chapter 8), information provided verbally at clinic appointments is poorly retained (Thomson et al., 2001; Kessels, 2003). Provision of written information ensures key information is made available to parents, teachers and other stakeholders involved in a child's care. It also ensures that parents are provided with a tangible document which can act as a starting point to obtain more information regarding their child's visual diagnosis and needs (McDowell, 2020). The present work has presented, refined and trialled a reporting template, and has highlighted the value of providing written information to parents and teachers following a vision and CVI assessment. It is therefore recommended that jargon-free written communication of vision assessment outcomes should be a mandatory component of an in-school eyecare model for children in special schools. Such

reporting should be supplemented with verbal information and practical support from education services, third-sector organisations and vision support services as required to ensure a joined-up approach in the child's care.

9.4.3. Recommendation for professionals to develop sector-agreed guidelines for the assessment and diagnosis of CVI

Systematic review of the scientific literature revealed a lack of consensus in the approach to investigate and diagnose CVI. Despite emerging awareness of the condition, CVI remains largely under-diagnosed and under-recognised. This ultimately impacts negatively on a child's education and personal development as appropriate support measures will not be in place to improve the child's access to education. It is acknowledged that a one-size-fits-all approach to assessment and diagnosis is not appropriate for this heterogeneous condition. Therefore, development of a strict diagnostic framework is unlikely to be of value. However, in order to ensure children are not disadvantaged by an unrecognised problem, it is recommended that assessment guidelines for childhood CVI are developed at the very least. This will aid the process of ensuring children receive a timely diagnosis and ultimately remove a barrier to accessing vision support services for which, at present, children with CVI may not qualify if their vision is not considered 'bad enough'. Without these services, children will be left disadvantaged and parents themselves may be forced to seek alternative sources of support through, for example, third-sector organisations who may be more available to listen to the concerns of the parent and child and offer advice.

9.5. Suggestions for future research

The current project has identified a number of areas which require further research. While specificity and sensitivity of the newly suggested 'key questions' were good for identifying CVI in the current study population (74.7% and 92.0% respectively), application of these questions to a wider group of children is required to determine their validity in screening for CVI. Such an evaluation should include participants with more profound learning disabilities than those included in the present study and specific subgroups of children, for example those with Down syndrome and cerebral palsy, in order to determine the validity of the 'key questions' in these populations.

The suggestion to supplement written information provided to parents and teachers with practical support has already been made. Further work is required to determine whether this is a viable suggestion and whether it really does help to ensure suggested actions are implemented, which would ultimately reduce a child's unmet visual need. A cost-benefit evaluation would be an important consideration as part of this work to ensure the benefits to children and their families outweigh the cost of implementing a comprehensive support service.

Further work is required to meet the recommendations made in Section 9.4.3. While various tests to assess for potential CVI among participants with SEN were employed as part of an in-school vision assessment in the current study, the majority did not adequately distinguish between participants with and without evidence of CVI. Future research is required to identify more

appropriate and effective assessments which could be applied in-school and also form part of assessment guidelines for childhood CVI. Chapter 1 has highlighted ocular deficits and characteristic behaviours which are commonly associated with CVI. Evaluation and identification of these deficits should be central when developing and implementing new assessment approaches. As mentioned previously, observation of children in their habitual environments outside of the clinical assessment could be an important first step.

9.6. Conclusion

While much work is still required in order to refine in-school CVI assessment procedures, this work has highlighted that gaining evidence of CVI is achievable as part of an in-school eyecare service for children in special schools. Evidence of CVI-related difficulties was elicited and practical management strategies were provided to parents and teachers with the aim of alleviating the impact of such difficulties on aspects of daily living. More work is needed to resource and facilitate the implementation of these management strategies at home and in school. While the method of communication and application of strategies needs refinement, the current study is a promising step in the right direction for ensuring that potential CVI-related visual needs of children in special schools are identified and addressed. In turn, this will help to improve their personal and educational outcomes.

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Appendix 1: Medline search terms used in systematic review

Cerebral visual impairment
Cerebral visual dysfunction
Cerebral blindness
Occipital blindness
Neurological visual impairment
Neurological blindness
Perceptual visual dysfunction
Perceptual visual impairment
Perceptual vision impairment
Perceptual disorder
Visual Perceptual disorders
Visual Perceptual defects
Cortical visual dysfunction
Cortical visual impairment
Cognitive visual impairment
Cognitive visual dysfunction
Cognitive visual problems
Visuoperceptual disturbance
Visual perceptual disturbance
Visual perceptual difficulties
Visuoperceptual difficulties
Visual perceptual impairment
Visuoperceptual impairment
Cortical blindness
Children
Adolescent
Infant
Paediatric
Baby
Dorsal stream dysfunction
Ventral stream dysfunction
Dorsal visual system
Ventral visual system`
Dorsal stream
Ventral stream
dorsal visual pathway
ventral visual pathway
Visual processing deficit
Visual skills inventory
cerebral vis* impair*
cerebral* vis* d?sfunction*
cerebral blind*
Occipital adj1 blind*
Neurolog* vis* impair*
Neurolog* blind*
Percept* vis* d?sfunction*
Percept* vis* impair*
percept* disorder*

Vis* Percept* disorder*
vis* Percept* defect*
Cortical* vis* d?sfunction*
Cortical* vis* impair*
Cognitive* vis* impair*
Cognitive* vis* d?sfunction*
Cognitive* vis* problem*
Visuopercept* disturbance*
Vis* percept* disturbance*
Vis* percept* difficult*
Visuopercept* difficult*
Vis* percept* impair*
Visuopercept* impair*
Cortical* adj1 blind*
child*
adolesc*
infant*
p$ediatric*
bab*
dorsal stream d?sfunction*
ventral stream d?sfunction*
dorsal vis* system*
ventral vis* system*
dorsal stream
ventral stream
dorsal vis* pathway*
ventral vis* pathway*
vis* process* def*
vis* skill* invent*

Appendix 2: List of professionals involved in assessment and diagnosis of CVI (Chapter 2)

List of disciplines and individuals involved in the assessment and diagnosis of cerebral visual impairment derived through systematic review of the literature discussed in Chapter 2. X= input reported by article, - = input not reported by article.

Article	Medicine (non-vision)			Vision			Therapy					Psychology										
	Paediatrician	Neuro-radiologist	Neurologist	Ophthalmologist	Optometrist	Orthoptist	Physiotherapist	Speech therapist	Occupational therapist	Therapists	Specialised developmental coach	Neuropsychologist	Psychologist	Neuropsychiatrist	Psychiatrist	Researcher	Parents	Educator	Nurse	Technical ophthalmological assistant	Multidisciplinary	Not stated
Duke et al. (2019)	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-
Geldof et al. (2015)	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	X	X	-	-	-	X	-
Ortibus et al. (2011)	-	X	-	X	-	X	-	-	X	-	-	X	-	-	-	-	X	-	-	-	X	-
Philip (2017)	X	-	X	X	-	X	-	-	X	-	-	-	-	-	X	-	X	-	-	-	X	-
Andersson et al. (2006)	-	-	-	X	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	-	X	-
van Genderen et al. (2012)	-	-	-	X	-	X	-	-	-	-	-	-	X	-	-	-	X	-	-	-	X	-

Bosch et al. (2014)	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Ortibus et al. (2009)	-	X	X	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-
Ferziger et al. (2011)	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-
Whiting et al. (1985)	-	-	X	X	-	-	X	X	-	-	-	-	X	-	-	-	-	-	-	-	X	-
Handa et al. (2018)	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
Roman-Lantzy. (2007)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	X
Fazzi et al. (2007)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Salati et al. (2003)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Macintyre-Beon et al. (2013)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Jasper & Philip (2018)	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
Salati et al. (2001)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Ben Itzhak et al. (2019)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	X
Weinstein et al. (2012)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Vancleef et al. (2020a)	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	-	X	-
Kooiker et al. (2015)	-	-	-	X	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-
Khetpal et al. (2007)	X	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-

Skoczenski & Good (2004)	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Matsuba & Jan (2006)	X	-	X	-	-	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	X	-
Mitry et al. (2016)	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-
Brodsky et al. (2002)	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eken et al. (1996)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Hård et al. (2004)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Lanzi et al. (1998)	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-
Weiss et al. (2001)	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Philip et al. (2016)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Pehere et al. (2018)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Houliston et al. (1999)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Good (2001)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Cioni et al. (1996)	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Good et al. (2012)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Chen et al. (1992)	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Dutton et al. (1996)	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-

Salavati et al. (2015)	-	-	-	X	-	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-	X	-
Cioni et al. (1997)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Huo et al. (1999)	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kooiker et al. (2014)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Salavati et al. (2017)	-	-	-	X	-	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-	X	-
Franki et al. (2017)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Macintyre-Beon et al. (2012)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Suner et al. (2016)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Total number of articles using professionals	***7***	***4***	***6***	***19***	***3***	***6***	***2***	***1***	***2***	***1***	***2***	***2***	***6***	***2***	***1***	***2***	***18***	***3***	***1***	***1***	***18***	***18***

Appendix 3: PLOS ONE Publication

Publication relating to over-arching SEE Project of which the current thesis formed part of. Full article accessible online at: https://doi.org/10.1371/journal.pone.0220480

PLOS ONE

RESEARCH ARTICLE

In-school eyecare in special education settings has measurable benefits for children's vision and behaviour

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Abstract

Objectives

To determine whether implementation of comprehensive in-school eyecare results in measurable benefits for children and young people in terms of visual status, classroom behaviours and how well their visual needs are met.

Design

School-based observational study.

Participants & Methods

200 pupils [mean age 10 years 9 months, 70% male, majority moderate (40%) or severe (35%) learning difficulty] of a special education school in the UK.

A sector-agreed in-school eyecare framework including full eye examination and cycloplegic refraction, dispensing of spectacles (as appropriate) and written reporting of outcomes to parents/teachers was applied. Classroom behaviours were observed and recorded prior to, and after, the in-school eyecare. Surveys were employed to obtain visual histories from parents/teachers. School records and statutory documents were reviewed for diagnostic and learning disability classifications. Visual function and ocular health were profiled at baseline and significant visual deficits identified. Where such deficits were previously unrecognised, untreated or not compensated for (e.g. correction of refractive error, enlargement of educational material) they were recorded as 'unmet visual need'. At follow-up, 2–5 months after initial (baseline) measures, eye examinations, parent/teacher surveys and behaviour observations were repeated. Follow-up measures were used to determine if measurable improvements were evident in visual function, ocular health, the level of unmet need and classroom behaviour following implementation of in-school eyecare.

Competing interests: The authors have declared that no competing interests exist.

Results

199 participants completed baseline and follow-up measures. 122 (61%) participants presented with at least one significant visual or ocular health deficit and 90 (45%) participants had at least one unmet visual need. Younger pupils and those with no previous history of eyecare were more likely to demonstrate unmet visual needs at baseline (OR 1.12 95% CI 1.03 to 1.21) p = 0.012; (OR 4.44 95% CI 1.38 to 14.29 p = 0.007 respectively). On follow-up, the number of pupils with unmet visual needs dropped significantly to 36 (18%) (McNemar's test p<0.001). Visual and behavioural metrics of participants without significant visual deficits or whose visual needs were adequately addressed at baseline remained relatively unchanged between baseline and follow-up (Wilcoxon signed rank p>0.05). Where significant refractive deficits were corrected at follow-up, near visual acuity improved significantly (Wilcoxon signed rank p = 0.013), however, poor spectacle compliance was a persistent cause of unmet visual need. Off-task behaviour reduced significantly after actions to address unmet visual needs were communicated to parents and teachers (Wilcoxon signed rank p = 0.035).

Conclusions

The present study demonstrates for the first time measurable visual and behaviour benefits to children in special education settings when they receive comprehensive in-school eye examinations, on-site spectacle dispensing and jargon-free reporting of outcomes to teachers and parents.

Introduction

It is evident from the literature that children with developmental disability are at a higher risk of visual problems compared to typically developing children [1–7] and UK charity SeeAbility report that children with learning disability are 28 times more likely to have a serious sight problem compared to their typically developing peers [8]. A variety of reports identify that this group of vulnerable children may have difficulty in accessing eyecare services and that where services are accessed, vital information regarding their visual status is not transferred in a meaningful way to education providers [1,9–11].

In-school vision checks (limited to measurement of distance vision in either eye) are recommended by Public Health England in the UK as a screening tool suitable for typically developing children in mainstream education settings. However, due to the increased risk of visual impairment, vision screening is not appropriate for children in special education settings [12,13] and instead comprehensive eye examinations are recommended [14].

However, access to eyecare can be challenging for children with developmental disabilities and their families. As a means to promote equitable access to regular eyecare, key eyecare stakeholders and charities in the UK have collaboratively designed a framework for in-school eyecare for special educational settings [15] and the Clinical Council for Eye Health Commissioning has recently given its endorsement for a comprehensive and targeted programme of eyecare for children and young people in special schools in England. This in-school eyecare framework aims to ensure children with special educational needs have access to eyecare, including comprehensive eye examinations and dispensing of spectacles, in a familiar setting;

and that parents, teachers and other stakeholders receive meaningful information to support children's visual needs at home and school.

The present study aimed to determine, for the first time, whether implementation of a comprehensive in-school eyecare framework results in measurable benefits for children in terms of vision and classroom behaviours.

Participants and methods

Ethical approval for the study was gained through Ulster University Research Ethics Committee (REC/15/0125) and the study adhered to the Tenets of the Declaration of Helsinki.

Recruitment

All parents of children and young people attending Castle Tower School were contacted to invite them and their child or young person to participate in the study. Castle Tower school is the largest special education school in Northern Ireland (a region of the United Kingdom), with 335 pupils ranging from mild/moderate to profound learning disability. Permission was also sought for the research team to contact teaching staff and to access the child or young person's school medical and educational records. Contact was made through the school, with permission of the Principal. Data collection took place September 2016 through June 2018, excluding school holidays. Fig 1 outlines the research process.

Baseline measures—Parents and teaching staff

Parents and teaching staff were questioned regarding several aspects of each participant's medical and ocular history and visual status. A member of the research team worked with parents to complete surveys and inventories either over the telephone, or in person, depending on preference. Teaching staff undertook these tasks independently, however, they were able to ask the research team for assistance, as required.

Visual history and knowledge of visual status. A written clinical history questionnaire was given to parents in order to establish:

- The participant's ophthalmic and brief medical history, including where and when they had their last eye appointments, history of glasses wear and any parental concerns about vision.
- Parental awareness or concerns about participant's visual function or ocular health
- Modifications made at home to account for any visual deficit, if known.

Teaching staff were issued with a written questionnaire to complete for each participant for whom consent had been gained. Information was obtained regarding:

- The teaching staff's awareness of any visual problems or limitations pertaining to the participant.
- Any modifications or adjustments currently in place to reduce the impact of each participant's visual deficits or difficulties in the classroom

Evidence of visual processing difficulties. To explore visual behaviours which may indicate visual processing difficulties, parents and teaching staff were asked to complete the Visual Skills Inventory (VSI) developed by Dutton and colleagues [16] for each participant.

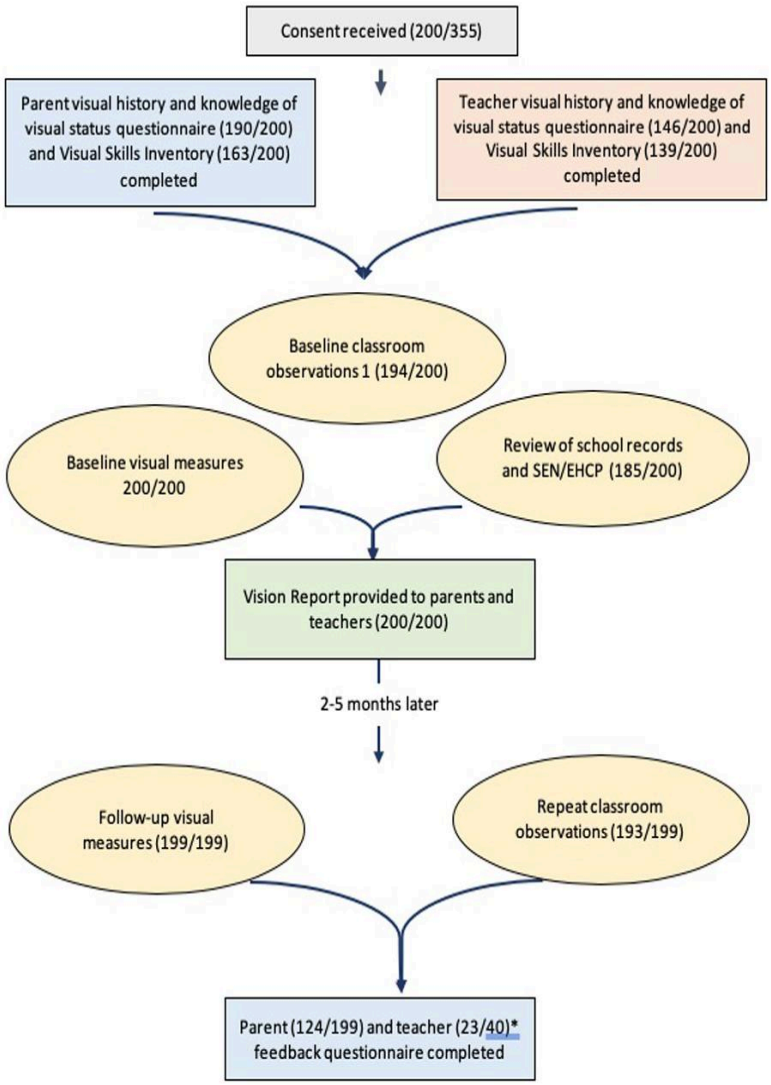

Fig 1. Summary of the research process and number of participants at each stage. *Many participants were in the same class and, therefore, teachers completed feedback questionnaires on more than one participant.

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Participants' school medical records and Statement of Educational Need (Education Health and Care Plan) were reviewed to determine the primary diagnosis and level of learning disability at the time of participation.

Baseline measures–Participants

Classroom engagement. Before any visual measures were undertaken, classroom observations were conducted by an experienced observer (LMcK), trained and monitored by a behaviour analyst (KD). Observations were scheduled to optimise the circumstances in which identified target behaviours could occur [17] i.e. periods of structured engagement in the learning environment. Note was taken of each participant's position in the classroom with respect to general learning resources such as TV screens and whiteboards. Each participant was observed over a period of ten minutes, using a time-sampling methodology. The number of specific behaviours occurring during one-minute intervals were noted [18]. The following target behaviours were chosen as appropriate behaviours with which to profile classroom engagement across the wide range of participant learning abilities and teaching methodologies employed across the school. Behaviours were documented using a modified check-sheet employed in the 'Good Inclusion Game' [19]:

- Initiates engagement with peer/teacher*
- Off task (defined as an event where a pupil disengages from the set task)
- Teacher's positive comment in response to pupil's behaviour
- Not visually engaged with task
- Repetitive behaviours
- Wearing spectacles during task

*'Teacher' refers to all staff members in classroom, including classroom assistants.

The check-sheet was amended, with permission from the authors' of the Good Inclusion Game, to reflect the needs and skills of participants who were pre-verbal and/or had limited communication skills.

Visual and ocular health assessment. A full eye examination was undertaken on all participants in a suitable, well illuminated room of minimum 3 metres in length and which could be blacked out. The following measures which were used to identify significant baseline visual deficits (see Table 1 for further detail): *Habitual visual acuity* at distance and near using tests appropriate for the participant's age and ability.

- Contrast sensitivity
- Accommodative function
- *Ocular alignment* using cover test at distance and near
- *Ocular movement assessment* including fixation quality and extent, quality and control of eye movements
- Binocular visual field assessment
- Refractive error (cycloplegic retinoscopy)
- Dilated internal and external ocular health assessment

Where formal tests of visual acuity failed to elicit a response, the Bradford Visual Function Box [20] was used to gain an indication of visual function.

In addition to gathering information from parents about visual processing deficits through the VSI, measurement of crowded and single binocular acuity using LEA symbols at 3 metres was attempted during the in-school eye examination. The difference between crowded and

Table 1. Tests attempted to ascertain visual status and success rates achieved at baseline.

Test		*Method*	*Success rate % (n)*
Vision	Distance	**Formal measurement of vision successfully achieved***	**98.5% n = 197**
		Sonsken crowded logMAR letters at 3m	60.9% *(120/197)*
		Sonsken logMAR single letters at 3m	0.5% *(1/197)*
		LEA crowded logMAR symbols at 3m	13.7% *(27/197)*
		LEA logMAR single symbols at 3m	1.5% *(3/197)*
		Cardiff acuity test	23.9% *(47/197)*
	Near	**Formal measurement of vision successfully achieved**	**70.5% n = 141**
		Sonsken crowded logMAR letters at 40cm	82.3% (116/141)
		LEA crowded logMAR symbols at 40cm	17.7% (25/141)
Ocular alignment	Distance	Prism cover test (3m)	99% (n = 198)
	Near	Prism cover test (40cm)	100% (n = 200)
Ocular movements		Pursuit and saccadic eye movement quality to penlight at 40cm	88.5% (n = 177)
		Ocular movements in eight directions of gaze	84% (n = 168)
		Near point of convergence to target, until break noted or diplopia reported	88.5% (n = 177)
Accommodative function		Dynamic retinoscopy (Ulster-Cardiff accommodation CUBE with target at 25cm/4D)	97% (n = 194)
Contrast sensitivity		Cardiff Contrast Test	91.5% (n = 183)
Visual Field		Binocular gross confrontation to a 15cm white ball	93.5% (n = 187)
Refractive error		Cycloplegic retinoscopy (1% cyclopentolate HCl)	91.9% (181/197)
		Non-cycloplegic distance static retinoscopy	8.1% (16/197)
		All methods	**98.5% (n = 197)**
Ocular health		Dilated direct/indirect ophthalmoscopy	91.8% (181/197)
		Un-dilated direct/indirect ophthalmoscopy	8.1% (16/197)
		All methods	**99.5% (n = 199)**
Visual Processing		LEA crowded logMAR symbols at 3m	73.5% (n = 147)
		LEA logMAR single symbols at 3m	
		Profiled using the Visual Skills Inventory (VSI) completed by parents and teachers	75.5% (n = 151)
		All methods	**91.5% (n = 183)**

* The Bradford Visual Function Box was used to gain an indication of visual function when a participant was not able to engage with a formal measure of vision.

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single measures were compared to further explore evidence of difficulties with processing 'crowded' visual information, a common feature of visual processing difficulties amongst children with developmental disability [21–23].

Eye examinations took place during the school day and parents were invited to attend. If necessary, eye examinations could be completed over more than one in-school testing session.

In-school spectacle dispensing. A range of suitable spectacle frames were available to fit, glaze and dispense up-dated or new spectacle corrections where required. The costs of spectacles and lenses were covered by the research funding. Parents were involved in the choice of frame. Alternatively, parents could take spectacle prescriptions to their community optometrist, if preferred. Where participants had a current spectacle correction, updated prescriptions were shared with the provider.

Reporting. Following baseline measures, parents and teachers were supplied with a semi-standardised written 'Vision Report' describing the participant's visual status in lay terms [24,25]. Reports were also shared with other health and care providers, as appropriate. The Vision Report identified visual strengths and weaknesses and highlighted actions needed to optimise visual potential and address unmet visual needs identified through the parent/teacher

questionnaires, VSI and eye examination. For example, the Vision Report contained advice and actions regarding:

- Requirements for new or updated spectacle wear and recommended wearing schedule
- Advice on appropriate classroom and home modifications e.g. enlarged print, high contrast educational materials, seating position, reducing clutter etc.
- Strategies to manage signs of visual processing difficulties identified through the VSI
- Requirement for referral to specialist services, e.g. ophthalmological attention and details on the referral made.

Eye examinations, dispensing and fitting of spectacles and report-writing was undertaken by two optometrists (ELM, SAB), experienced in paediatric assessment.

Follow-up measures- Participants

Two to five months after the Vision Report was provided, follow-up measures were instigated. This time period allowed sufficient time for the report to be received, suggested actions/advice to be implemented, whilst limiting the impact of the participant's natural development on visual and behavioural metrics. The following measures were repeated;

- Classroom Engagement: observations repeated by same observer, masked to outcomes of baseline eye examination and Vision Report.
- Eye examination: repeat measures of visual status, including distance and near visual acuity, refractive error and accommodative response.

Follow-up measures: Parents and teaching staff

Feedback questionnaires were issued to parents and teachers after the follow-up assessment. To ensure maximal return rates of the questionnaires, reminders were issued to parents and teachers in person, over the phone, via text message or via email. These questionnaires were used to determine whether appreciation of the participants' visual status had altered and whether actions recommended in the Vision Report had been implemented i.e. whether spectacles were worn, learning material adapted, environmental modifications made.

Statistical approach

All statistical analyses were performed using (IBM SPSS Statistics for Macintosh, Version 25.0. Armonk, NY:IBM Corp 2017). Categorical variables were summarised by frequencies and percentages and the Shapiro-Wilk test was applied to test whether data were distributed normally. Count data obtained through behavioural observations were summarised by median and IQR (inter-quartile range). McNemar's test was used to evaluate differences in the number of participants demonstrating dichotomous traits at baseline compared with follow-up and multiple logistic regression analyses were used to investigate the association between dichotomous traits at baseline and independent variables such as age, level of learning disability and previous history of eyecare. Pearson's correlation was used to investigate relationships between normally distributed related continuous variables. Changes in paired metrics (non-parametric distributions) were evaluated using Wilcoxon signed ranked test. One-tailed tests were used when testing the hypothesis that visual status or behaviour had improved between baseline and follow-up measures.

Das et al (2010) report that 24% of their sample of 228 children in a special education setting presented with uncorrected, or sub-optimally corrected, refractive error (as determined by cycloplegic retinoscopy) and requiring a new/updated prescription. To determine a reduction of 50% or more in this metric, with a statistical power of 95%, required a sample size of 106. This sample size was inflated, to allow for drop-outs at follow-up.

Results

Participant profile

Consent was obtained for 200 of the 335 pupils enrolled in the school; representing a 59.7% consent rate. Participants were aged from 3 years 7 months to 19 years 9 months (mean age 10 years 9 months), 70% were male.

According to school medical and statutory records, participants were diagnosed with a range of medical conditions and syndromes including Autistic spectrum disorders (33%), Down syndrome (9.7%) and cerebral palsy (2.7%). The majority were reported by parents to be born at (or near) term (78.2%), with 15.3% born prematurely (before 37 weeks). According to records, the level of learning difficulty ranged from Profound (1.2%; n = 2) to Mild/Moderate (0.5%; n = 1). The majority of participants had either Severe (35%; n = 70) or Moderate (40%; n = 80) learning difficulties. The sample was representative of the pupil profile of the school in terms of gender, level of learning disability and age (Chi-square p = 0.446, p = 0.722 LD and Mann-Whitney U for age p = 0.053 respectively).

One participant withdrew from the study after the baseline measures. No reason was given for withdrawal.

Visual history. Visual histories were available for 190 (95%) of participants through parent survey. According to parent report, 11.1% (n = 21) of participants had no previous history of eyecare and eyecare history was unknown for 1.1% (n = 2) participants. Of those participants for whom a positive history of eyecare was reported (n = 167), half had received their last eye examination in a hospital clinic (50.2%, n = 84), 37.7% (n = 63) in community optometry practices and four were reported as having received in-school eyecare. The remainder were unsure of the setting of the last eye examination (10.2%, n = 17). The last eye examination had occurred within the previous two years for 66.5% of participants with a history of eyecare. Three participants were registered as severely sight impaired.

Success rates for baseline eye examination. Seventy-one percent of participants (n = 142) completed the baseline eye examination in one sitting, 29% (n = 58) required repeat sessions (52 two sessions, 5 three sessions, 1 four sessions). At follow-up, 192 (96.5%) participants completed the eye examination in one session and the remaining seven needed one further session to complete. Table 1 details the tests used to assess visual status and the success rates achieved.

Baseline/Presenting visual profile of participants

Presenting visual impairment. A formal measure of distance visual acuity was achieved for all but three participants. The remaining participants were assessed using the Bradford Visual Function Box. These participants' data were not included in the analysis of presenting visual impairment. Distance visual impairment was identified using the criteria of Cumberland et al (2016) and the World Health Organisation (ICD-11, 2018) i.e. a presenting visual acuity of poorer than 0.3logMAR (either binocular or in their best eye). Near visual impairment was identified using the World Health Organisation (ICD-11, 2018) criteria, i.e. a presenting near acuity of 0.4logMAR or poorer. Twelve (6.1%; 12/197) participants presented with a distance visual impairment, seven (5.0%; 7/141) had a presenting near visual impairment and two were

impaired at both distance and near. In ten cases of impaired vision (distance or near), these visual impairments were unknown to the parents or teacher, according to visual history-taking. These participants' visual impairments were not being considered in the classroom or at home, and no modifications had been made to educational or recreational materials to accommodate reduced vision. Three participants had acuity of 1.0logMAR or poorer, meeting the threshold for registration as severely sight-impaired; all were identified as being appropriately certified through parent report and in the statutory document detailing their educational support needs.

Refractive error and accommodation. A large range of ametropia (SER –14.00D to +9.00D) and astigmatism were found in this cohort, consistent with the literature for children with developmental disability. For the present analysis, criteria were required to enable consideration of refractive error as an unmet visual need. So, rather than consider refractive error using parameters appropriate to describe prevalence, a criterion was required where lack of refractive correction would mean a significant detriment to visual function. Accordingly, the conservative American Academy of Ophthalmology (AAO) guidelines for refractive correction of children over three years of age [26] was used to define **significant** uncorrected refractive error for the least ametropic eye (Table 2). These criteria were also used to prescribe and update spectacles at baseline. A more clinical approach was taken at follow-up to address lower levels of refractive error.

Sixty-three (32%) participants had significant refractive errors as defined by the AAO criteria; 20 of whom (31.7%) presented without correction. Of these, by parental report, two had no reported history of previous eyecare and eight, whilst having a previous history of eyecare, had never had spectacles.

Thirty-three (17%) participants presented with significantly reduced accommodative responses (hypo-accommodation) to a near target [27]; only four participants had evidence that this deficit was being appropriately managed at baseline (bifocal correction).

Twenty participants presented with both significant refractive error and hypo-accommodation; in 11 cases these deficits were uncorrected.

Participants who presented wearing appropriately powered spectacles to correct their refractive error and/or accommodative deficit or had no significant refractive error (as defined above) were regarded as having their refractive needs met at baseline (82.2%, n = 162/197). The remainder were regarded as having an 'unmet need' in relation to refractive error. Thirty-five participants needed a first time correction, updated spectacles, a bifocal correction or had a history of spectacle wear but presented unaided.

Table 2. Prevalence of significant refractive error in the present study.

Significant Refractive Error [26]	N (%)
Isometropia	
Myopia ≤-2.50	1 (0.5)
Hyperopia ≥+3.50 (No manifest deviation)	14 (7.0)
Hyperopia ≥+1.50 (with esotropia)	14 (7.0)
Astigmatism* ≥1.50DC	29 (14.5)
Anisometropia*	
Myopia ≤-2.50	5 (2.5)
Hyperopia ≥+1.50	15 (7.5)
Astigmatism ≥1.50DC	4 (2.0)
Total with Significant Refractive Error (AAO criteria)	**63 (32%)**

*Participants with these refractive errors may also be represented in spherical groups.

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Contrast sensitivity. Twenty-four (13.1%) participants presented with reduced contrast sensitivity compared with published normative data [28]. In none of these cases were parents or teachers aware of the visual deficit and no compensations or modifications had been made in class or at home to reduce the impact of this deficit. Twenty-three (95.8%) participants with contrast deficits had a history of eyecare.

Visual field deficits. Gross confrontation revealed four (2%) participants with significant restrictions of their visual fields [29]; three presented with hemianopia and one participant demonstrated a general constriction of their visual field. Visual histories revealed that all had a history of eyecare but that parents and teachers were not aware of these visual field restrictions and no account was taken of them either at home or in the school environment to compensate for the deficit.

Eye movement control. Most participants had full ocular movements and normal pursuits, saccades and convergence. However, 20 (11.3%) participants demonstrated abnormal ocular movements, including seven with significantly reduced near point of convergence (NPC). All but one participant with abnormal eye movements had a previous history of eyecare but only seven parents appreciated the presence of abnormal ocular movements (35%).

Ocular health. Eighteen (9.0%) participants had one or more ocular anomaly (Table 3). While 17 had a history of previous eyecare, six were receiving no current treatment/management as parents were unaware of the condition.

Ocular alignment. Thirty-nine (19.5%) participants had a manifest strabismus at distance or near or both and nine had nystagmus (Table 4).

Crowding deficits and evidence of visual processing difficulties. A total of 43 (23.5%) participants presented with a crowding deficit and/or evidence of visual processing difficulties. Thirty-one (16.9%) participants had evidence of crowding deficits identified through the Dutton Visual Skills Inventory (VSI) or where comparison of crowded binocular acuity was more than two lines poorer than the measure achieved using single optotypes [30] Evidence of difficulties with additional aspects of visual processing (beyond crowding issues), was reported through the VSI for 24 (15.9%) participants. Twelve participants demonstrated difficulties with both crowding and other aspects of visual processing.

Where evidence of visual processing deficits was revealed through the VSI and/or deficits in crowded versus single optotype acuity was found, there was no evidence of parents or teachers having previously been given strategies or information to support pupils in coping with these difficulties, except for one participant who had a diagnosis of cerebral visual impairment. Neither did parents report previous exploration of these difficulties by eye/health professionals prior to the in-school eye examination. Of the 43 participants identified as having a deficit, 41 (95.3%) had a previous history of eyecare.

Table 3. Anomalies of ocular health or structure noted during the internal and external ocular examination.

Condition	N (%)
Blocked tear ducts	3 (1.5)
Blepharitis	4 (2.0)
Lens anomalies (cataracts, subluxated lens, IOLs)	6 (3)
Ptosis	2 (1)
Tortuous blood vessels	1 (0.5)
Optic disc anomalies (pale disc, drusen)	2 (1)
Iris synechae	1 (0.5)
Retinal naevus	1 (0.5)

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Table 4. Prevalence and type of ocular alignment anomalies.

Type of Strabismus	Distance N (%)	Near N (%)
Esotropia	18 (9)	17 (8.5)
Exotropia	16 (8)	15 (7.5)
Hyper/hypotropia	2 (1)	2 (1)
Nystagmus	9 (4.5)	

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Most common visual deficits. Refractive issues, including poor focus and significant ametropia, reduced contrast sensitivity and evidence of visual processing difficulties (including crowding) were the most common visual deficits identified through the in-school eye examination and application of the VSI. 122 (61%) participants presented with at least one significant visual deficit.

How well were visual needs met at baseline?. Where participants presented with a significant visual or ocular deficit as described above, data from the baseline eye examination and the visual histories were used to identify whether these deficits were known about and accounted for. Where this was not evidenced, the participant was defined as having 'unmet visual need(s)'. Ninety participants (45.0%) presented with an unmet visual need (Table 5) at baseline; 31 had more than one unmet visual need and three presented with four unmet visual needs.

Refractive deficits, reduced contrast sensitivity and evidence of higher visual processing deficits were not only the most common presenting deficits, they were also the least well-met

Table 5. Percentage (n) of participants presenting with significant visual deficits at baseline, the proportion of these visual deficits which were unrecognised and/or unaddressed and, as such, defined as an 'unmet visual need', at baseline and follow-up.

Visual deficit	% presenting with a significant visual deficit at baseline (n)	% with visual deficit and 'unmet visual need'* (n)		McNemar's chi-square test
Significant Refractive Error and/or Accommodative Deficit [26,27]	38.6 (76/197)	Baseline	17.5 (35) [13 no/poor compliance with current spectacles, 13 no previous Rx, 6 update Rx]	p<0.001
		Follow-up	8.5 (17) [14 no/poor compliance; 3 new/updated spectacle Rx not acquired]	
Reduced contrast sensitivity [28]	13.1 (24/183)	Baseline	12.0 (24)	p<0.001
		Follow-up	3.5 (7)	
Reduced distance and/or near acuity [33,34]	8.6 (17/197)	Baseline	5.0 (10)	p = 0.016
		Follow-up	2.0 (4)	
Ocular pathology/anomaly	1. (18/199)	Baseline	3.0 (6)	p = 0.016
		Follow-up	0 (0)	
Visual field deficit[29]	2.1 (4/187)	Baseline	2.0 (4)	p = 0.250
		Follow-up	1 (2)	
Anomalous eye movement control [35,36]	(20/177)	Baseline	6.5 (13)	p<0.001
		Follow-up	0.5 (1)	
Evidence of visual processing deficits [30,37]	(43/183)	Baseline	21.0 (42)	p<0.001
		Follow-up	6.0 (12)	
TOTAL	61.0 (122/200) with at least one visual deficit	Baseline	45.0 (90)	p<0.001
		Follow-up	18.1 (36)	

*Methods of meeting unmet visual needs included provision of new/updated spectacles to correct refractive deficits, implementation of advice relating to environmental modifications such as increased print/image size and increased contrast, onward referral for treatable ocular and eye movement disorders such as blepharitis or reduced near point of convergence.

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visual needs. Younger age and no previous history of eyecare were independently associated with increased odds of having at least one unmet visual need at baseline (Odds ratio 1.12 95% CI 1.04 to 1.21, p = 0.012; Odds ratio 4.44 95% CI 1.38 to 14.29 p = 0.007 respectively). Neither level of learning disability or gender were significantly associated with the presence of an unmet need at baseline (multinomial regression analysis both $p>0.05$).

Reports and actions to address visual deficits and unmet visual needs. Vision Reports were issued for all participants. All reports summarised participants' visual status and, where an unmet visual need had been identified, reports included advice or actions required to address these needs. Nine reports initiated onward referral to a general medical practitioner or hospital eye services and 35 contained information about new or updated spectacle correction and/or advice to support spectacle compliance. Nineteen (9.5%) participants with a significant refractive error or accommodative deficit were supplied with a first-time (n = 13) or updated (n = 6) spectacle correction. Sixty-five (32.5%) Vision Reports provided advice about environmental and learning material modification to reduce the impact of contrast deficits, visual field defects, impaired vision and/or evidence of difficulties with visual processing. These reports provided examples of appropriate large print/image size, strategies to increase contrast of learning materials, and modifications to seating position at home and in the classroom to maximise access to learning and recreational stimuli [31]. Where evidence of visual processing difficulties was found, strategies to manage these difficulties were given, as recommended by Dutton et al [21,32] and these difficulties were also communicated to the participants' wider healthcare teams for further investigation, as appropriate.

Where Vision Reports contained actions and strategies for parents or teachers to implement, 80.3% of parents responded to the question probing whether they had made environmental modifications as suggested in the report. Half (50.9%) reported that they had actioned the suggestions in the report. Teaching staff were also asked to report whether modifications to classroom seating and/or learning material had been made as suggested by the Vision Reports they received. Eighty-eight percent reported that modifications had been made to maximise pupil's visual access to learning and recreational material.

How well were visual needs met at follow-up?. Data from the follow-up eye examination and the parent/teacher feedback questionnaires were used to determine how in-school eyecare had influenced the number of participants whose visual deficits were treated, recognised and/or appropriately addressed. Table 5 illustrates the number of participants with significant visual deficits at baseline and the number whose visual needs were unmet (unrecognised and/or unaddressed) at baseline and follow-up. Significantly more visual needs were met at follow-up (NcNemar's test $p<0.001$), with the exception of visual field defects (Table 5).

A statistically significant improvement in presenting near visual acuity was recorded for children where refractive deficits present at baseline had been addressed at follow-up.

At follow-up, the number of participants with unmet needs in relation to refractive error significantly decreased but while a notably greater number (regardless of age, level of learning difficulty or gender, multiple logistic regression $p>0.05$ for all) who had spectacles were compliant, poor compliance with spectacles remained the primary reason for unmet need in this category. Where refractive deficits present at baseline had been addressed at follow-up, participants demonstrated significantly improved near visual acuities (Wilcoxon signed rank z = -2.226, p = 0.013). This was not the case for peers who either had no unmet need in relation to refractive error at baseline or follow-up, or those who retained an unmet need in relation to refractive error from baseline to follow-up.

The primary aim of the study was to assess the impact of in-school eyecare in special educational settings as described by the sector-approved framework [15]. The framework does not explicitly include assessment of crowding deficits or potential visual processing deficits. If

crowding and visual processing difficulties are not considered in these analyses, the findings are similar; the number of participants whose visual needs were all met at follow-up (n = 175) is also statistically significantly greater than at baseline (n = 139) (McNemar's test $p<0.001$).

Did the in-school eyecare and identification of visual deficits affect classroom engagement and behaviours?. Baseline and follow-up classroom observations were completed for 193 participants. Participants whose parents or teachers had received actions or advice to alleviate unmet visual needs identified at baseline, demonstrated significantly less 'off task' behaviour at follow-up (paired Wilcoxon rank test p = 0.035), while their peers showed no such change in behaviour (p = 0.261) (Table 6). Pupils in the former group were younger at baseline, but their age did not significantly influence the magnitude of the improvement in off-task behaviour (Pearson correlation coefficient r = -0.087, p = 0.414). While there was also evidence for improvements in other observed behaviours at follow-up, the improvements failed to reach significance. Although more participants were wearing spectacles during classroom observations at follow-up (n = 54), compared with baseline (n = 51), nine with significant refractive deficits which would have impacted on the clarity of their learning material were not wearing spectacles during the observed period.

Discussion

The present study demonstrates measurable benefits associated with providing comprehensive eyecare in a special education setting. Although the majority of participants had a previous history of eyecare, nearly half presented with at least one significant visual deficit which was not currently identified or addressed. After undergoing in-school eyecare with dispensing of spectacles (as appropriate) and written reporting of visual status, the number of children with deficits which were not being appropriately addressed or managed reduced. Where presenting visual deficits were identified through the in-school eye examination and advice or action was given to address previously unrecognised or untreated deficits, significant improvements in aspects of children's visual function (near visual acuity) and classroom engagement (less time spent 'off-task') were measured.

Refractive deficits were common in the present study, as expected from previous studies of similar populations [1,9]. While the participants in the present study had a more comprehensive history of previous eyecare than either Das et al (2010) or Woodhouse et al (2012)

Table 6. Observed classroom behaviours at baseline vs follow-up using paired data from individual participants' two measurement periods.

	Participants with at least one unmet visual need at baseline (n = 90)			Participants whose visual needs were met at baseline (n = 110)		
Target behaviour	Baseline Count	Follow-up Count	Wilcoxon signed rank test, z (p)	Baseline Count	Follow-up Count	*Wilcoxon signed rank test, z (p)
	Median (IQR)	Median (IQR)		Median (IQR)	Median (IQR)	
Initiates engagement	3 (1–5)	2 (1–4)	-0.039 (0.485)	3 (1–6)	2 (1–5)	-1.632 (0.052)
Teachers' positive comment	2 (1–5)	2 (0–4)	-0.115 (0.454)	2 (0–5)	1 (0–3)	-2.617 (0.005)
Off task	1 (0–3)	0 (0–2)	***-1.817 (0.035)***	0 (0–2)	0 (0–1)	-0.641 (0.261)
Not visually engaged with task	0 (0–0)	0 (0–0)	-0.881 (0.189)	0 (0–0)	0 (0–0)	-0.408 (0.342)
Repetitive behaviour	0 (0–1)	0 (0–0)	-1.525 (0.064)	0 (0–0)	0 (0–1)	-1.632 (0.052)

*The Wilcoxon signed rank test was applied to test the null hypothesis that there was no difference in count between baseline and follow-up against the alternative hypothesis of an improvement in behaviour. Negative z values represent an improvement in the following behaviours (off task, not visually engaged, repetitive behaviours) and positive z values represent an improvement in the remainder (initiates engagement, teachers' positive comment). Only p-values less than 0.05 which are associated with improved scores (the hypothesis under test) should be considered significant in this one-tailed analysis.

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refractive deficits still constituted a large portion of the unmet visual need identified at baseline, mainly due to unmanaged accommodative deficits and poor compliance with spectacles. The latter is a well acknowledged issue amongst children with special needs and their typically developing peers [1,9,38]. Children with developmental disability have been shown to have a higher prevalence of accommodative deficits than typically developing children [39–41] and these deficits are relatively easy to quantify and manage with refractive correction, including prescription of bifocal spectacles [42,43]. The majority of children with hypo-accommodation in the present study had a history of eyecare; suggesting that more attention needs to be paid to the measurement and optimisation of accommodative accuracy by eyecare professionals. When visual deficits are identified and addressed, the present study demonstrates improvements in visual function, specifically near visual acuity. Conversely, failure to address poor accommodation has implications for quality of near vision and engagement with learning materials. Previous studies reporting visual status in special educational settings have not reported measures of near vision. Given the importance of both near and distance vision in the learning environment, the high success rates for measuring this function and the improvements measured when unmet visual needs are addressed, our data support the inclusion of this functional measure within comprehensive eye examinations for children with special educational needs and in future research studies.

Spectacle compliance in a large study of typically developing school children [38] revealed that approximately 25% of children who had spectacles (and whose vision was reduced without them), failed to routinely bring their spectacles to school. Compliance was also problematic in the present study; 50% of participants with significant refractive deficits and spectacles did not present to the in-school eye examination wearing their spectacles and parents/teachers reported poor or no compliance. Furthermore, compliance was further reduced when participants were observed in class, rather than presenting for an eye examination and it is likely that the former observation is more reflective of habitual behaviour. At follow-up, significantly more children who needed spectacles presented wearing spectacles and more children were wearing their spectacles during classroom observation. Parent/teacher feedback reported the benefit of strategies to encourage spectacle wear and the added benefit of the eyecare professionals dispensing the spectacles in school and regularly being in the school to support spectacle wear. Nonetheless, compliance with spectacles remained a significant issue, being the most common reason for a refractive deficit being unaddressed at follow-up, suggesting that enhanced strategies and support are needed to encourage compliance with spectacle wear amongst children in special educational settings to promote optimal visual and learning outcomes. An ongoing in-school eyecare service with in-school spectacle dispensing component, would allow for further support in compliance issues and provide the opportunity for in-school repair and replacement of spectacles. Frequent repair and replacement is often a feature of early spectacle wear for children and is essential to maintain good compliance and optimise vision.

'Environmental' modifications were advised for a large number of children with visual deficits which could not be eliminated by spectacle wear or other 'treatment'. Despite the majority of participants having a previous history of eyecare, there was little evidence that such deficits and their day-to-day impact had been effectively articulated to teachers or parents, or included in statutory documents defining the child's need for support. For example, deficits in contrast sensitivity were common and entirely unaddressed or appreciated at baseline. Contrast sensitivity deficits are relatively easy to measure using validated preferential-looking techniques and whilst they are not generally treatable, advice and environmental modifications are straightforward and inexpensive. Parents and teachers reported that the Vision Report issued after the in-school eye examination was valuable and few had previously received such

information [24]. Where environmental modifications such as increased contrast, increased print size or change in seating position were advised in the Vision Report, teachers reported a high level of pro-activity in implementing these low-tech modifications and, as a consequence, the number of children whose visual deficits were appropriately addressed in the school environment were increased. Parents appeared to need more support in implementing environmental modifications in the home. The outcomes of the present study support the inclusion of jargon-free reports describing visual strengths and weaknesses and highlighting actions required to address visual deficits, including environmental modifications, as a necessary component of visual assessments of children with special educational needs. Without such reporting, the findings of the present study suggest visual deficits will remain unaddressed, to the detriment of the child's vision and learning opportunities.

Visual processing deficits, such as those elicited by the Visual Skills Inventory (VSI), are reported to be common amongst children with developmental disability [16,21,44]. The present study used comparisons between crowded and isolated optotype acuities and the VSI to reveal a large number of children with evidence of visual processing deficits, very few of which had previously been investigated or reported to parents or teachers. In the absence of agreed diagnostic or management protocols, where evidence of visual processing deficits was found strategies to address the specific deficit highlighted by the VSI or crowded/isolated acuity measures were provided to parents and teachers. Liaison with local tertiary care providers allowed for onward referral for further investigation as indicated (n = 4). The high number of unrecognised visual processing deficits revealed in the present study underlines the urgent need for the development of agreed protocols for the diagnosis and management of visual processing deficits. While such deficits are not routinely identified through the methods employed in traditional eye examinations, they can have significant impact on daily living activities and behaviour [21,45,46]. The evaluation of visual processing deficits in the present analysis was limited to two relatively straight-forward measures which were considered achievable in the context of the special school setting. The authors acknowledge that additional visual processing deficits [47], which were unexplored and unaddressed in the present study, could restrict the benefit measured from the in-school vision care. Additionally, some authors have suggested that excessive levels of lighting in standard school rooms may exacerbate visual processing deficits [48,49]. The present study did not formally measure lighting levels in the classroom settings, but baseline and follow-up measures were conducted under semi-standardised conditions.

This is the first study to attempt to measure the impact of in-school eyecare on the classroom behaviour of children in special education settings. Previous work has shown that appropriate vision correction for children with learning disability may result in improvements across a wide range of behaviours; for example, improvements in social behaviour, gross and fine motor skills and literacy were noted in two groups of children (aged 0–6 and 7–17 years) whose vision needs were addressed [50]. The outcomes from the present study demonstrate a significant improvement in classroom engagement in one domain; the amount of time spent 'off-task' during the ten-minute observation period. The number of times participants were 'not visually engaged with the task' or were engaged in 'repetitive behaviours' also decreased from baseline to follow-up, but these improvements failed to reach significance. Two behaviours, 'initiates engagement' and 'teacher's positive comment', were recorded on fewer occasions at follow-up. These behaviours may indicate that children were working more independently and needing less encouragement or intervention from the teacher, but the difference in counts is not statistically significant. The authors acknowledge the challenges of identifying whether in-school eyecare and identification of previously unrecognised or unaddressed visual deficits has an impact on classroom behaviour, particularly given the

heterogenous nature of the participant group in terms of age and learning disability. Careful, repeat measures by a masked observer using previously validated measures of classroom engagement at baseline and follow-up for each participant, was undertaken to limit the impact of these variables. The time interval between baseline and follow-up was also designed to be as brief as possible within the constraints of the school timetable and the research protocol, to limit the effect of normal development on measures. Observations were undertaken in a standardised way but it was not possible to entirely standardise the type of learning activity the participants were engaging in during the timed period, and some variation existed between baseline and follow-up observation activities. Ideally, the same activity would have been set for the observation periods at baseline and follow-up and this may have proved a more sensitive methodology with which to explore improvements in engagement and participation following in-school eyecare. Further evaluation of the impact of in-school eyecare on classroom behaviours though individual case studies is planned.

The participation rate of pupils from the participating school was high and the children and young people involved in the study were representative of the underlying pupil profile. Although nearly 30% required more than one attempt to complete the eye examination, success rates in obtaining formal measurement across a comprehensive range of visual functions was high when given this opportunity, illustrating that provision of in-school eye care in special education settings should yield a high level of success in providing a thorough evaluation of children's visual status and needs. While the pupil profile of the present school reflects primarily individuals with moderate and severe learning disability, and therefore the outcomes may not be entirely generalisable to pupils with more profound impairments, Donaldson et al (2019) demonstrate that in-school eye examinations can also be successfully applied in schools catering for more pupils with profound and complex needs.

The UK government has identified the need for better access to healthcare for children with special needs and improved cooperation and sharing of information between healthcare and educational services [51–55]. The importance of delivering care in the most appropriate setting, with minimal disruption to education, has also been identified as an important component of paediatric health services [56–57]. Delivering comprehensive eyecare services in special education settings promotes improved access to eyecare, facilitates information flow between health, education and families and causes minimal disruption to children's education. Evaluation of parent and teacher views on the benefits and drawbacks of in-school eyecare is ongoing. The outcomes from the present analysis demonstrate that not only does in-school eyecare in special education settings address government aspirations in relation to equality of care for children with learning disabilities, it has measurable benefits for their visual status and opportunities to engage with learning material.

Conclusions

The present study demonstrates measurable benefits to children and young people in a special education setting from undergoing comprehensive in-school eye examinations with on-site spectacle dispensing and jargon-free reporting of outcomes to teachers and parents. Benefits were apparent in both visual and behavioural domains. In-school eyecare services offer an opportunity to improve health and education outcomes for people with learning disability.

Supporting information

S1 Fig. Anonymised data set.
(PDF)

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Appendix 4: British Journal of Learning Disabilities Publication

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ORIGINAL ARTICLE

Meeting vision needs of children with special educational needs: Case studies of the impact on behaviour and academic achievement

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Accessible summary

- Children with learning disabilities often have problems with their eyesight.
- We tested the eyes of nine children and checked whether they needed glasses or bigger print.
- We found that when they got what they needed to see better, their behaviour improved.
- This is important because children with learning disabilities need to be able to see as well as anyone else.

Abstract

Background: Children with identified special educational needs are at higher risk than other children of having visual needs that are not adequately met. This paper evaluates the impact of addressing the visual needs of these children on behaviour and academic achievements in a number of case studies.

Method: Nine children (4–11 years of age, from four classrooms), who attended a special school in a medium-sized town in the UK, took part in the case studies reported here. The children were part of the Special Education Eyecare (SEE) Project. Six of the children were selected because they had unmet visual needs at baseline and required bespoke interventions to meet these needs; the other three children were selected because their visual needs had been met prior to the study and no further adjustments were needed. Repeated direct observations were conducted to assess the impact of the intervention on the children's behaviour in the classroom. The observer was "blind" with regard to the visual needs of the participants. Parents and teachers completed the Strength and Difficulties Questionnaire (SDQ) for each child, before and after the intervention. School files were analysed to assess effects on academic achievement.

Findings: Subsequent to the implementation of bespoke visual adjustments, for example prescription of spectacles or changed seating in classroom, significant and sustained changes were observed with regard to the children's behaviour (i.e., increased engagement with peers and/or teachers and decreased off-task behaviour). Strength

and Difficulties Questionnaire scores showed improvements regarding total difficulties, emotional difficulties, hyperactivity and prosocial (kind and helpful) behaviour. Due to highly variable data in school files, the effects on academic achievement were inconclusive.

Discussion: The case studies reported here explored changes in behaviour of children with identified special educational needs after their visual needs were met. Findings show a positive overall effect on the behaviour of these children.

KEYWORDS

applied behaviour analysis, behaviour measures, in-school vision testing, SDQ, special education, vision, visual needs

1 | INTRODUCTION

The prevalence of visual disorders in children who have identified special educational needs is known to be greater than in their typically developing peers (Das, Spowart, Crossley, & Dutton, 2012; Little & Saunders, 2015; Woodhouse, Davies, McAvinchey, & Ryan, 2014). Children without developmental disabilities have a much lower risk of visual impairment (0.16% compared to 10.5%) as well as other vision disorders (Salt & Sargent, 2014); children in special schools have reported prevalence of visual impairment between 12% and 16% (Little & Saunders, 2015). It is estimated that up to two-thirds of children with visual impairments have other identified special educational needs, co-occurring most frequently with neurological or developmental conditions such as autism, attention deficit/hyperactivity disorder or epilepsy (Morale et al., 2012).

However, in children with complex needs visual disorders can be difficult to identify and assess (Salt & Sargent, 2014). Although specific guidelines for vision care exist, there is evidence that visual care for children with special educational needs is frequently neglected (Pilling, 2011; Woodhouse et al., 2014). These children also experience barriers to accessing eyecare services in hospital or community optometry settings, partly because the stress of unfamiliar surroundings and communication difficulties can make cooperation in such situations challenging (Das et al., 2012).

A relationship between visual deficits and impaired academic performance has been demonstrated repeatedly, both in mainstream and in special schools (Toledo et al., 2010; Dudovitz, Izadpanah, Chung, & Slusser, 2016). Consequently, it is possible that appropriate vision correction for children with identified learning disability results in improvements across a range of behaviour, including social behaviour, gross and fine motor skills, and academic achievements, for example in literacy (Nandakumar & Leat, 2010; Woodruff, Cleary, & Bader, 1980). Conversely, unaddressed visual conditions can have long-term adverse implications for quality of life and lead to challenging behaviour in adulthood (Jones et al., 2008).

Vision assessment that actively involves parents, children and teaching staff addresses not just issues regarding the child's visual difficulties but also their educational, developmental, health and social outcomes (Dudovitz et al., 2016). This holistic approach is welcomed by parents and teachers (Little & Saunders, 2015; Woodhouse et al., 2014) and contributes to reducing stress for parents and children (Morale et al., 2012).

Research reported in the present paper was part of the large-scale Special Education Eyecare (SEE) Project (Black et al., 2019). The SEE Project included 200 children and young people (4–18 years of age) with identified special educational needs, school staff and parents/guardians in a comprehensive in-school vision assessment programme. Following the visual assessment, parents and teachers received a comprehensive report with detailed information about each child's visual status and, where relevant, jargon-free advice on how to address previously unmet visual needs for each of the children. The in-depth case studies reported here offer an analysis of the effects of this on the children's behaviour in the classroom and at home and their academic achievements.

2 | METHODOLOGY

Ethical approval was granted by relevant Research Ethics Committees of Ulster University and Queens University Belfast. The research was conducted in line with the research governance and data protection guidelines for both universities. This included parental consent for vision assessment, questionnaires, as well as file research. The children's names were changed to preserve anonymity.

2.1 | Participants

Nine pupils (three girls and six boys) from four classes took part in in-depth case studies. The sample ensured opportunity for repeated in vivo observations in a relatively short time span. The

children's ages ranged from 4 years 5 months to 11 years 8 months of age. Six of the children (three girls and three boys) required adjustments to support their visual needs, and three of the children did not require additional interventions according to comprehensive eye examinations (Table 1). The children were a representative sample (based on their visual needs profiles) selected from participants in the larger SEE study. The children for the case studies were chosen by the "vision team" of the SEE study to ensure that the "behaviour team" were unaware of (blinded to) the vision needs of each case study child, until after data collection was completed.

2.2 | Research tools

2.2.1 | Behavioural observation recording sheets

The observation recording sheet was adapted from the interval recording sheet developed by Coyle and Dillenburger (2018; Dillenburger & Coyle, 2019). This recording sheet listed a number of "observable, measurable and specific" (Nock & Kurtz, 2005, p. 362) target behaviours to be observed in all children, regardless of their age, level of learning disability or teaching environment.

The target behaviours were as follows:

- Being on-task, including initiating engagement with peer and/or teacher/teaching staff, either verbally, by sign or by touch;
- Being off-task, such as being disengaged from the set task or engaging in non-task-related behaviour, including playing with toys or equipment, delaying log-on to computer, staring out of a window or at a workbook without engaging in the task, distracting other children, and direct noncompliance (e.g., refusing to complete a task, eating a snack instead of working), and being out-of-seat;
- Receiving a positive comment from a member of staff (e.g., "nice work" or "well done");
- Repetitive stereotypic behaviours (e.g., hand flapping, rubbing eyes, rocking in seat);

To the right of each of the target behaviour were 10 small boxes, each representing 1-min observation intervals, in which each occurrence of the behaviour was tallied (e.g., 𝍸 representing a count of five occurrences of the behaviour). Thus, the frequency of each behaviour was counted across the ten 1-min observation periods for each child. At the bottom of the observation sheet, there was blank space to record field notes about events that occurred during the observation period, for example interruptions to class, specific interactions, child's position in classroom with respect to screens and play areas. Field notes also specified the antecedents and consequences of the target behaviour (Nock & Kurtz, 2005). There also was a "yes/no" tick box to record if the child was wearing spectacles.

2.2.2 | Strengths and difficulties questionnaire

The Strengths and Difficulties Questionnaire (SDQ; Goodman, 2001) is considered a robust and well-validated instrument to assess behavioural issues in children and young people across time (Muris, Meesters, & van den Burg, 2003; Rothenberger, Becker, Erhart, Wille, & Ravens-Sieberer, 2008; Stone, Otten, Engels, Vermulst, & Janssens, 2010; Wolpert et al., 2015). It is completed by parents or teachers and comes in short and extended versions. The extended version used in this study has 25 core questions and a supplement that focuses on the impact and the duration of reported problems and difficulties (Goodman, 2001). The follow-up SDQ, administered after any intervention, contains two additional social validity questions regarding the respondent's views of the intervention.

2.2.3 | Academic attainment scores

Files held in the school for each child were used to assess academic scores (e.g., spelling and maths) across time. Data contained in the files were collated annually in the school (Wyers, 2018), using tests for spelling and maths. Spelling tests included the Diagnostic Spelling Test series (Crumpler & McCarty, 2006), Daniels and Diack Spelling Tests (Daniels & Diack, 1958), Vernon Graded Spelling Tests (Vernon, 2006) and/or the InCAS, a computer-adaptive assessment to identify and diagnose learning need and measure progress in key developmental areas (CEM, 2019). Maths tests included the Numeracy Baseline Test (NBT)/Numeracy Progress Test (NPT) (Vincent & Crumpler, 2000), Young's Group Test A (Young, 1996) and/or the InCAS (CEM, 2019). Special educational needs statements (the Northern Irish equivalent of Education, Health and Care Plans) were available in the files. These were used to record the level of support needs for each child.

2.3 | Research procedure

2.3.1 | Participant selection

The nine children included in the present study constituted a carefully selected sample from the SEE Project population (n = 200) (Black et al., 2019). The SEE Project took place over two academic years in a large special school in a mid-sized town in Northern Ireland and included very thorough in-school vision tests, a bespoke visual needs report for parents and teachers, behavioural screening (parent and teacher SDQ) and two brief in vivo classroom observations, one before and one after the vision intervention. Due to wide variations in the school timetable, it was not possible to obtain longitudinal data of all the children and therefore the small sample of children (n = 9) was selected for in-depth case studies.

TABLE 1 Participants' details

Name[a]	Age	Diagnosis (EHCP); parent description	Vision assessment outcome	Recommendations/adjustments required to meet visual needs
Luke	4 years 5 months	MLD, autism, SL and global developmental delay.	Luke was significantly hyperopic (R: +6.00/−0.50 × 90, L: +6.50DS). He had previously been given spectacles, but did not wear them. Without spectacles, Luke had an accommodative deficit, which reduced his visual performance. Luke exhibited evidence of cerebral visual processing impairment in relation to reduced performance with crowded/cluttered visual information (corrected binocular crowded LEA symbol acuity 0.4logMAR; single LEA symbol acuity 0.1logMAR). UNMET VISUAL NEED: uncorrected refractive error and cerebral visual impairment (CVI)	Parents and teachers were advised on the importance of full-time spectacle wear for Luke and were issued with strategies to encourage him to wear his spectacles. *Classroom intervention*: Spectacles should be worn at all times. Reduce clutter in environment and educational material. Ensure nonessential items are removed from desktop and schoolwork presented in a simple, uncrowded format.
Áine	9 years 8 months	SLD, epilepsy, ADHD, Asperger's syndrome	Áine was significantly hyperopic (R: +4.50DS, L: +3.75DS) and wore spectacles full-time. Even with her spectacles in place, Aine's nystagmus caused her distance and near vision to be reduced compared to her peers (binocular distance crowded LEA symbol acuity 0.225logMAR [distance], 0.3logMAR [near]). UNMET VISUAL NEED: reduced vision at distance and near	*Classroom intervention*: Aine should be seated at the front of the class for whiteboard work. School/homework should be enlarged, bold and spaced out. Teaching staff were given examples of the size of print/pictures that Áine can see easily and which should be used for her educational and recreational materials.
Ciara	10 years 2 months	MLD/SLD, SL, OMCS—cyst on right hemisphere.	Ciara had good vision at both distance and near and did not need spectacles. Ciara had evidence of cerebral visual impairment; she had difficulties negotiating uneven ground and tripped at kerbs and over low furniture. She found crowded areas and cluttered visual information challenging. UNMET NEED: cerebral visual impairment	*Classroom intervention*: Ciara should sit at the front of the class where there are fewer visual distractions from other classmates. Reduce clutter in environment and educational material. Ensure nonessential items were removed from desktop and schoolwork was presented in a simple, uncrowded format.
Shane	10 years 4 months	Cerebral palsy, quadriplegia, polymicrogyria, epilepsy	Shane was hyperopic and had astigmatism (R: +3.00/−1.00 × 165 L: +3.50/1.50 × 160). He had never worn spectacles, and without spectacles, his focusing was inaccurate and his distance and near vision were reduced (binocular crowded LEA symbol acuity 0.3logMAR [distance], 0.5logMAR [near]). Shane had a restricted visual field; he did not see objects that were positioned peripherally. Shane had evidence of cerebral visual impairment; his visual performance was poorer when visual information was cluttered and he took a long time to engage with visual information. UNMET NEED: uncorrected refractive error, visual field restriction, cerebral visual impairment.	Spectacles were dispensed to Shane. Parents and teachers were advised on the importance of full-time spectacle wear, and strategies were issued to advise his carers on how best to encourage spectacle wear. *Classroom intervention*: Spectacles should be worn at all times. Shane should be seated directly in front of the whiteboard. Place educational and play material directly in front of Shane to allow him to engage with it more easily. Present schoolwork in a clear and uncluttered format, using simple pictures and words. Give extra time to visually process and engage with tasks. Appreciate that Shane is likely to become tired and fatigued quickly when doing schoolwork due to his visual processing difficulties.

(Continues)

TABLE 1 (Continued)

Name[a]	Age	Diagnosis (EHCP); parent description	Vision assessment outcome	Recommendations/adjustments required to meet visual needs
Rose	10 years 5 months	MLD	Rose was significantly hyperopic (R: +4.50/−3.25 × 175, L: +4.25/−3.25 × 170) and wears her spectacles full-time. With her spectacles on, she had good vision for both distant and near objects. Rose had evidence of cerebral visual processing difficulties; she had difficulties negotiating uneven ground, walking downstairs and bumping into low furniture. She found crowded areas and cluttered visual information challenging. UNMET NEED: cerebral visual impairment	*Classroom intervention*: Rose should sit at the front of the class where there are fewer visual distractions from other classmates. Reduce clutter in environment and educational material. Ensure nonessential items were removed from desktop, and schoolwork was presented in a simple, uncrowded format. Give verbal information to encourage increased awareness of obstacles when moving about.
Alan	11 years 8 months	MLD, Asperger's syndrome, ADHD, SL	Alan was hyperopic, anisometropic and astigmatic (R: +4.75/−1.25 × 180 L: +1.00DS) but had no spectacles to correct this refractive error. Alan's ability to see low contrast objects was significantly reduced for his age. Alan had evidence of cerebral visual processing difficulties; his behaviour deteriorated in crowded and busy environments, he was easily distracted and trips over edges of pavements and other low obstacles. UNMET NEED: uncorrected refractive error, reduced contrast sensitivity, cerebral visual impairment.	Spectacles were dispensed, and full-time wear was advised. Parents and teachers were advised on the importance of full-time spectacle wear, and strategies were issued to advise his carers on how best to encourage spectacle wear. *Classroom intervention*: Spectacles should be worn at all times. Alan should sit at the front of the class where there are fewer visual distractions from other classmates. Reduce clutter in environment and educational material. Ensure nonessential items are removed from desktop, and schoolwork is presented in a simple, uncrowded format. Provide high contrast (e.g., black text on white, thick dark marker pen rather than pencil to write) reading and writing materials. Give verbal information to encourage increased awareness of obstacles when moving about.
Billy	4 years 11 months	MLD/SLD, autism, SL, SEBD	Billy had good visual function in all domains.	No adjustments required
Timothy	9 years 11 months	MLD, SEBD, autism	Timothy had good visual function in all domains.	No adjustments required
Conall	11 years 6 months	MLD	Conall had good visual function in all domains.	No adjustments required

Abbreviations: ASD, autism spectrum disorder; CP, cerebral palsy; EHCP, Education Health and Care Plan; MLD, moderate learning disability; OMCS, other medical conditions (not specified); PHYS, physical disabilities; SEBD, social, emotional and behavioural disorder; SENS, special educational needs statement, equivalent to Education, Health and Care Plan; SL, speech and language difficulties; SLD, severe learning disabilities.

[a]Not their real name.

To prevent selection bias, the "vision team" selected the children for the case studies without disclosure to the "behaviour team" of whether or not the child required visual adjustments. Decoding occurred after completion of all observations and other data collection.

2.3.2 | Visual and ocular health assessment

Vision and ocular health assessments were carried out twice. Once at baseline and again 2–5 months after the necessary adjustments had been recommended. The tests included measures of visual acuity using tests appropriate for the participant's age and ability and following standard test protocols; contrast sensitivity; accommodative function; ocular alignment; ocular movement assessment; binocular visual field measurement; refractive error; and dilated internal and external ocular health assessment. The tests led to two main recommendations: (a) the need for a new spectacle prescription and (b) modifications to the learning environment (e.g., seating near the front of the class, employing large print material). Full details of the tests and test results are provided elsewhere (Black et al., 2019).

2.3.3 | Behavioural observations

Using the behavioural observation recording sheet, total of eight 10-min observation sessions (total 80 min) were carried out for each of the nine case study children. This included one baseline observation session (Obs.1) prior to the visual and ocular health assessment and seven observations after the visual and ocular health assessment had occurred and adjustments had been recommended (Obs.2–Obs.8). The time span between the first (baseline) and the final observation ranged between 26 and 30 weeks (average 28 weeks).

For the behavioural classroom observations, arrangements were agreed in advance with the relevant teacher. The observer sat at the back of the class to prevent the Hawthorne effect, that is to ensure that the participants' behaviour was not affected by the observer's presence (Johnston & Pennypacker, 2009). The observer had full visual of the child being observed throughout the session (Martin & Bateson, 2007).

Classroom layout and activities and any additional unstructured observations were recorded in freehand field notes at the bottom of the observation sheet and included observations related to potential recommendations, such as was the child wearing/not wearing spectacles; was the child seated at the front of the class; and/or was enlarged print used (the observer was not aware of the specific visual recommendations for the child at the time of observation). Inter-observer agreement (IOA) measures were not possible due to the fact that, due to concerns about disruption to teaching, permission was not granted by the school for a second observer to be present in the classroom. Video recording, that would have allowed for post-session IOA calculations, also was not permitted.

The children took part in a range of classroom activities, and observations were scheduled to occur under conditions that were similar with regard to classroom, learning activity, time and day of week, within the natural constraints of school timetables and resources. The two youngest children (Luke and Billy) were involved in a combination of desktop activities, such as counting or reading one-to-one with the support of a teaching assistant, free play or whole class activity time, such as singing, "weekend news" or watching videos with all pupils seated in front of a large screen. Both children engaged in a number of activities (including periods with no set tasks) over the 10-minute observation; Luke engaged in an average of 3.4 activities, with a maximum of 5 activities per session, while Billy was occupied with an average of 2.6 activities, with a maximum of 4 activities per observation session. The older children were engaged in subject-based, whole class teaching either in English or in History. Aine and Ciara received frequent support from teaching staff to complete tasks; Timothy worked independently, receiving occasional teacher support, for example to answer a query. Shane needed consistent support to complete tasks as his motor skills were very poor, although support was not always available. Rose worked independently, on two occasions with a peer in group work, receiving occasional support. Two children (Conall and Alan) were observed during maths classes in all observation sessions. After the first observation, Conall was moved to a separate learning zone at the back of the classroom with another pupil, where they were supported by a classroom assistant for most of the lessons. Alan was observed while he worked independently, receiving occasional support from his support teacher. All other children were observed in a classroom, while they were taught by their class teacher.

2.3.4 | Strength and difficulties questionnaire

Parent SDQs were completed by telephone interview. The researcher rang the parent at a pre-arranged time and read out the questions, one at a time, and recorded the parental response to each question on the SDQ form. Hard copy SDQs were available on request (no such request was made).

Teacher SDQs were completed in the school. The case study children were drawn from four classes and the teaching staff who knew the child best completed an individual SDQ for each child; this was either the class teacher (for younger children) or the form teacher (for older children). Both parent and teacher SDQs were administered twice for each child: once before and once after the vision assessment and report. All parents (n = 9) and teachers (n = 4) completed the relevant SDQ, although baseline teacher SDQ data were incomplete for Conall and Alan.

2.3.5 | File search

A search of records held in school files was conducted for each of the children (Carroll & St Peter, 2014). The file search took place in the school office. The door was locked, while the files were searched. None of the files were taken out of this room, and on completion of the file search, the files were placed back in a locked filing cabinet.

The files included a written record of the results of the annual review for each pupil. Annual reviews were conducted by the teachers at the beginning of each academic year and resulted in a child's numerical "attainment age" for each subject studied. Annual reviews were not carried out for a number of children: those in preschool (3–4 years old), year 1 (4–5 years old), year 2 (5–6 years old) and children with severe learning disabilities. The data retrieved from the files included attainment age with regard to spelling and numeracy as well as the child's chronological age. Pre- and post-intervention records were incomplete for 8 of the children. A full data set was available for one child (Timothy) (Table 6).

3 | RESULTS

3.1 | Adjustments to meet visual needs

The vision assessment led to spectacle corrections being prescribed for three children; Shane had never had spectacles and

both Luke and Alan had been prescribed spectacles in the past, but neither had worn them. Two children (Áine and Rose) had spectacles prior to the study and wore them full-time; no changes to their spectacle prescription or wearing schedule were recommended in the vision assessment. The other children did not require spectacles.

Three children (Luke, Áine and Rose) wore their spectacles during all post-baseline observations. Alan did not wear his spectacles at any time, although they were placed on his desk during some of the observations. Shane wore his spectacles for five out of the seven follow-up observations. He had very limited fine motor skills and needed assistance to retrieve his spectacles from a school bag and put them on. In all cases where modifications to the learning environment had been advised following the visual assessment, teachers had implemented these strategies.

3.2 | Engagement with staff or peers

Table 2 shows the frequency of child-initiated engagement with staff or peers during direct observations, both at baseline (Obs.1) and at follow-up (Obs.2–8). For five of the six children who required vision adjustments, the frequency of initiating contact with staff or peers increased post-intervention. Before the visual assessment, these children instigated interaction an average of 2.5 times (range 1–6) each per observation. After visual assessment, the children's interaction with peers and teacher increased to an overall average of 3.3 times (range 0–11) per observation period (Obs.2–Obs.8). The three children who did not require visual adjustments (Billy, Timothy and Conall) initiated an average of four interactions (range 0–9) prior to their vision assessment (Obs.1), this rose slightly to an average of 4.2 interactions (range 0–13) across subsequent observations (Obs.2–Obs.8).

3.3 | Off-task behaviour

Table 3 shows the frequency of off-task behaviour observed before and after the visual assessment. For the six children whose visual needs were unmet at baseline (Obs.1), the average off-task behaviour decreased after adjustments had been made to meet their visual needs. On average, these children were off-task 1.3 times (range 0–4) at baseline. After the vision intervention, off-task behaviour reduced to an average of 0.9 times (range 0–4) per 10-min observation (Obs.2–Obs.8). Field notes made by the observer indicated that more off-task behaviour occurred at the start of an activity or when the children being observed were engaged in a task that they found difficult and support was not available (such as logging in or searching on the computer when staff were engaged with others). For the three children who did not require any modifications after the vision assessment, off-task behaviour averaged three occasions (range 2–4) during the first observation (Obs.1) and remained three during the latter observations (Obs.2–Obs.8), although the range increased (range 0–8).

3.4 | Teacher comments

Table 4 shows the frequency of positive teacher comments before and after the vision intervention for all nine children. During the first observation (Obs.1), children who had unmet visual needs received an average of 1.3 (range 0–3) positive teacher comments. Following adjustment to meet their visual needs, during Obs.2–Obs.8, the frequency of positive teacher comments rose to an average of 2.2 (range 0–13) comments per observation for each of these children. For those children who did not require modifications to accommodate visual needs, the average of positive teacher comments rose from an average of 1 (range 0–3) comment (Obs.1) to 3.3 (range 0–11) comments per observation session (Obs.2–Obs.8). Positive teacher comments were unevenly distributed between the children and the classes they attended. Both Luke (range 2–13) and Billy (range 0–11), who attended the same class, received particular high levels of positive comments, while Shane (range 0–1) and Rose (range 0–1), who attended a different class, received very infrequent positive teacher comments, although they were very rarely off-task. Field notes indicate that Luke and Billy received most of these positive comments during one-to-one support for academic tasks.

3.5 | Repetitive behaviours

Table 5 shows the frequency of repetitive behaviours. For the children who required adjustments, repetitive behaviour increased from an average frequency of 0.7 (range 0–2) (Obs.1) to 2 (range 0–10) per observation period (Obs. 2–Obs. 8). For the children who did not require visual interventions, only Billy showed any repetitive behaviours during observations and these were sporadic. Field notes indicated that Alan engaged in repetitive behaviours most often and across a greater time period than others; more episodic events occurred for Luke, especially when he was left without a task (Obs. 7). Ciara and Áine both had neurological conditions which could lead to a fairly constant movement of hands or legs at times, while engaged in tasks. The observer was not aware of their condition at the time of the observations. These movements were not included in the analysis of "repetitive behaviours" as it would be very difficult to ascertain their aetiology.

3.6 | Strength and difficulties questionnaire

Figure 1 shows parent and teacher SDQ scores pre- and post-vision assessment for each of the children. The figure shows scores for total difficulties, emotional difficulties, behaviour difficulties, hyperactivity and concentration difficulties, peer problems, prosocial behaviour and overall impact, and compares these with British norm scores (Strength and Difficulties Questionnaire (SDQ), 2001). Most of the children in the present study scored "slightly raised" or "high" scores in many of the categories. Some of these scores reduced for

the children who required adjustments to support their visual needs after these needs were met.

3.7 | Total difficulties

The total difficulties score reported by parents for the children who required vision adjustment improved by an average of 3.3 points. Teacher-reported total difficulties scores for these pupils improved by an average of 0.8 points. Only Ciara's total difficulties score at school worsened to slightly above the norm for her age group. For the children who did not have unmet visual needs at the start of the project and who therefore did not require additional adjustments to support their vision needs, parent-reported difficulties improved by an average of 2.3. However, this score was still well above normative UK scores for children of their age. Teacher-reported total difficulties scores for two of these children (Billy and Alan) worsened by an average of 4.5; no comparative data were available for Conall.

3.8 | Emotional difficulties

For three of the children who received vision adjustments, emotional difficulties scores improved at home; this was particularly noticeable for Alan, although his and Rose's scores remained above the norm for their age. Slight worsening in scores was recorded for two of these children; Luke's score remained within the average range, but Ciara's score moved from "raised" to "high." In school, improvements in the emotion scores were recorded by the teachers of four of these children, with only Ciara showing a slightly worse score than at baseline. Two of the children who did not require vision adjustments (Billy and Timothy) had slightly enhanced emotion scores at home, while a deterioration in scores to a "high" level was reported for Conall.

3.9 | Behaviour difficulties

Two of the children (Luke and Alan) who received vision support had somewhat improved conduct scores at home, although these were still above the norm for boys of their age. For Áine and Rose scores remained stable, while for Ciara and Shane the scores indicated slightly increased parental concerns about behaviour difficulties. Teacher scores indicated that for Luke and Rose, behaviour difficulties had decreased; this was particularly noticeable for Rose, whose initial score was above the norm but reduced to zero after vision adjustments. Scores for Áine, Ciara and Shane remained stable. Insufficient teacher-reported data were available for Alan. On the other hand, of the children who did not need additional vision support Billy showed worsening behaviour difficulties at home (well above the norm for boys of his age) and Timothy showed worsening behaviour at school; although no initial data were available, his follow-up SDQ indicated Conall's behaviour at school was a concern, scoring considerably above the UK average.

3.10 | Hyperactivity and concentration difficulties

Four of the children who received additional adjustments to meet their visual needs showed improvements with regard to levels of hyperactivity and concentration difficulties at home, although their scores remained higher than the UK average. In school, teacher scores also indicated an improvement for four of these children, for example from the limited data available from his partially completed initial SDQ, Alan's score improved from "very high" to "slightly raised." Parental SDQ scores for one of the three children who did not require additional vision adjustments (Timothy) showed an improvement over time, but for Billy, hyperactivity and level of concentration scores worsened at home. Teacher scores for all of these children categorised their levels of hyperactivity and concentration difficulties as "very high," with no major changes being recorded over time.

3.11 | Peer relationships

Parental scores for one of the children (Rose) who received additional visual supports indicated much-improved peer relationships, while only Shane's parent reported worsening of peer problems for their child, although the score was still less than the UK average. Parental scores relating to peer problems of the children who did not require additional vision support improved for Billy and Timothy and worsened for Conall.

Teacher scores indicated that four of the children who required visual modifications had few problems with their peers prior to the assessment; no score was available for Alan. Following vision adjustments, a positive change in peer relations was recorded for Luke, while small deteriorations in peer relations were reported for Shane and Alan, although the scores were still below the UK norms for both children. Teacher scores indicated that Luke had decreased peer problems, while Shane and Alan had increased problems with peers; data were missing for Conall.

3.12 | Prosocial (kind and helpful) behaviour

For three of the children who received additional vision supports, social behaviour scores increased at home, and for Luke, they improved at home and at school. A small deterioration was recorded for Shane. The prosocial behaviour of children who did not need further modifications to meet their visual needs stayed the same or improved slightly, with the exception of Billy at home, where his prosocial behaviour worsened, although his school score remained at zero.

3.13 | Impact

The total impact score for children who required vision adjustments improved by an average of 0.08 points. For two of these children,

the score improved at home, and for three of the children, the impact scores improved at school, particularly for Luke. For the children who did not require additional modifications to support their vision, the total impact score worsened by an average of 0.33 points. This was particularly true at home, where the impact score deteriorated for all of these children, while at school, the scores worsened for Conall as well.

3.14 | Academic attainment

Academic attainment was measured by comparing chronological age to test/attainment age and noting the deficit in years. Table 6 shows all available academic attainment data retrieved from school files across 1–4 school years. The test age was lower than the chronological ages for all of the children in all of the tests, although data in the files were patchy and no academic scores were included in any of the files for Luke, Billy or Shane.

For Áine, data were available for only 1 year and only for maths (deficit of 3.34 years); therefore, progress could not be assessed. For Ciara, data were available for two nonconsecutive years for maths and showed an increase in deficit years, meaning that her math skills regressed despite 3 years of schooling. For Rose, there was only one set of data for spelling, but for maths, her test age improved more than a year for 1 year of schooling, from a deficit of 4.41 years to a deficit of 3.25 years. For Alan, data were available for two consecutive academic years and showed significant regression in spelling, an additional year deficit (from a deficit of 1.58 years to a deficit of 2.58 years) as well as a year and a half additional deficit in maths (from 4.75 years to 6.33 years) despite the fact that he was prescribed new spectacles for the first time.

Timothy was the only child for whom the full 4-year data set was available for spelling as well as math attainments. No new vision adjustments had been recommended for Timothy. Overall, his recorded results showed a lack of consistency; in the years of the study, his academic attainment scores for spelling worsened significantly, from 1.92 to 3.26 deficit years for the time span of the study, while his maths scores had suffered significantly in the year previous to the study (an increase in deficit years from 1.50 to 3.34 years) but improved slightly (to 3.09 deficit years) in the years of the study. For Conall, who required no additional visual adjustments, data were available only for 1 year for spelling, while his maths attainment scores improved dramatically during the years of the study, albeit from a very low starting point (from 7.42 to 4.84 deficit years).

4 | DISCUSSION

Unrecognised visual needs can impact negatively on a child's development, cognitive and motor functions as well as physical wellbeing, social interaction and academic attainment (Dudovitz et al., 2016; Morale et al., 2012; Roe, 2012; Salt & Sargent, 2014). It is, of course, important to meet visual needs for all children but it can be particularly difficult to achieve for children who have additional identified special educational needs. Nine case studies were carried out to gain a detailed picture of the effects of whole-school vision and ocular health assessments and bespoke recommendations for visual adjustments (cf., SEE Project; Black et al., 2019). Data included repeated direct classroom observations, parent and teacher reports, and academic scores. Six of the case study children required visual adjustments, such as new spectacle correction or specific seating arrangements in class, while the visual needs of three of the children had been met prior to the vision assessment, and therefore, these children did not require additional visual adjustments.

This study was conducted in the "real world," where research required flexibility and methodologies need to be tailored to the realities of often complex contexts (Robson & McCartan, 2016). The SEE Project included only two classroom observations for each child (Black et al., 2019). Clearly, a one-probe baseline observation does not constitute a stable baseline and a once off post-intervention observation does not allow for individual conclusions about long-term effects on a single child. However, in the context of the whole-school SEE Project (n = 200 children; Black et al., 2019), brief probes yielded statistically significant results, that is statistical analysis revealed that the vision intervention had an overall effect on this large group of children of significantly decreasing off-task behaviours and improving (all be it not statistically significant) one-task and social communication behaviours.

With regard to the nine case study children reported here, the SEE Project methodology was adjusted to include repeated observations (a total of eight observations per child) and an extended observation period (over 28 weeks) and thus to allow for a more in-depth analysis of long-term behaviour patterns. For Luke, Shane and Alan, who were identified as needing spectacles to meet their vision needs, it became apparent that they needed behavioural supports to comply with their new prescription. Luke needed little encouragement. He wore his new spectacles consistently in school and parents reported that he also wore them at home. In contrast, Shane, however, who had fine and gross motor coordination difficulties, required staff or peer support to put on his spectacles. The observations revealed that there were times when his spectacles remained in his school bag or they fell off his nose and no one helped him put them back on. Shane's case is unlikely to be an exception, and therefore, findings reported here should alert teaching and support staff as well as children's peers to pay attention and help a child like Shane. Alan's case was different. He did not wear his spectacles at all. He would require bespoke positive behaviour interventions to ensure he wears his spectacles and thereby access better learning opportunities (Cooper, Heron, & Heward, 2007).

Furthermore, direct observations revealed that visual adjustments led to improvements on a number of levels. One of the key improvements was the frequency with which the children initiated interactions with peers and teachers. For example, Shane, who had no vocal speech, increasingly attracted the attention of his peers through physical contact, such as holding their hands. In

TABLE 2 Frequency of initiating engagement with peer/teacher

Name	Obs.1*	Obs.2	Obs.3	Obs.4	Obs.5	Obs.6	Obs.7	Obs.8	Average Obs.2–8
Luke	6	0	0	1	0	0	0	0	0
Áine	2	4	7	3	6	5	4	2	4.4
Ciara	1	0	3	10	4	1	6	3	3.8
Shane	3	1	4	2	2	2	11	2	3.4
Rose	2	3	4	7	2	5	4	3	4.0
Alan	1	7	0	5	2	6	8	0	4.0
Average	2.5								3.3
Billy	0	4	1	0	0	0	1	1	1.0
Timothy	9	13	13	5	8	5	5	5	7.7
Conall	3	9	4	4	2	8	1	0	4.0
Average	4.0								4.2

*Obs.1 = baseline observation; Obs.2–8 = post-intervention observations.

TABLE 3 Frequency of off-task behaviour

Name	Obs.1*	Obs.2	Obs.3	Obs.4	Obs.5	Obs.6	Obs.7	Obs.8	Average Obs.2–8
Luke	0	2	0	0	0	0	2	2	1.0
Áine	3	0	2	2	5	0	0	2	1.8
Ciara	1	0	1	1	1	0	1	1	0.8
Shane	0	3	0	0	0	0	0	0	0.5
Rose	0	0	0	2	0	0	0	0	0.3
Alan	4	2	0	0	2	4	1	1	1.6
Average	1.3								0.9
Billy	3	0	5	3	0	0	1	0	1.5
Timothy	4	3	7	6	7	6	5	3	5.3
Conall	2	0	2	2	8	0	5	0	2.4
Average	3.0								3.0

*Obs.1 = baseline observation; Obs.2–8 = post-intervention observations.

turn, his peers responded appropriately to conversations with him, by smiling and making eye contact. Luke, who also had communication difficulties and generally engaged in solitary play, initiated engagement with peers most frequently during a short period of structured play supported by a classroom assistant. On one occasion, this was particularly pertinent as it followed a dispute with a peer.

The children who did not require additional visual supports showed a brief increase in terms of initiating communication and interactions after the vision assessment; however, this did not last and decreased again to levels similar to baseline. Conall engaged with another pupil, who was seated next to him in a separate working zone; both children were supported by a classroom assistant. Billy's engagement with peers and staff showed a small improvement after visual screening but remained very low. Timothy was able to engage confidently with his peers although the rate of initiation reduced somewhat after the visual assessment.

The frequency of off-task behaviours decreased notably for the children who received visual adjustments, consistent with the findings of the larger SEE Project group (n = 200) that reported statistically significant decreases in off-task behaviour when the children's vision needs had been met (Black et al., 2019). These findings are consistent with research for typically developing children, that showed the effects of in-school provision of corrective spectacles to be positive, in particular with regard to improved attention, on-task behaviour and compliance in academic tasks (Dudovitz et al., 2016).

For the children who did not require additional adjustments, off-task behaviour briefly reduced after the assessment, only to increase again to baseline levels. In fact, off-task behaviour increased markedly for two pupils who had not received a visual intervention, for example, when Conall was presented with a difficult task, he was argumentative and off-task behaviour occurred frequently. As such, the increased attention each child received due to the visual assessment appeared to have had a short-lived positive effect on their communication and off-task behaviours, while the fact that nothing changed for these three children after the assessment meant that their behaviour returned to baseline levels.

TABLE 4 Frequency of positive teacher comments

Name	Obs.1*	Obs.2	Obs.3	Obs.4	Obs.5	Obs.6	Obs.7	Obs.8	Average Obs.2–8
Luke	2	8	13	9	9	11	5	2	8.1
Áine	0	0	2	1	0	3	0	0	0.9
Ciara	2	0	6	0	0	0	0	0	0.9
Shane	0	0	0	1	0	0	0	0	0.1
Rose	1	1	0	0	0	0	1	0	0.3
Alan	3	2	1	4	0	7	1	7	3.1
Average	1.3								2.2
Billy	0	4	6	3	9	11	7	7	6.7
Timothy	0	0	1	0	0	4	0	1	0.9
Conall	3	1	2	0	2	5	5	2	2.4
Average	1.0								3.3

*Obs.1 = baseline observation; Obs.2–8 = post-intervention observations.

TABLE 5 Frequency of repetitive behaviours

Name	Obs.1*	Obs.2	Obs.3	Obs.4	Obs.5	Obs.6	Obs.7	Obs.8	Average Obs.2–8
Luke	0	0	0	0	0	0	2	0	0.3
Áine	0	10	0	0	0	0	0	0	1.4
Ciara	2	0	8	9	9	10	10	10	8.0
Shane	2	2	0	3	0	0	0	0	0.7
Rose	0	0	0	0	0	0	0	0	0
Alan	0	0	2	5	2	0	3	0	1.7
Average	0.7								2.0
Billy	0	0	8	0	0	0	0	2	1.4
Timothy	0	0	0	0	0	0	0	0	0
Conall	0	0	0	0	0	0	0	0	0
Average	0								0.5

Note: Subsequent to completion of the observations, it was revealed that both Áine and Ciara had neurological conditions, that resulted in repetitive movements at times.

*Obs.1 = baseline observation; Obs.2–8 = post-intervention observations.

TABLE 6 Academic attainment scores

			Spelling		Maths	
Name	School year	Chronological age in years	Test age in years	Deficit years	Test age in years	Deficit years
Áine	2017/2018	9.67	–	–	6.33	3.34
Ciara	2015/2016	8.00	–	–	5.08	2.92
	2017/2018	10.08	–	–	7.08	3.00
Rose	2017/2018	10.33	–	–	5.92	4.41
	2018/2019	11.33	7.50	3.83	8.08	3.25
Alan	2017/2018	11.57	10.00	1.58	6.92	4.75
	2018/2019	12.58	10.00	2.58	6.25	6.33
Timothy	2015/2016	8.17	6.83	1.34	6.58	1.59
	2016/2017	8.83	6.50	2.33	7.33	1.50
	2017/2018	9.92	8.00	1.92	6.58	3.34
	2018/2019	10.92	7.66	3.26	7.83	3.09
Conall	2017/2018	11.42	–	–	4.00	7.42
	2018/2019	12.42	5.33	7.09	7.58	4.84

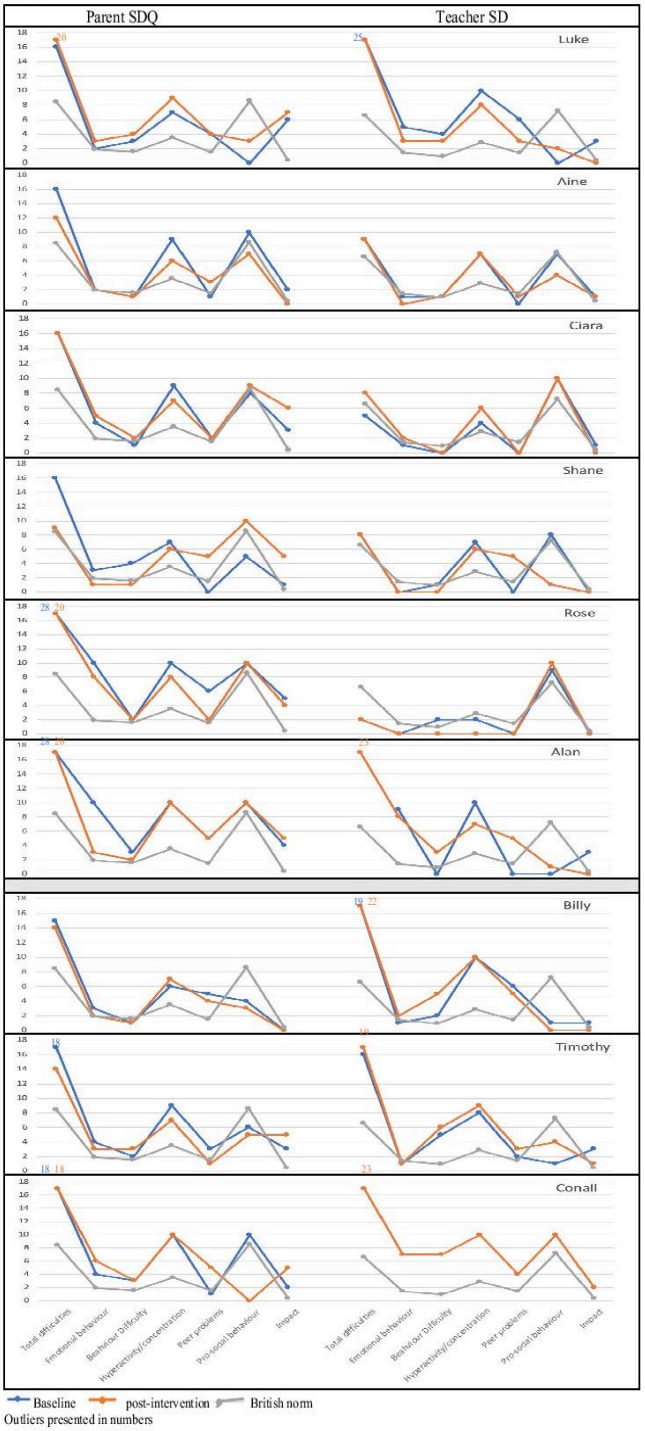

FIGURE 1 Parent and teacher SDQ scores for each child pre- and post-assessment of visual needs, compared to British norm data [Colour figure can be viewed at wileyonlinelibrary.com]

The average frequency of positive comments from teaching staff increased over time. The reason for this remains unclear; however, it is feasibly explained by the fact that, unlike the children, teaching staff were aware of reasons for the observer's presence. Therefore, these findings may reflect a Hawthorne effect with regard to the teachers (McCambridge, Witton, & Elbourne, 2014). However, the spread of positive teacher comments was very inconsistent. Some children received high levels of teacher comments, while others received very little positive feedback from teachers. For example, Luke, Alan and Billy received intensive one-to-one support from teaching assistants during tabletop activities. This obviously increased the potential for staff/pupil interaction and for positive feedback, especially when compared to pupils who mainly worked independently, such as Rose and Ciara who were expected to work independently, for example using set texts. Their on-task observations indicated that they were working consistently receiving very few prompts or comments from teachers, in part explainable by teaching methodologies that focus on independent learning skills.

With regard to overall behaviour difficulties, SDQ results reported here confirm that children with intellectual disabilities are more likely than other children to have elevated SDQ scores (Hysing, Elgen, Gillberg, Atle Lie, & Lundervold, 2007; Kaptein, Jansen, Vogels, & Reijneveld, 2008). Obviously, the small number of case study children did not merit statistical analysis; however, findings indicated that meeting the visual needs had a small positive effect in terms of the children's overall strengths and difficulties. Of course, it is possible that parent and teacher perception of the children was influenced by the mere fact that the children had undergone a vision assessment and they had received a comprehensive and accessible report and feedback. This interpretation is supported by the fact that parents and teachers reported that they found the assessment and report useful.

With regard to the academic scores, clearly, the educational profile of the case study children was heterogeneous and was largely due to the range and severity of their learning disability and their level of functioning and academic testing policies and practices with regard to younger children or those with more severe learning disabilities. Consequently, the range of tests used, abilities assessed and frequency of assessment rendered a full assessment of the impact of the intervention on academic scores impossible. For example, for Rose's spelling data were only available for 1 year, while her annual maths scores showed improvements of more than a year for 1 year of schooling. It is possible that her spelling had also improved and that her vision adjustment (i.e., to reduce crowding, change seating position; see Table 1) played a part in this progress. Alan significantly regressed in terms of his spelling scores, which evidenced the importance of not only capturing these data, but also keeping a close eye on them over the years. Alan was prescribed new spectacles for the first time, but his relatively poor academic scores may not be surprising, because Alan did not wear his spectacles at all during the study, despite the fact that they were placed on his desk. Future research should focus on the consistency in academic measures used as well as behavioural interventions to support the utilisation of visual supports, such as spectacles.

5 | CONCLUSION

For children with identified special educational needs, vision problems are often overlooked (Little & Saunders, 2015; Woodhouse et al., 2014). It is well recognised that visual deficits can act as barriers to learning (Salt & Sargent, 2014) and social inclusion (Roe, 2012); in fact, children with vision deficits are frequently misdiagnosed as having learning difficulties (Salleh & Ali, 2010).

Findings reported here support the drive to combat health and educational inequalities through in-school vision testing (Black et al., 2019). They show that bespoke visual adjustments are beneficial and can lead to improvements in behaviours, particularly in terms of initiation of peer-engagement, reduction in off-task behaviours and reduction of overall behavioural difficulties.

However, this paper also illustrates the complexity of what at first may seem like a fairly straightforward objective. Establishing a correlation between vision assessment and meeting previously unmet visual needs and child behaviour and academic achievements is a complex task that requires collaboration between the vision and the behaviour analysis research teams, parents and teachers. As evidenced in cases where spectacles were prescribed for the first time, effective visual supports depended not only on identifying need correctly, but also on the behavioural support provided to ensure that recommendations were carried out, both in school and at home. In sum, findings reported here show what can be achieved when parents and teachers work together with eye care and behaviour analysis teams to meet the visual needs and thereby enhance learning opportunities of children with identified special educational needs.

DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions from Prof Karola Dillenburger, Centre for Behaviour Analysis, Queens University Belfast.

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Appendix 5: Ulster University Research Ethics Committee approval letters

Ulster University

Memo

To: Professor K Saunders, G151, School of Biomedical Sciences, Coleraine

From: Elaine McCormick, Research Governance, 1H12, Jordanstown

Date: 17 December 2015 **Ref: EM/JD**

Ulster University
Research Ethics Committee

Project Number: REC/15/0125

Project Title: The Special Education Eyecare (SEE) project: Exploring the Impact on Visual Health of In-School Vision Care for Children in Special Education

Outcome: Approved to proceed subject to amendment – to be reviewed by the Research Office and lead reviewer

Please find attached the comments of the Research Ethics Committee on your recent application.

You should address these comments point by point in a covering letter and highlight or underline any revisions made to the application and associated materials. Please send your response (either 1 copy, or by e-mail to e.mccormick@ulster.ac.uk) to the Research Governance section. You should note that your application does not require to be resubmitted for reconsideration at a future meeting, but you should also note that you cannot commence any research on human subjects until your response has been considered and a letter of approval has been issued.

If you have any queries, please contact Nick Curry or Elaine McCormick.

If you do not intend to proceed with the project or if you anticipate a significant delay in responding to the concerns of the committee, please contact the Research Governance section.

I look forward to hearing from you in the near future. Please quote the **Project Number** in all correspondence.

Thank you and best wishes.

Elaine McCormick
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Research Governance
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Our Ref: NC:GOV

25 February 2016

Professor K Saunders
Room G151
School of Biomedical Sciences
Coleraine Campus

Dear Professor Saunders

Research Ethics Committee Application Number: REC/15/0125

Study Title: The Special Education Eyecare (SEE) project: Exploring the Impact on Visual Health of In-School Vision Care for Children in Special Education

Thank you for your recent response to matters raised by the committee. This has been considered and the decision of the committee is that the research should proceed.

Please also note the additional documentation relating to research governance and indemnity matters, including the requirements placed upon you as Chief Investigator.

The committee's decision is valid for a period of three years from today's date (this means that the study should be completed by that date). If you require this period to be extended, please contact the Research Governance section.

1. **Please complete and return the Chief Investigator Statement of Compliance prior to commencing the study and keep a copy for your file.**

2. **Please retain all other documents.**

Further details of the University's policy along with guidance notes, procedures, terms of reference and forms are available at the following web address:

http://research.ulster.ac.uk/office/rofficeeg.html

If you need any further information or clarification of any points, please do not hesitate to contact me.

Yours sincerely

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ULSTER UNIVERSITY

RESEARCH GOVERNANCE

Project Reference Number: REC/15/0125

Project Title: The Special Education Eyecare (SEE) project: Exploring the Impact on Visual Health of In-School Vision Care for Children in Special Education

Statement on indemnity for staff and students conducting research on human participants

The University is indemnified, through its insurance policies (and subject to the terms and conditions of these policies), for its staff and students engaged in the pursuit of research involving human participants where the research is being conducted for and on behalf, and with the prior knowledge and consent of, the University.

However, the University is not indemnified through its insurance for non-negligent harm. Legal liability does not arise where a person suffers harm but no-one has acted negligently. The University cannot offer advance indemnities or, generally, insure against non-negligent harm, although such indemnity can be applied for in specific cases and where it is considered to be an essential element of the study.

Participants in research studies (research subjects) should be made aware in the information provided to them of the University's position.

This statement is only valid if it is on headed paper, is signed and bears the Research Governance stamp.

Nick Curry
Senior Administrative Officer
Research Governance

DATE: 25 February 2016

University of Ulster
RESEARCH GOVERNANCE UNIT

Ulster University
Shore Road
Newtownabbey
County Antrim
BT37 0QB
Northern Ireland
T: +44 (0)28 9036 6552/6518/6629
F: +44 (0)28 9036 6479
ulster.ac.uk

ULSTER UNIVERSITY **RESEARCH GOVERNANCE**

Research on human participants being conducted by staff and/or students of the University

Please find attached a letter from the University Research Ethics Committee confirming that it has considered and approved your application to undertake research involving human participants.

The University's policy requires the Research Governance section to:

- Seek confirmation that arrangements are in place for the research to begin, including arrangements to manage the study
- Ensure that the research protocol, the investigators and the environment are appropriate
- Confirm that ethical approval has been obtained before a study begins
- Ensure that good practice arrangements are maintained for the duration of the study in relation to the conduct of the study, monitoring and reporting (including the immediate reporting of adverse events)

The requirements upon the investigators are to:

- conduct the study in line with the approved protocol
- retain and maintain records, including hard copies of signed consent forms, appropriately
- provide reports as required during and at the end of the study
- report any adverse events
- seek prior approval for amendments to the protocol

In addition to complying with the University's requirements, you must also familiarise yourself with the requirements of any other organisations involved in the research as collaborators, hosts or funders.

Please do not hesitate to contact Research Governance should you require any further information.

Nick Curry
Senior Administrative Officer
Research Governance
028 9036 6629
n.curry@ulster.ac.uk

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ULSTER UNIVERSITY **RESEARCH GOVERNANCE**

Chief Investigator Statement of Compliance

To be returned following receipt of a favourable ethical opinion and/or HSC Trust permission and prior to commencement of the study

Name of CI: Professor K Saunders
Ulster Research Governance Study Ref: REC/15/0125
ORECNI Study Ref: N/A
Study title: The Special Education Eyecare (SEE) project: Exploring the Impact on Visual Health of In-School Vision Care for Children in Special Education

Collaborating HSC/NHS organization:N/A

I understand that Ulster University has agreed to act as sponsor/co-sponsor or equivalent for the above study and that this places certain obligations upon me as Chief Investigator.

These are:

- to adhere to the research ethics, governance and other appropriate policies of the University and any HSC/NHS organisation involved in the study
- to conduct the study in full compliance with the approved protocol
- to report any adverse events as required by the University and HSC/NHS procedures
- to provide interim and final reports on the progress and outcomes of the study
- to seek advance permission for any amendments or extensions to the study
- where appropriate to register the study on a publicly accessible database

I agree to the above and confirm that:

- the host HSC/NHS organisation (where applicable) is aware of and supports this study
- a favourable ethical opinion has been obtained (where applicable) and the study will commence on

  date: 01·03·2016

  and end on

  date: 28·02·2019

Signed: KSaunders Date: 29/02/2016
(Chief Investigator)

Ulster University

Memo

To: **Prof K Saunders, G151, Biomedical Sciences, CE**

From: Elaine McCormick, Research Governance, 1H12, JN

Date: 23 March 2016 **Ref:**

Dear Professor Saunders

Research Ethics Committee application number: REC/15/0125

Project Title: The Special Education Eyecare (SEE) project: Exploring the Impact on Visual Health of In-School Vision Care for Children in Special Education

Amendment Number: 1

Following submission of Amendment Number 1 for ethical approval, the Research Ethics Committee is pleased to confirm that the amendment should proceed.

The period for which the committee's decision is valid remains unchanged from the original approval.

If you need any further information please do not hesitate to contact me.

Thanks and best wishes.

Elaine McCormick
Admin Officer
Research Governance Section
Ext. 66518
e.mccormick@ulster.ac.uk

Ulster University

Memo

To: Prof K Saunders, G151, Biomedical Sciences, CE

From: Elaine McCormick, Research Governance, 26A17, JN

Date: 04 August 2016 **Ref:**

Dear Professor Saunders

Research Ethics Committee application number: REC/15/0125

Project Title: The Special Education Eyecare (SEE) project: Exploring the Impact on Visual Health of In-School Vision Care for Children in Special Education

Amendment Number: 2

Following submission of Amendment Number 2 for ethical approval, the Research Ethics Committee is pleased to confirm that the amendment should proceed.

The period for which the committee's decision is valid remains unchanged from the original approval.

If you need any further information please do not hesitate to contact me.

Thanks and best wishes.

Elaine McCormick
Admin Officer
Research Governance Section
Ext. 66518
e.mccormick@ulster.ac.uk

Ulster University

Memo

To: Prof K Saunders, G151, Biomedical Sciences, CE

From: Elaine McCormick, Research Governance, 26A17, JN

Date: 18 August 2016 **Ref:**

Dear Prof Saunders

Research Ethics Committee application number: REC/15/0125

Project Title: The Special Education Eyecare (SEE) project: Exploring the Impact on Visual Health of In-School Vision Care for Children in Special Education

Amendment Number: 3

Following submission of Amendment Number 3 for ethical approval, the Research Ethics Committee is pleased to confirm that the amendment should proceed.

The period for which the committee's decision is valid remains unchanged from the original approval.

If you need any further information please do not hesitate to contact me.

Thanks and best wishes.

Elaine McCormick
Admin Officer
Research Governance Section
Ext. 66518
e.mccormick@ulster.ac.uk

Ulster University

Memo

To: **Prof K Saunders, G151, Biomedical Sciences, CE**

From: Elaine McCormick, Research Governance, 26A17, JN

Date: 15 September 2016 **Ref:**

Dear Professor Saunders

Research Ethics Committee application number: REC/15/0125

Project Title: The Special Education Eyecare (SEE) project: Exploring the Impact on Visual Health of In-School Vision Care for Children in Special Education

Amendment Number: 4

Following submission of Amendment Number 4 for ethical approval, the Research Ethics Committee is pleased to confirm that the amendment should proceed.

The period for which the committee's decision is valid remains unchanged from the original approval.

If you need any further information please do not hesitate to contact me.

Thanks and best wishes.

Elaine McCormick
Admin Officer
Research Governance Section
Ext. 66518
e.mccormick@ulster.ac.uk

Ulster University

Memo

To: **Prof K Saunders, G151, Biomedical Sciences, CE**

From: Elaine Bell, Research Governance, 26A17, JN

Date: 15 May 2017 **Ref:**

Dear Professor Saunders

Research Ethics Committee application number: REC/15/0125

Project Title: The Special Education Eyecare (SEE) project: Exploring the Impact on Visual Health of In-School Vision Care for Children in Special Education

Amendment Number: 5

Following submission of Amendment Number 5 for ethical approval, the Research Ethics Committee is pleased to confirm that the amendment should proceed.

The period for which the committee's decision is valid remains unchanged from the original approval.

If you need any further information please do not hesitate to contact me.

Thanks and best wishes.

Elaine Bell
Admin Officer
Research Governance Section
Ext. 66518
e.mccormick@ulster.ac.uk

Ulster University

Memo

To: Prof K Saunders, G151, Biomedical Sciences, CE

From: Elaine Bell, Research Governance, 26A17, JN

Date: 20 September 2017 **Ref:**

Dear Professor Saunders

Research Ethics Committee application number: REC/15/0125

Project Title: The Special Education Eyecare (SEE) project: Exploring the Impact on Visual Health of In-School Vision Care for Children in Special Education

Amendment Number: 6

Following submission of Amendment Number 6 for ethical approval, the Research Ethics Committee is pleased to confirm that the amendment should proceed.

The period for which the committee's decision is valid remains unchanged from the original approval.

If you need any further information please do not hesitate to contact me.

Thanks and best wishes.

Elaine Bell
Admin Officer
Research Governance Section
Ext. 66518
e.bell2@ulster.ac.uk

Appendix 6: School permission form

The Special Education Eyecare (SEE) Project

School Permission form

Name of Researchers: Shelley Black, Emma McConnell, Lynne McKerr, Karola Dillenburger Kathryn Saunders, Julie McClelland and Julie-Anne Little.

Name of school	
Address	
County / LEA	
Postcode	
Telephone number	
Email address	
Website	
Name of Head Teacher	
Name(s) of school nurse(s)	

Please confirm, by marking the boxes, that you agree with the following statements:

- I confirm that I have been given and have read and understood the research procedures for the study and have asked and received answers to any questions raised. •
- The school premises are permitted to be used for the examination of the children who are involved in the study both at the initial visit and follow-up. •
- The researchers are granted permission to have contact with the students involved in the study, and their teachers, on the school premises. •

Date: ……..

Signature……

Position……

Please return via the envelope provided

Appendix 7: Information packs distributed to parents and young adults

The Special Education Eyecare (SEE) Project

Parent/Guardian Information Leaflet

What are we doing?

We are inviting your child to take part in a research study as he/she attends a school which provides Special Education. We are interested in finding out more about vision and visual health of children attending special education schools and how their vision interacts with classroom activities. Before you decide if your child can take part, it is important that you understand what the research is for and what your child will be asked to do. Please read the information sheet and do not hesitate to contact us to ask any questions about anything that might not be clear to you.

How may this research benefit your child?

This research may benefit your child directly as we will be examining your child's eye health and we can provide information on their vision and eye health for you and anyone else involved in the care of your child. If we find that there is something that needs to be done as a result of our examination, we can put actions in place to make sure this happens, e.g. providing glasses if needed. Our research will also help other children by providing them with eye health checks and our study will raise awareness about the importance of eye health checks for children amongst children, teachers and parents.

Thank you for taking the time to consider this invitation.

Background

A 2015 report from the charity SeeAbility estimates that within the general UK population, children with learning difficulties are 28 times more likely to have serious sight problems than other children and many children in special education have never had a full eye examination.
The aim of study is to find out more about vision and visual health of children in special education, how vision affects classroom activities and whether children in special education benefit from having their eyes tested in the familiar and convenient environment of their school.

Who are we?

Shelley Black: Shelley is a qualified optometrist and PhD student who has practiced within the community for the last eight years. She has also worked alongside the Kwale District Eye centre in Kenya testing the eyes of children with special needs in their school.

Emma McConnell: Emma is an optometrist and research associate for this project. She has experience examining children both with and without special educational needs in community practice. She also has experience examining patients with visual impairment in a research setting.

Dr Lynne McKerr: Lynne is a researcher in the Centre for Behaviour Analysis at Queen's University. Trained as an anthropologist, she is also a qualified teacher who has worked with children with special needs and is the parent of a young adult with autism.

Dr Pamela Anketell: Pamela is an orthoptist based in Health and Social Care services. Pamela works with a range of children including those with and without special educational needs.

Prof. Karola Dillenburger: Karola is Professor of Behaviour Analysis and Education and Director of the Centre for Behaviour Analysis at QUB. She is a Clinical Psychology (HCPC) and Board Certified Behaviour Analyst-Doctoral (BCBA-D). She co-ordinates the MSc Autism Spectrum Disorders. Her research focusses on behavioural parent training and evidence-based interventions for people with autism and their families.

Associate Prof. A Jonathan Jackson: Jonathan is currently Head of Optometry at the Royal Victoria Hospital Belfast (BHSCT) and Chairs the Northern Ireland Translational Research Group (Vision). His research interests include Low Vision, Paediatric Visual Impairment and Contact Lenses. He is passionate about interagency multi-professional clinics research.

Dr Julie-Anne Little: Julie-Anne is an optometrist and senior lecturer at University. She has several years' experience providing vision care for children with and without special needs, including children with Down syndrome, autism spectrum disorder, and complex neurological disorders. She is keen to promote multidisciplinary working and communication through her research and clinical work.

Dr. Julie McClelland: Julie is an optometrist and lecturer at Ulster University. She is highly experienced in examining children both with and without complex neurological needs. Her previous studies have involved her working with children who have cerebral palsy, albinism and reading difficulties.

Prof. Kathryn Saunders: Kathryn is an optometrist and is the chief investigator of this project. She has many years experience providing vision care for children with and without special needs, including children with Down syndrome, cerebral palsy, complications of extreme premature birth and complex neurological disorders. She runs a paediatric and special needs clinic at Ulster University.

What is involved?

Before we carry out any tests we will contact you soon after we receive your consent form to complete a Strengths and Difficulties questionnaire (SDQ) relating to your child. This should only take 5-10 minutes of your time. 4-6 weeks later we will contact you again (either by post or telephone) to repeat the SDQ and ask a number of questions to help us better understand your child's vision and behaviour e.g. do they bump into objects when they walk, have a history of tripping over things, are they easily distracted.

Then we will test your child's eyes in school during the school day. **We have special eye tests for children who can't read, talk, point or who have very limited attention. Even if a child can't do all the tests, we still want them to take part, and we will make sure they don't feel they have 'failed' the tests.** In addition, we will spend time with your child to see how they use their eyes and participate in the classroom.

Afterwards we will provide you with a written report describing our findings. We hope this will give you a better idea of how your child can see, what you can do to make the most of their vision and whether any further action is recommended e.g. information about vision problems included in the Statement of Educational Need. If you agree, we will also give a copy to other people involved in your child's care e.g. teacher, doctor, ophthalmologist etc. This report can be used to make sure that any visual problems your child has are taken into consideration by teachers and any therapists they see. Two to five months after we first test your child we will contact you again to repeat the SDQ a final time and then repeat our tests on your child to see if any of the measurements have changed.

We want to test at least 159 children's eyes across a range of ages and abilities.

This study has received ethical approval from the University of Ulster Research Ethics Committee.

It is up to you to decide whether or not to allow your child to take part. If you allow your child to take part, you will be given this information sheet to keep and be asked to sign a consent form. A simplified information sheet will also be provided which you can read with or to your child. If you decide your child may take part, you are still free to withdraw at any time and without giving a reason and without their rights being affected in any way.

What does the Eye Examination involve?

- We will assess how much your child can see. For some children this only involves the child looking at pictures while we observe their eye movements. Other children may match or name pictures or letters. We will try and measure what your child can see with both eyes open and what they see with each eye alone (using a patch or special glasses to cover one eye at a time).

- Eye movement testing will involve identifying if the eyes squint or turn in and how the eyes move in each direction. This involves your child looking at toys, pictures or a light for a short period of time.
- Where possible and appropriate your child's 3D depth perception will be tested using a simple 3D task that doesn't require any special glasses.
- We will also test, if appropriate, your child's ability to arrange simple 3D shapes to a given pattern.
- Your child's need for glasses will be measured. This will require drops being put into the eyes as this is the best, most accurate way of assessing the need for glasses in children. These drops are used routinely by eye care professionals to test children's eyes. The drops take 30 minutes to work. After 30 minutes we will shine a light into the eye to find out if there is a significant need for glasses.
- Finally, the health of your child's eyes will be examined by shining a light into the eyes for a short period of time. We will also take a photograph of the back of the eye.

N.B. If any previously unidentified eye anomaly is detected during the test process we will discuss the finding with you including advice on further management. If required, we may arrange a referral letter to the appropriate eye care professional with your permission.

Side Effects of Eye Drops

After having drops put in the eyes, most people find their vision is blurry when looking at things close to them. This lasts about 3-4 hours. The drops make the pupil of the eye larger and this means that bright lights can be uncomfortable for up to 24 hours. Children do not normally complain but they may be uncomfortable in bright sunlight.

Very rarely people experience facial flushing, dry mouth, increased heart rate and confusion after having these drops put in their eyes. These rare side effects only last a short time. We will monitor closely for any signs of side effects.

If your child has had a reaction to eye drops before, please let us know.

We have successfully used these drops in many previous studies in over a thousand children in mainstream and special education settings.

Ulster University Procedures

It is extremely unlikely that something will go wrong if your child takes part in the study. However, the University of Ulster has procedures in place for reporting, investigating, recording and handling adverse events and complaints from study volunteers. The University is insured for its staff and students to carry out research involving people. The University knows about this research project and has approved it. Any complaints will be taken seriously and should be made in the first instance to the Chief investigator, Professor Kathryn Saunders.
This study forms part of a postgraduate research fellowship funded by the Department for Employment and Learning.

Photos/Video

We would like to take photographs/videos of the children involved in the project to create an educational video/document about the SEE project. The video will be used to show other academics, teachers, parents and other children in special education what in-school eye testing involves. This video may be put on the University or school website. If you do not wish your child to be photographed/videoed please note this on the consent form.

What now?

If you consent to your child being involved in the study, please complete and return the enclosed consent form in to the school office and we will contact you regarding a time for your child's appointment.

If you would like more information regarding this study or have any concerns, please contact us:
Shelley Black: black-s19@email.ulster.ac.uk, 028 7012 3718, 07399783696
Emma McConnell: e.mcconnell@ulster.ac.uk, 028 7012 3650
Professor Kathryn Saunders: kj.saunders@ulster.ac.uk, 028 7012 3047
Dr Julie McClelland: jf.mclelland@ulster.ac.uk

Thank you for taking the time to consider this study.

Right at the end, two last things to do,

Shine a light in your eyes and take a photo, or two.

Then that is all and we'll write to your mum,

To tell her about all the things we have done

If you want us to look at your eyes

tick YES, YES I do,
If not, then say NO and that's ok too

✔Yes or ✗ No

Thank you for listening,

We hope our poem was cool,

And if you ticked 'YES' then we'll see you at school!

Ulster University

The SEE Project

Queen's University Belfast

The Special Education Eyecare (SEE) Project

Child Information Leaflet

Hi our names are Shelley and Emma, how do you do?

We're going to tell you what an Optometrist can do,

We look at your eyes and check what you see,

We want your eyes to be as good as they can be.

We'll chat to your mum and ask a question or two,

And find out what yours eyes can do.

We are coming to school to see the girls and boys,

We'll be checking their eyes with our lights and fun toys!!

Everyone gets funny glasses to wear,

They're light like a feather - you'll not know they're there.

We will look at your eyes as they follow our light,

So we know that you can look left and look right,

We will put in some drops that may sting a bit,

Then we'll sing a quick song, and you'll no longer feel it.

When the drops are all in you can have a rest,

For being so brave and for doing your best,

Then after the rest we'll do some more checks -

You can look at our light, you can wear more cool specs.

We will see if you need spectacles of your own,

To see the TV, or your mum, or her phone!

The Special Education Eyecare (SEE) Project

Young Adult Information Leaflet

Hi, our names our Shelley and Emma,

We would like to ask you to help us understand what you can see. If we can, we will try and help you see better. You do not have to take part if you do not want to. You can say Yes or No.

✓ Yes or ✗ No

For your eye check, we will ask you to look at letters or pictures

Sloan Letters Chart - 735000

LEA Symbols Chart - 250200

We will also get you to put on some glasses while you look at the letters and pictures.

We will get you to look at some 3D pictures and watch how your eyes move together.

We will check your eyes to see if they are healthy by shining a small light in your eyes.

For the last test we will need to put some drops in your eyes. The drops sting a little but this stops after a few seconds. The drops take 30 minutes to work while you have a break. The drops will make reading blurred.

When your break is finished we will shine a light in your eyes while you wear some glasses with changeable lenses in them to see if you need glasses of your own.

If we find that you need any extra help with your eyes we will tell you after your eyes have been checked. We will give your teacher, parent/guardian and doctors a written copy of the results of your eye check for their records.

We will come back within a few months to check your eyes again to see how you are getting on.

We would also like to take a photo or a video of some pupils having their eyes checked so that we can show other young people what it is like to have their eyes tested. Would this be ok?

As well as checking your eyes, we would like to speak to your parent/guardian, your teacher/ classroom assistant and your vision support worker (if you have one) about how well they think you can see. We will also ask your teacher to show me your classroom notes.

Thank you for looking at this information. If you would like us to test your eyes, or have any questions, please contact us by email or telephone.

Thank you,

Shelley and Emma

Emma McConnell: e.mcconnell@ulster.ac.uk, 028 7012 3650

Shelley Black: black-s19@email.ulster.ac.uk, 028 7012371

The Special Education Eyecare (SEE) Project

Parent/Guardian Consent Form

Name of Researchers: Shelley Black, Emma McConnell, Lynne McKerr, Kathryn Saunders, Julie McClelland, Julie-Anne Little and Karola Dillenburger.

Parent/guardian name

Child's name

Date of Birth

Relationship to child

Child's class at school

Contact details	**Preferred contact?**
Landline _____	☐
Mobile _____	☐
Email _____	☐
Home Address	☐

Please confirm, **by marking the boxes**, that you agree with the following statements:

- I agree for my child to take part in the above study. ☐
- I understand that my child's participation is voluntary and that they are free to withdraw at any time without giving a reason and without their rights being affected in any way. ☐
- I understand that if my child does not take part in this research, this will not affect their routine eyecare. ☐
- I understand that the researchers will hold all information and data will be collected securely and in confidence and that all efforts will be made to ensure that my child cannot be identified as a participant in the study (except as might be required by law) and I give my permission for the researchers to hold relevant personal data. ☐
- I consent for the researchers to access my child's Statement of Educational Need and teacher's classroom notes. ☐
- I consent to completing a number of questionnaires regarding my child's vision and behaviour before and after the eye tests (e.g. Strengths and Difficulties Questionnaire) ☐
- I consent for the researchers for to speak to the teacher/ classroom assistant about my child. ☐
- I consent to in-classroom observation of my child's participation and learning. ☐
- I consent for the researchers to speak the vision support worker about my child. ☐
- I consent that my child's image can be recorded on a photograph/ video and can be used in accordance with the conditions detailed in the information sheet. ☐
- I consent for my child to receive follow-up advice or treatment as necessary due to any abnormalities detected during the study. ☐
- I give consent for a letter of information to be written to my child's GP or other health care professional involved in the care of my child to inform them of the findings of my child's eye examination. ☐
- I confirm that I have been given and have read and understood the information sheet for the above study and have asked and received answers to any questions raised. ☐
- I consent to the research group contacting me about future studies, where appropriate. ☐

Parent/Guardian Signature_____ Date_____

Please return to the school office via the envelope provided

The Special Education Eyecare (SEE) Project

Young Adult Consent Form

Name of Researchers: Shelley Black, Emma McConnell, Lynne McKerr, Pamela Anketell, Karola Dillenburger, Julie-Anne Little, A. Jonathan Jackson, Julie McClelland, Julie McClelland and Kathryn Saunders.

Name

Date of Birth

Contact details	**Preferred contact?**
Landline----------	☐
Mobile ----------	☐
Email ----------	☐
Home Address	☐

Please confirm, by marking the boxes, that you agree with the following statements:

- I agree to take part in the above study. ☐
- I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason and without my rights being affected in any way. ☐
- I understand that if I do not take part in this research, this will not affect my routine eyecare. ☐
- I understand that the researchers will hold all information and data will be collected securely and in confidence and that all efforts will be made to ensure that I cannot be identified as a participant in the study (except as might be required by law) and I give my permission for the researchers to hold relevant personal data. ☐
- I consent for the researchers to access my Statement of Educational Need and my teacher's classroom notes. ☐
- I consent for the researchers to speak to my teacher/ classroom assistant about me. ☐
- I consent to in-classroom observation of my participation and learning. ☐
- I consent for the researchers to speak the vision support worker about me. ☐
- I consent that my image can be recorded on a photograph/ video and can be used by the researchers in educational videos and presentations. ☐
- I consent to receive follow-up advice or treatment as necessary due to any abnormalities detected during the study. ☐
- I give consent for a letter of information to be written to my GP or other health care professional involved in my care to inform them of the findings of my eye examination. ☐
- I confirm that I have been given and have read and understood the information sheet for the above study and have asked and received answers to any questions raised. ☐
- I consent to the research group contacting me about future studies, where appropriate. ☐

Signature_____

Date _____

Please return via the envelope to the school office

Appendix 8: Parent visual and medical history questionnaire

The Special Education Eyecare (SEE) Project
Questions for Parents/Guardians

Thank you for your participation in the study. Before we test your child's eyes we want to learn more about them so we can tailor the eye test to your child's needs. We have special eye tests for children who can't read, talk, point or who have very limited attention. Even if your child can't do all the tests, we still want them to take part, and we will make sure they don't feel they have 'failed' the tests.

The questions focus on five main areas:

1. Your child's current vision and any previous eye examinations they may have had
2. Your child's health and birth history
3. History of eye problems in your child's family
4. Your child's vision in relation to the world around them
5. Communicating with your child

We understand that you may not be able to, or may prefer not to, answer all the questions and that some of them may not apply to your child. Fill in the answers as best you can return to the school office or return it to Emma McConnell in the envelope provided.

If you would like more information you can contact us:

Emma McConnell: e.mcconnell@ulster.ac.uk, 028 7012 3650
Shelley Black: black-s19@email.ulster.ac.uk, 028 70123718, 07912502889
Professor Kathryn Saunders: kj.saunders@ulster.ac.uk
Dr. Julie McClelland: jf.mclelland@ulster.ac.uk
Dr. Julie-Anne Little: ja.little@ulser.ac.uk

Child's Initials: _____ Child's ID:_____

Your child's details	
Name and address of your child's GP:	
Name and address of your child's paediatrician:	

Your child's eyes	
Has your child ever had an eye test? yes ☐ ✔ no ☐ ✖ don't know ☐ ?	
Where did they last have their eyes tested?	
Date of last check:	
Date of next check:	
Does your child have any eye sight problems that you are aware of? yes ☐ ✔ no ☐ ✖ don't know ☐ ? If yes, please describe your child's vision problems as you understand them: _____ _____	
Do you have any concerns about your child's eyes? yes ☐ ✔ no ☐ ✖ don't know ☐ ? If yes, please provide details: _____ _____	
Does your child have glasses? yes ☐ ✔ no ☐ ✖ don't know ☐ ?  If yes, are they worn: Always / Sometimes / Rarely / supposed to but doesn't	

Does your child have any problems with their glasses?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, please provide details: _____

Do you ever see a turn in your child's eye?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, please provide details:

_____

Does your child tend to shut one eye?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, which eye do they shut?

_____

Does your child appear sensitive to bright lights?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

Visits to the Hospital

Has your child ever been to the eye clinic at the hospital?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, who did they see? *(Please circle)*

Ophthalmologist (eye doctor) / orthoptic clinic / hospital optometrist / low vision clinic

Please provide details:

_____

_____

_____

Which hospital did they go to?	
Date of last appointment:	
Date of next appointment:	

Does your child wear a patch on their eye or have they in the past?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, please provide details *e.g. age your child wore the patch from and to, which eye etc.*

Has your child ever had an operation or surgery on their eyes?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, why?

Does your child have a Certificate of Visual Impairment?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, are they registered:

Severely sight impaired / sight impaired / not sure

Your child's family history

Is there a history of blastoma in your family?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

Has anyone in your child's family had eye problems?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

For example wears glasses, blastoma, squint, lazy eye, patching one eye, eye condition etc?

If yes, please write who has had problems and what problems they've had:

Who	What problem
e.g. sister, mum	*Has a lazy eye and glasses*

Your child's health

Does your child use a wheelchair?

yes ☐ ✔ no ☐ ✖ sometimes ☐

Does your child have a diagnosis of any medical conditions, syndromes or disabilities?

yes ☐ ✔ no ☐ ✖

If yes, please say what they are:

Does your child take any medication?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes,

What is it called? How much do they take? What is it for?

Does your child have any allergies?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, please provide details:

Does your child complain of headaches?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

Is your child deaf or hard of hearing?

yes ☐ ✔ no ☐ ✖

If yes, please provide details:

_____

Birth history

How many weeks into pregnancy was your child born? _____

Were there any problems at the time of birth?

(i.e: mother having infection, prematurity, low birth weight, need for special care etc)

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, please provide details:

_____

_____

Your child's communication

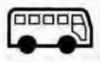
Does your child find it hard to communicate?

yes ☐ ✔ no ☐ ✖ sometimes ☐

What helps your child to communicate? Tell us if you use things like:

Makaton  yes ☐ ✔ no ☐ ✖

Yes/ no answers yes ☐ ✔ no ☐ ✖

Pictures  yes ☐ ✔ no ☐ ✖

Gestures yes ☐ ✔ no ☐ ✖

Other *(please describe how you communicate with your child):*

Your child's education and environment

Is there any information about your child's eyesight on their Statement of Educational Need?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

Does a vision support worker/ teacher visit your child while they are at school or at home?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, how often? _____

Are you concerned about your child's eyesight and how it affects their education?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, please provide details:

_____

_____

Does your child get support from any vision charities or groups e.g. Angel Eyes, RNIB?

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, please provide details:

_____

Do you modify anything at home to help your child with their vision? *E.g. moving their chair closer to the television etc.*

yes ☐ ✔ no ☐ ✖ don't know ☐ ?

If yes, please provide details:

_____

_____

Five Key Questions

We would also like you to consider the following five questions. These questions are designed for a range of ages and abilities, so some questions may not be relevant. Your child may have difficulty with some behaviours listed below but not others – this is normal. You may also notice that some of the behaviours described occur only occasionally or more frequently when your child is tired - this is common.

Tick the box which best describes your child's current behaviour and if, for example, you child uses a wheelchair and the question involving stairs is not relevant, tick "not applicable".

1. Does your child have difficulty walking down stairs?

Never	Rarely	Sometimes	Often	Always	Not applicable

2. Does your child have difficulty seeing fast-moving objects?

Never	Rarely	Sometimes	Often	Always	Not applicable

3. Does your child have difficulty seeing something that is pointed out in the distance?

Never	Rarely	Sometimes	Often	Always	Not applicable

4. Does your child have difficulty locating an item of clothing in a pile of clothes?

Never	Rarely	Sometimes	Often	Always	Not applicable

5. Does your child find copying words or pictures time-consuming and difficult?

Never	Rarely	Sometimes	Often	Always	Not applicable

Please tell us any other information we may need to know that will help us test your child's eyes *e.g. if they have had an eye test before, is there anything they found difficult or stressful?*

Appendix 9: Teacher visual history questionnaire

The Special Education Eyecare (SEE) Project

Questions for Teachers

The parent/guardian of _____ has given their consent for their child to be part of this study. We would like you to answer the questions to help us learn more about this child's eyes.

We understand that you may not be able to answer all the questions and that some of them may not apply to this child. Fill in the answers as best you can and return them to the school office or Emma McConnell directly in the envelope provided.

If you would like more information you can contact us:

Emma McConnell: e.mcconnell@ulster.ac.uk, 028 7012 3650
Shelley Black: black-s19@email.ulster.ac.uk, 028 70123718
Professor Kathryn Saunders: kj.saunders@ulster.ac.uk
Dr. Julie McClelland: jf.mclelland@ulster.ac.uk
Dr. Julie-Anne Little, ja.little@ulster.ac.uk

Questions for Teachers *(Please circle as appropriate)*

1. Does the child wear glasses? Yes / No / Not Sure

   If yes, are they worn: Always / Sometimes / Rarely / Supposed to but not

2. Is there any information about eye sight on the child's Statement of Educational Need?

   Yes / No / Not Sure

3. Does a Vision Support teacher or QTVI visit this child?

   Yes / No / Not Sure

   If yes, how often?

   _____

4. Does the child have any eye sight problems you are aware of?

   Yes / No / Not Sure

   If yes, please describe the child's eye sight problem(s) as you understand them

   _____
   _____
   _____

5. Do you know if the child has a Certificate of Visual Impairment?

   Yes they do / No they don't/ Not Sure

   If they do are they registered as: Severely Sight Impaired / Sight Impaired / Not Sure

6. Do you modify anything in the classroom to help with the child with their vision?
   E.g. desk wedge, large print reading materials, iPad etc.

   Yes / No

   If yes, please describe these adjustments

   _____
   _____
   _____

Appendix 10: Visual Skills Inventory

The SEE Project
VSI Parent/Guardian
V4 18.08.16

Visual Skills Inventory

Child's initials: _____ Child's ID: _____

This questionnaire is designed to explore a range of behaviours which may be affected by your child's vision. The questions are designed for a range of ages and abilities. **We understand that some questions may seem odd or may not be relevant to your child (e.g. they may be unable to read), but please try and give an answer for each question.** If a question does not apply to your child, then just select 'Not Applicable'.

Your child may have difficulty with some of the activities listed below but not others – this is normal!

For each of the items listed on the following pages, please tick the box which best fits with your child's current behaviour:

Never / Rarely / Sometimes / Often / Always / Not Applicable

The questionnaire should take about 10 minutes to complete. Once completed, please return to the school office via the envelope provided.

Thank you for taking the time to complete this questionnaire.

Based on a visual skills inventory developed at the Royal Hospital for Sick Children, Glasgow

The SEE Project
VSI Parent/Guardian
V4 18.08.16

Does your child...	Never	Rarely	Sometimes	Often	Always	Not Applicable
1. trip over toys and obstacles on the floor?	O	O	O	O	O	O
2. have difficulty walking down stairs?	O	O	O	O	O	O
3. trip at the edges of pavements going up?	O	O	O	O	O	O
4. trip at the edges of pavements going down?	O	O	O	O	O	O
5. appear to 'get stuck' at the top of a slide/ hill?	O	O	O	O	O	O
6. look down when crossing floor boundaries e.g. where lino meets carpet?	O	O	O	O	O	O
7. leave food on the near or far side of their plate?	O	O	O	O	O	O
If so, on which side? Near / Far						
8. leave food on the right or left side of their plate?	O	O	O	O	O	O
If so, on which side? Right / Left						
9. have difficulty finding the beginning of a line when reading?	O	O	O	O	O	O
10. have difficulty finding the next word when reading?	O	O	O	O	O	O
11. walk out in front of traffic?	O	O	O	O	O	O
If so, on which side? Right / Left / Both						
12. bump into doorframes or partly open doors?	O	O	O	O	O	O
If so, on which side do they bump? Right / Left / Both						
13. miss pictures or words on one side of a page?	O	O	O	O	O	O
If so, on which side do they miss words? Right/ Left/ Both						
14. have difficulty seeing scenery from a moving vehicle?	O	O	O	O	O	O
15. have difficulty seeing things which are moving quickly, such as small animals?	O	O	O	O	O	O
16. avoid watching fast moving TV?	O	O	O	O	O	O
17. choose to watch slow moving TV?	O	O	O	O	O	O
18. have difficulty catching a ball?	O	O	O	O	O	O

The SEE Project
VSI Parent/Guardian
V4 18.08.16

Does your child...	Never	Rarely	Sometimes	Often	Always	Not Applicable
19. have difficulty seeing something which is pointed out in the distance?	O	O	O	O	O	O
20. have difficulty finding a close friend or relative who is standing in a group?	O	O	O	O	O	O
21. have difficulty finding an item they want if there is too much visual information e.g. biscuits in the cupboard, toy in a box?	O	O	O	O	O	O
22. get lost in places where there is a lot to see, e.g. a crowded shop?	O	O	O	O	O	O
23. get lost in places which are well known to them?	O	O	O	O	O	O
24. have difficulty locating an item of clothing in a pile of clothes?	O	O	O	O	O	O
25. have difficulty selecting a chosen toy in a toy box?	O	O	O	O	O	O
26. sit closer to the television than about 30cm?	O	O	O	O	O	O
27. find copying words or drawings time-consuming and difficult?	O	O	O	O	O	O
28. hold onto your clothes, tugging down when walking?	O	O	O	O	O	O
29. find uneven ground difficult to walk over?	O	O	O	O	O	O
30. bump into low furniture such as a coffee table?	O	O	O	O	O	O
31. bump into low furniture if it is moved?	O	O	O	O	O	O
32. get angry if furniture is moved?	O	O	O	O	O	O
33. explore floor boundaries (e.g. lino/carpet) with their foot before crossing the boundary?	O	O	O	O	O	O
34. find inside floor boundaries difficult to cross?	O	O	O	O	O	O
34a. If so, boundaries that are <u>new</u> to them?	O	O	O	O	O	O
34b. boundaries that are <u>well known</u> to them?	O	O	O	O	O	O
35. reach incorrectly for objects, i.e. do they reach beyond or around the object?	O	O	O	O	O	O
36. grasp incorrectly when picking up an object, i.e. do they miss or knock the object over?	O	O	O	O	O	O

The SEE Project
VSI Parent/Guardian
V4 18.08.16

		Never	Rarely	Sometimes	Often	Always	Not Applicable
Does your child…							
37.	find it difficult to keep to task for more than 5 minutes?	O	O	O	O	O	O
38.	find it difficult to get back to what they were doing after being distracted?	O	O	O	O	O	O
39.	bump into things when walking and having a conversation?	O	O	O	O	O	O
40.	miss objects that are obvious to you because they are different from their background and seem to 'pop out' e.g. a bright ball in the grass?	O	O	O	O	O	O
41.	Do rooms with a lot of clutter cause difficult behaviour?	O	O	O	O	O	O
42.	Do quiet places/ open countryside cause difficult behaviour?	O	O	O	O	O	O
43.	Is behaviour in a busy supermarket or shopping centre difficult?	O	O	O	O	O	O
44.	Does your child react angrily when other restless children cause distraction?	O	O	O	O	O	O
Does your child…							
45.	have difficulty recognising close relatives in real life?	O	O	O	O	O	O
46.	have difficulty recognising close relatives from photographs?	O	O	O	O	O	O
47.	mistakenly identify strangers as people known to them?	O	O	O	O	O	O
48.	have difficulty understanding the meaning of facial expressions?	O	O	O	O	O	O
49.	have difficulty naming common colours?	O	O	O	O	O	O
50.	have difficulty naming basic shapes such as squares, triangles and circles?	O	O	O	O	O	O
51.	have difficulty recognising familiar objects such as the family car?	O	O	O	O	O	O
52.	have difficulty recognising objects on a similar background e.g. white t-shirt on a white sheet?	O	O	O	O	O	O
53.	have difficulty accessing the computer?	O	O	O	O	O	O

Appendix 11: Parent and teacher Strengths and Difficulties Questionnaire (SDQ)

Strengths and Difficulties Questionnaire P 4-17

For each item, please mark the box for Not True, Somewhat True or Certainly True. It would help us if you answered all items as best you can even if you are not absolutely certain or the item seems daft! Please give your answers on the basis of the child's behaviour over the last six months.

Child's Name ..... Male/Female

Date of Birth.....

	Not True	Somewhat True	Certainly True
Considerate of other people's feelings	☐	☐	☐
Restless, overactive, cannot stay still for long	☐	☐	☐
Often complains of headaches, stomach-aches or sickness	☐	☐	☐
Shares readily with other children (treats, toys, pencils etc.)	☐	☐	☐
Often has temper tantrums or hot tempers	☐	☐	☐
Rather solitary, tends to play alone	☐	☐	☐
Generally obedient, usually does what adults request	☐	☐	☐
Many worries, often seems worried	☐	☐	☐
Helpful if someone is hurt, upset or feeling ill	☐	☐	☐
Constantly fidgeting or squirming	☐	☐	☐
Has at least one good friend	☐	☐	☐
Often fights with other children or bullies them	☐	☐	☐
Often unhappy, down-hearted or tearful	☐	☐	☐
Generally liked by other children	☐	☐	☐
Easily distracted, concentration wanders	☐	☐	☐
Nervous or clingy in new situations, easily loses confidence	☐	☐	☐
Kind to younger children	☐	☐	☐
Often lies or cheats	☐	☐	☐
Picked on or bullied by other children	☐	☐	☐
Often volunteers to help others (parents, teachers, other children)	☐	☐	☐
Thinks things out before acting	☐	☐	☐
Steals from home, school or elsewhere	☐	☐	☐
Gets on better with adults than with other children	☐	☐	☐
Many fears, easily scared	☐	☐	☐
Sees tasks through to the end, good attention span	☐	☐	☐

Do you have any other comments or concerns?

Please turn over - there are a few more questions on the other side

Overall, do you think that your child has difficulties in one or more of the following areas: emotions, concentration, behaviour or being able to get on with other people?

No	Yes- minor difficulties	Yes- definite difficulties	Yes- severe difficulties
☐	☐	☐	☐

If you have answered "Yes", please answer the following questions about these difficulties:

• How long have these difficulties been present?

Less than a month	1-5 months	6-12 months	Over a year
☐	☐	☐	☐

• Do the difficulties upset or distress your child?

Not at all	Only a little	Quite a lot	A great deal
☐	☐	☐	☐

• Do the difficulties interfere with your child's everyday life in the following areas?

	Not at all	Only a little	Quite a lot	A great deal
HOME LIFE	☐	☐	☐	☐
FRIENDSHIPS	☐	☐	☐	☐
CLASSROOM LEARNING	☐	☐	☐	☐
LEISURE ACTIVITIES	☐	☐	☐	☐

• Do the difficulties put a burden on you or the family as a whole?

Not at all	Only a little	Quite a lot	A great deal
☐	☐	☐	☐

Signature ..... Date .....

Mother/Father/Other (please specify:)

Thank you very much for your help

Strengths and Difficulties Questionnaire

T 4-17

For each item, please mark the box for Not True, Somewhat True or Certainly True. It would help us if you answered all items as best you can even if you are not absolutely certain or the item seems daft! Please give your answers on the basis of the child's behaviour over the last six months or this school year.

Child's Name ..... Male/Female

Date of Birth.....

	Not True	Somewhat True	Certainly True
Considerate of other people's feelings	☐	☐	☐
Restless, overactive, cannot stay still for long	☐	☐	☐
Often complains of headaches, stomach-aches or sickness	☐	☐	☐
Shares readily with other children (treats, toys, pencils etc.)	☐	☐	☐
Often has temper tantrums or hot tempers	☐	☐	☐
Rather solitary, tends to play alone	☐	☐	☐
Generally obedient, usually does what adults request	☐	☐	☐
Many worries, often seems worried	☐	☐	☐
Helpful if someone is hurt, upset or feeling ill	☐	☐	☐
Constantly fidgeting or squirming	☐	☐	☐
Has at least one good friend	☐	☐	☐
Often fights with other children or bullies them	☐	☐	☐
Often unhappy, down-hearted or tearful	☐	☐	☐
Generally liked by other children	☐	☐	☐
Easily distracted, concentration wanders	☐	☐	☐
Nervous or clingy in new situations, easily loses confidence	☐	☐	☐
Kind to younger children	☐	☐	☐
Often lies or cheats	☐	☐	☐
Picked on or bullied by other children	☐	☐	☐
Often volunteers to help others (parents, teachers, other children)	☐	☐	☐
Thinks things out before acting	☐	☐	☐
Steals from home, school or elsewhere	☐	☐	☐
Gets on better with adults than with other children	☐	☐	☐
Many fears, easily scared	☐	☐	☐
Sees tasks through to the end, good attention span	☐	☐	☐

Do you have any other comments or concerns?

Please turn over - there are a few more questions on the other side

Overall, do you think that this child has difficulties in one or more of the following areas: emotions, concentration, behaviour or being able to get on with other people?

No	Yes- minor difficulties	Yes- definite difficulties	Yes- severe difficulties
☐	☐	☐	☐

If you have answered "Yes", please answer the following questions about these difficulties:

• How long have these difficulties been present?

Less than a month	1-5 months	6-12 months	Over a year
☐	☐	☐	☐

• Do the difficulties upset or distress the child?

Not at all	Only a little	Quite a lot	A great deal
☐	☐	☐	☐

• Do the difficulties interfere with the child's everyday life in the following areas?

	Not at all	Only a little	Quite a lot	A great deal
PEER RELATIONSHIPS	☐	☐	☐	☐
CLASSROOM LEARNING	☐	☐	☐	☐

• Do the difficulties put a burden on you or the class as a whole?

Not at all	Only a little	Quite a lot	A great deal
☐	☐	☐	☐

Signature ..... Date .....

Class Teacher/Form Tutor/Head of Year/Other (please specify:)

Thank you very much for your help

Appendix 12: Vision Report template

The SEE Project

A research study by Ulster University exploring visual health in Special Education.

Section 1 - Details of child	
Child's name	
D.O.B	
School	
Date of test	

Results of your child's research vision assessment

Thank you for allowing your child to take part in our research study. We hope the following information, gathered during the research, is useful. We have used the information you gave us about your child and the results we obtained when testing their eyes, to describe their vision.

Section 2 - Additional detail about the eye test	
Who was present at the eye test?	
What was already known about eyes and vision? Did anyone have questions about eyes and vision?	

Section 3 – Summary: The child's eyes and vision

Actions from today's test:	
Glasses needed	NO
Modifications to classroom/ schoolwork needed	NO
Statement of Educational Need should include information about vision needs	NO

Child is eligible for certification as visually impaired	NO
GP Action required	NO
Another specialist needs to see this child	NO

Section 4 – We tested to see if glasses are needed

This was tested: Yes ☒ No ☐ This was difficult to assess today ☐

We measured for **focusing accuracy**:

This was tested: Yes ☒ No ☐ This was difficult to assess today ☐

Details:.

We gave a new prescription for glasses: Yes ☐ No ☒

Section 5 – Results of the vision tests we did today
Visual acuity: describes how well a person sees black on white detail with glasses if needed.
We were able to measure visual acuity for looking at things: in the distance ☒ close up ☒ both were difficult to test today ▬
Binocular vision and eye movements: This is how well your child's eyes work together
This was tested today: Yes ▬ No ▬ This was difficult to assess today ▬ **Details:**
Visual Field: This is how well your child can see things to the side of their central vision
This was tested today: Yes ▬ No ▬ This was difficult to assess today ▬ **Details:**
Contrast Sensitivity: This is how well objects are seen against different backgrounds
This was tested today: Yes ▬ No ▬ This was difficult to assess today ▬ **Details:**
Evidence of Cerebral Visual Impairment (CVI): This is when there are visual difficulties caused by problems in the brain rather than the eyes.
This was tested today: Yes ▬ No ▬ This was difficult to assess today ▬ **Details:**

Section 6 – Results of the eye health check		
This was tested today: Yes ___ No ___ This was difficult to assess today ___ Does the child need to see another specialist about their eye health? Yes ___ No ___ **Details:**		
Section 7 – Technical details for other health professionals		
Visual Acuity	*LEA crowded LogMAR test at 3m (naming)*	**logMAR binocularly**
	LEA crowded LogMAR near test at 40cm	**logMAR binocularly**
Refractive Error	*With cycloplegia*	**R: L:**
Accommodative Function	*Dynamic retinoscopy*	**to a target of 25cm**
Ocular Posture and Eye Movement	*Ocular Motility, Cover Test*	**OM grossly full and smooth. No manifest strabismus at distance or near to target**
Contrast	*LEA low contrast 2.5% symbols*	**logMAR**
Visual Field	*Gross confrontation*	**Full**
Eye Health Exam	*Direct ophthalmoscopy*	**External eye healthy R+L; media clear R+L, healthy disc R+L; healthy fundi; normal maculae; normal BVs R+L**
Stereopsis	*Frisby*	"
Colour Vision	*CVTME*	**All plates seen, no colour vision deficit**
CVI	*LEA Postbox and rectangles; shape sorter*	
Section 8: Assessors		
Whom is this report from? Name: **Emma McConnell and Shelley Black** Role: **Optometrists** Address: **The SEE Project, Optometry Clinic, Ulster University, Cromore road, Coleraine. BT52 1SA** Who is getting a copy of this report? **Parents and School**		

Appendix 13: REC/16/0061 and REC/17/0088 Ulster University Research Ethics Committee approval letters

Ulster University
Shore Road
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County Antrim
BT37 0QB
Northern Ireland
T: +44 (0)28 9036 6552/6518/6629
ulster.ac.uk

Our Ref: NC:GOV

22 August 2016

Dr J-A Little
Room G159
School of Biomedical Sciences
Ulster University
Coleraine Campus

Dear Dr Little

Research Ethics Committee Application Number: REC/16/0061

Study Title: Focussing on near work: the impact of uncorrected hyperopic refractive errors

Thank you for your recent response to matters raised by the committee. This has been considered and the decision of the committee is that the research should proceed.

Please also note the additional documentation relating to research governance and indemnity matters, including the requirements placed upon you as Chief Investigator.

The committee's decision is valid for a period of three years from today's date (this means that the study should be completed by that date). If you require this period to be extended, please contact the Research Governance section.

1. **Please complete and return the Chief Investigator Statement of Compliance prior to commencing the study and keep a copy for your file.**

2. **Please retain all other documents.**

Further details of the University's policy along with guidance notes, procedures, terms of reference and forms are available on the Ulster University Portal.

If you need any further information or clarification of any points, please do not hesitate to contact me.

Yours sincerely

Nick Curry
Senior Administrative Officer
Research Governance
028 9036 6629
n.curry@ulster.ac.uk

Research & Innovation

Ulster University
Shore Road
Newtownabbey
County Antrim
BT37 0QB
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Our Ref: NC:GOV

04 December 2017

Professor K Saunders
Room G151
School of Biomedical Sciences
Ulster University
Coleraine Campus

Dear Professor Saunders

Research Ethics Committee Application Number: REC/17/0088

Study Title: "How does the Brain interpret what the Eyes see?" Investigating Cerebral Visual Processing in children and young people with Down Syndrome

Thank you for your recent response to matters raised by the committee. This has been considered and the decision of the committee is that the research should proceed.

Please also note the additional documentation relating to research governance and indemnity matters, including the requirements placed upon you as Chief Investigator.

The committee's decision is valid for a period of three years from today's date (this means that the study should be completed by that date). If you require this period to be extended, please contact the Research Governance section.

1. **Please complete and return the Chief Investigator Statement of Compliance prior to commencing the study and keep a copy for your file.**

2. **Please retain all other documents.**

Further details of the University's policy along with guidance notes, procedures, terms of reference and forms are available on the Ulster University Portal.

If you need any further information or clarification of any points, please do not hesitate to contact me.

Yours sincerely

Nick Curry
Head of Research Governance
028 9036 6629
n.curry@ulster.ac.uk

Appendix 14: Invite letter sent to parents of children participating in REC/16/0061

Parent study invitation

Cerebral visual processing is a term used to describe how our brains interpret what we see with our eyes. For example, if we want to pick a glass of water up from a table we can see the glass with our eyes, but it is our brain that helps us to identify this object and determine how we interact with it in order to pick it up. Sometimes, even if the eye itself is healthy and functioning normally, the brain doesn't process and interpret visual information in a typical way and this can lead to difficulties. We call this Cerebral Visual Impairment (CVI).

Researchers at Ulster University are currently investigating how children and young people with Down Syndrome process the information they see. As part of this study, we are comparing results from the Down Syndrome study group to a group of typically developing children who don't have Down syndrome.

Since you have recently taken part in another research study by Ulster University at your child's school, and have consented to be contacted about future studies, we are inviting you to complete this short questionnaire. It is used by eye care professionals to find out how your child interprets the information they see. The questionnaire should take approximately 5-10 minutes to complete. With your consent, we will use information from this questionnaire and information about your child's eyes from when we tested them in the school to look at how well they see compared to children with Down Syndrome.

By completing this questionnaire we are assuming that you are giving your consent to participate in this study, however you are free to withdraw at any time. Once completed please return the questionnaire in the stamped envelope provided.

Ethical approval has been granted by the School of Biomedical Sciences Ethics Filter Committee at Ulster University.

If you would like more information, or if you would prefer not to be contacted about studies in the future please contact us:

Emma McConnell **T:** 028 7012 3650, **E:** e.mcconnell@ulster.ac.uk
Prof Kathryn Saunders: **T:** 028 7012 3047 **E:** kj.saunders@ulster.ac.uk
Dr Julie-Anne Little **T:** 028 7012 4374 **E:** ja.little@ulster.ac.uk

Appendix 15: Parent and teacher feedback questionnaires

Evaluating In-School Vision Testing: How was it for you?

Parent Questionnaire

We would like to thank you again for allowing your child to take part in **The SEE Project**. As you know, we have been offering in-school eye examinations to pupils in special educational schools as part of a research study. We hope that this research will be helpful in planning future eye care services for children in special education.

This is your chance to tell us what you think eye care services for children in special education should be like and to tell us what you think of the in-school eye examination your child had by filling in this short survey. ***We would be very grateful for your feedback, comments and suggestions.*** This questionnaire should take 5-10 minutes to complete.

By completing this questionnaire we are assuming that you are giving your consent to participate in this study, however you are free to withdraw at any time. Once completed please return the questionnaire to the school in the envelope provided.

Ethical approval has been granted by the Research Ethics Committee at Ulster University.

Child's initials_____ Child ID_____

1. **How useful do you think the in-school eye test was for you, your child and school staff?**

	Not at all useful	Somewhat useful	No strong opinion	Useful	Very useful
You	1	2	3	4	5
Your child	1	2	3	4	5
School staff	1	2	3	4	5

2. **Please rate your experience of the following items regarding in-school eye tests:**
1= very poor, 2= poor, 3= no strong opinion, 4= good, 5 = very good, 6=don't know

Convenience
1 2 3 4 5 6

Flexibility of appointment times
1 2 3 4 5 6

Suitability of tests used for my child's ability
1 2 3 4 5 6

Verbal communication of test results
1 2 3 4 5 6 ☐ I didn't receive any

Written communication of test results
1 2 3 4 5 6 ☐ I didn't receive any

Other comments _____

3. **In your opinion, do any of the following benefits or limitations apply to in-school eye tests?** *Please tick any that you think apply.*

Benefits

- ☐ Familiar environment for my child
- ☐ Convenient for parents
- ☐ Parent may not be present
- ☐ Testing can be carried out over multiple short visits if required
- ☐ Other classmates taking part encourages compliance
- ☐ Teacher can ask eye care provider questions directly about child's vision
- ☐ Increases awareness of vision among teachers
- ☐ Child cooperates better for school staff

Other _____

Limitations

- ☐ Child misses class activities during eye test
- ☐ Parent may not be present
- ☐ Blurred vision from drops disrupts school work
- ☐ Disrupts school routine
- ☐ Unsettling for child
- ☐ Unable to ask eye care provider questions about my child's eyes at the time of test

Other _____

4. **If your child had an eye test in school and needed to get glasses, where would you like to get the glasses from?**
   - ☐ I would be happy for my child to get the glasses at school – I don't mind if I don't choose the glasses
   - ☐ I would be happy for my child to get the glasses at school – as long as I could help choose the glasses
   - ☐ I would prefer to take my child to the local opticians to get glasses
   - ☐ I have no preference

5. **If your child has previously had their eyes tested at <u>the hospital</u> please rate your experience of the following items:** 1= very poor, 2= poor, 3= no strong opinion, 4= good, 5 = very good, 6= don't know

	1	2	3	4	5	6	
Convenience of attending appointment							
Flexibility of appointment times							
Suitability of tests used for my child's ability							
Verbal communication of test results							☐ I didn't receive any
Written communication of test results							☐ I didn't receive any

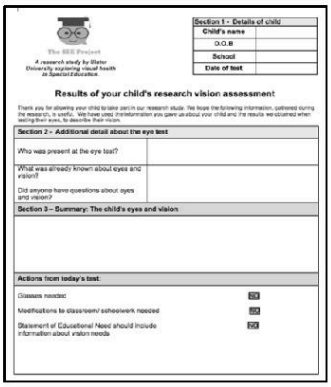
Other _____

6. **If your child has previously had their eyes tested at <u>the local opticians</u> please rate your experience of the following items:** 1= very poor, 2= poor, 3= no strong opinion, 4= good, 5 = very good, 6=don't know

	1	2	3	4	5	6	
Convenience of attending appointment							
Flexibility of appointment times							
Suitability of tests used for my child's ability							
Verbal communication of test results							☐ I didn't receive any
Written communication of test results							☐ I didn't receive any

Other _____

The following questions relate to the report we sent you after we tested your child's eyes in school.


Section 1 - Details of child

Child's name

D.O.B

School

Date of test

The SEE Project

A research study by Ulster University exploring visual health in Special Education

Results of your child's research vision assessment

Thank you for allowing your child to take part in our research study. We hope the following information, gathered during the research, is useful. We have used the information you gave us about your child and the results we observed when testing their eyes, to describe their vision.

Section 2 – Additional detail about the eye test

Who was present at the eye test?

What was already known about eyes and vision?

Did anyone have questions about eyes and vision?

Section 3 – Summary: The child's eyes and vision

Actions from today's test:

Glasses needed: YES

Modifications to classroom/ schoolwork needed: YES

Statement of Educational Need should include information about vision needs: YES

7. **Did you receive a report for your child?**

☐ Yes ☐ No *If no, please go to question 16.*

8. **Did you read the report?** *(Don't worry if you haven't read the report – this is useful for us to know).*

☐ Yes ☐ No

If no, please tell us why you didn't read it, then go to question 16

_____

_____

9. **Is the information contained in the report useful on a day-to-day basis?**

Not at all useful	Parts are useful	No strong opinion	Quite useful	Very useful
1	2	3	4	5

10. **What were the *<u>most</u>* helpful parts of the report?**

_____

_____

11. **What were the *<u>least</u>* helpful parts of the report?**

_____

_____

12. Was the information in the report written in a way you could understand?

Difficult to understand	Somewhat difficult	No strong opinion	Fairly easy	Easy to understand
1	2	3	4	5

13. Did the report contain any information about your child's eyes and vision that you didn't know about before?

☐ Yes ☐ No ☐ Not sure

If yes, please provide details.

_____

14. If the report contained any action points or modifications (e.g. wearing glasses full time, needing large print material etc.) relating to how your child could best use their vision, have any adaptations been made or planned:

a) at home?

☐ Yes ☐ No ☐ Don't know ☐ Not applicable

Please comment on any modifications that have been made, or reasons why modifications have not been made.

_____

_____

b) at school?

☐ Yes ☐ No ☐ Don't know ☐ Not applicable

15. a) Does your child's Statement of Educational Need (SEN) include information about your child's eyes or vision?

☐ Yes ☐ No ☐ Don't know ☐ Not applicable

b) Do you think it is important to include information about your child's eyes or vision in their SEN?

☐ Yes ☐ No ☐ No strong opinion

16. Please use the space below to make any other comments about **The SEE Project**. We would welcome your feedback on the project and value any suggestions about how it can be improved in the future.

_____

_____

_____

Thank you for taking the time to complete this questionnaire.

Evaluating In-School Vision Testing: How was it for you?

Teacher Questionnaire

We would like to thank you again for taking part in **The SEE Project**. As you know, we have been offering in-school eye examinations to pupils in special educational schools as part of a research study. We hope that this research will be helpful in planning future eye care services for children in special education.

As part of the research we would like to find out your opinion of the in-school vision testing by completing this short questionnaire. We would be very grateful for your feedback, comments and suggestions. This questionnaire should take 5-10 minutes to complete.

By completing this questionnaire we are assuming that you are giving your consent to participate in this study, however you are free to withdraw at any time. Once completed please return to The SEE Project postbox in the envelope provided.

Ethical approval has been granted by the Research Ethics Committee at Ulster University.

Class _____

1. **How useful do you think the in-school eye tests were for the pupils, school staff and parents?**

	Not at all useful	Somewhat useful	No strong opinion	Useful	Very useful
Pupils	1	2	3	4	5
Staff	1	2	3	4	5
Parents	1	2	3	4	5

2. **To what extent do you feel the eye tests disrupted the pupils' other school activities?**

Disrupted a lot		No strong opinion		Did not disrupt at all
1	2	3	4	5

3. **In your opinion, do any of the following benefits or limitations apply to in-school eye tests?** *Please tick any that you think apply.*

Benefits

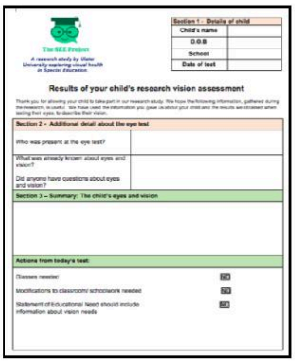
- ☐ Familiar environment for child
- ☐ Convenient for parents
- ☐ Parent may not be present
- ☐ Testing can be carried out over multiple short visits if required
- ☐ Other classmates taking part encourages compliance
- ☐ Teacher can ask eye care provider questions directly about child's vision
- ☐ Increases awareness of vision among teachers

Limitations

- ☐ Pupils miss class activities during eye test
- ☐ Parent may not be present
- ☐ Not enough staff to accompany pupils
- ☐ Blurred vision from drops disrupts school work
- ☐ Disrupts school routine
- ☐ Unsettling for child
- ☐ Lack of space available to carry out eye tests

Other _____

The following questions relate to the report provided describing your pupils' visual status following their sight test.


Results of your child's research vision assessment

4. Did you receive a report for any of your pupils?

☐ Yes ☐ No *If no, go to question 13.*

5. Did you read the report(s)? *(Don't worry if you haven't read the report – this is useful for us to know).*

☐ Yes, straight away. ☐ No, but I plan to during the holidays.

☐ Yes, several weeks later. ☐ No, I have not read the reports.

☐ Yes, several months later. Month read (if known) _____

If no, please tell us why you didn't read them, then go to question 13

_____

_____

6. Did you find the information in the report(s) useful and relevant to your work with the pupil(s)?

Not at all useful	No strong opinion	Parts are useful	Quite useful	Very useful
1	2	3	4	5

7. Was the information contained in the report(s) written in a way you could understand?

Difficult to understand	Somewhat difficult	No strong opinion	Fairly easy	Easy to understand
1	2	3	4	5

8. What were the *most* helpful parts of the report(s)?

_____

_____

10. What were the *least* helpful parts of the report(s)?

_____

_____

11. a) If the report(s) contained any recommendations relating to how the pupil(s) could best use their vision in the classroom, have any adaptations (e.g. classroom position, enlarging text size) been made or planned? *Please provide details.*

☐ Yes ☐ No ☐ Not sure

_____

_____

b) If a child in your class has a vision problem, do you feel confident implementing suggested classroom modifications?

☐ Yes ☐ No ☐ Not sure

c) Would you be interested in having further training to help you learn how to adapt a child's learning environment/materials if they have a vision problem?

☐ Yes ☐ No ☐ Not sure

12. **Do you think the pupils' Statement of Educational Need should include details from the report(s) if they highlight a visual problem?**

☐ Yes ☐ No ☐ No strong opinion

13. **Please use the space below to make any other comments about The SEE Project. We would welcome your feedback on the project and value any suggestions about how it can be improved in the future.**

_____

_____

_____

Thank you for taking the time to complete this questionnaire.

Appendix 16: QR code link for The SEE Project video