Asia Pacific Journal of Developmental Differences
Vol. 7, No. 1, January 2020, pp. 27—60
DOI: 10.3850/S2345734120000039

An Exploratory Study to Investigate Eye Movement Performance and Visual Perceptual Skills in Children with Dyslexia

Isobelle Wong [1*]

1. Educational Therapist / Optometrist

ABSTRACT

During recent years, many studies have shown that reading difficulties such as dyslexia can co-exist with visual processing deficits. As estimated, 80% of the time, a child learns through the visual channel; any deficits in visual processing may affect learning. While intervention related to phonological deficits is well accepted and practised in Singapore, the possible impact of visual deficits is rarely considered, especially with regard to eye movements and visual perception. Hence, these deficits are usually discovered much later or remain undiagnosed. This study investigates the eye movement performance and visual perception skills in a group of 30 children with dyslexia from the Dyslexia Association of Singapore (DAS) learning centres. The tests used for assessment were the Developmental Eye Movement (DEM) test and the Test of Visual Perceptual Skills (non-motor) 4th Edition (TVPS-4). The data collected were analysed against the normative data. Among the participants, 56.67% of them showed eye movement deficits and 46.67% of them displayed visual perceptual weaknesses. Sixty percent of the parents were aware that their child tends to leave out or confuse words when reading. However, only eleven of the participants had an eye examination by an ophthalmologist or optometrist.

Based on the key findings in this study, it is essential to raise awareness among professionals and parents regarding the importance of eye movements and visual perception in children with dyslexia. Any child who shows signs of visual difficulties should be referred for more in-depth visual assessment to identify the actual cause of the difficulties.

Keywords: dyslexia, reading difficulties, eye movement, visual perception, visual perceptual skills, visual processing deficits, rapid automatized naming (RAN)

*Correspondence to:
Isobelle Wong, Educational Therapist / Optometrist, Email: isobellewong@gmail.com

INTRODUCTION

Dyslexia is a specific learning difficulty that occurs in reading and spelling, which may be due to an abnormal developmental process (developmental dyslexia) or neuropathological diseases (acquired dyslexia). Developmental dyslexia (DD) is the focus of this study. Dyslexia is a lifelong condition, usually persisting throughout life. It has long been known that dyslexia is linked to impairments in processing the phonological features of written or spoken language (Snowling, 2000). Those with dyslexia tend to encode phonemes differently while all the other language subsystems remain relatively intact (Ramus et al., 2003). Recently, studies have demonstrated that the pathophysiology of dyslexia is more complicated than formerly thought, beyond the classically defined phonological deficits. Through the use of functional neuroimaging, a more precise definition of the pathophysiology of dyslexia is achieved.

The role of vision in reading difficulties has received interest for these past few decades. Numerous studies have shown that visual deficits are present in dyslexia (Eden et al., 1996). There have been ongoing debates regarding the existence of a link between visual anomalies and reading difficulties.

During recent years, studies have shown that reading difficulties such as dyslexia can co-exist with visual processing deficits (Everatt, 2002). Peer (2001) noted that dyslexia may accompany weaknesses involving visual perception. Griffin et al. (1997) posit that reading difficulties can be a result of vision problems. They proposed that people with reading difficulties can be divided into three main groups according to the causes and manifested signs and symptoms:

i) specific vision problems causing general reading dysfunction;
ii) coding problems of dyslexia causing specific reading dysfunction and
iii) other problems that cause general reading dysfunction, such as attention-deficit disorder and auditory deficits.

As some of the conditions can co-exist, additional subsets of deficits may be formed. By subdividing into these categories, it is apparent that if vision problems can cause reading dysfunctions, proper management of these visual issues can improve the visual functions and ease the related signs and symptoms, hence optimising the children's reading potential.

Everatt (2002) argued that many studies have shown that reading difficulties such as dyslexia can co-exist with visual processing deficits. To date, dyslexia stands out as one that directly impacts the learning ability of an individual (Stein, 2014). It has led to an increased focus on dyslexia, and restructuring of learning in a way to help the learner to improve their capabilities. Eden et al. (1996) suggested that the deficits may be associated with the magnocellular subsystem which is related to visual processing.

According to Arthur Marten Skeffington, the 'father' of developmental optometry, the fundamental functional components of vision consist of visual acuity, binocular vision, eye movements and visual perception, and they are interdependent (Schuhmacher, 2017). Hence, a comprehensive visual assessment for children with learning issues should include these four components.

While the phonological deficit is relatively accepted, the impact of visual deficits remained debatable. Peer and Reid (2003) have suggested that there is growing evidence that visual factors are associated with dyslexia. In 2014, Stein mentioned that visual complaints are common in children with dyslexia, which may be caused by the abnormal development of visual nerve cells. The vision-related symptoms include distortion, blurring, merging or moving of letters or words (Stein and Walsh, 1997). Moreover, misread words, missing words and skipping lines when reading, are also frequently presented, suggesting a consequence of poor visual processing.

These symptoms may lead to eye strain and headaches (Wilkins, 1995). However, it is unclear from the work of Wilkins, whether those with dyslexia are more subjected to visual stress, than those without dyslexia.

RELEVANCE OF TESTING FOR CHILDREN IN SINGAPORE

In Singapore, the diagnosis of dyslexia is usually carried out by an educational psychologist. The Dyslexia Association of Singapore (DAS) works closely with the Singapore government, to provide educational therapy under the MOE-aided DAS Literacy Programme at the learning centres, which cater to the needs of the majority of students from local mainstream schools (Dyslexia Association of Singapore, 2018).

The Health Promotion Board (HPB, 2018) in Singapore has been conducting vision screenings at schools to detect potential vision problems. However, the routine eye examinations conducted locally focus on ocular health, visual acuity and refractive errors (due to high myopia incidence). Although it is not necessary for a child to have a detailed optometric psychometric assessment to be diagnosed as having dyslexia, it is recommended that all children suspected by teachers or parents of struggling with academic work should be examined by an ophthalmologist or optometrist, preferably one who has undergone specific training in assessing children with learning difficulties.

The diagnosis and intervention for dyslexia by psychologists or educators focuses mainly on auditory examination only, which may be insufficient and inconclusive. Often, visual information processing deficits remained undetected, and these deficits inevitably affect school achievement (Vaughn, Maples and Hoenes, 2006).

AIMS

Despite all the visual and magnocellular theories, we are still not sure what is the percentage of children who had been previously diagnosed with dyslexia using the conventionally available assessments, who may have possible underlying visual deficits in either the international or local context. Hence, this forms an initial study to investigate the eye movement performance and visual perceptual skills in children who have been previously diagnosed with dyslexia and are receiving phonics-based literacy intervention at the DAS learning centres. This group of children are bilingual, studying in local mainstream schools. They have average or similar general cognitive skills as compared to their peers, studying in this highly competitive and demanding educational environment. It is vital for us to investigate and provide the appropriate accommodations and interventions accordingly.

DYSLEXIA

Dyslexia is primarily divided into two causes, language processing and visual processing (Campbell, 2009), it is separated from reading difficulties caused by vision or hearing problems, or by insufficient teaching (Peterson and Pennington, 2012). According to Stein (2014), vision problems may be caused by atypical development of the visual nerve cells. Dyslexia can be classified into three types: phonological dyslexia, surface dyslexia and deep dyslexia, although these last two are less frequently used in recent terminology.

Many theories attempt to explain the possible causes of dyslexia. According to Mody and Sillman (2008), the five main theories of dyslexia are the cerebellar theory, the phonological processing theory, the rapid auditory processing theory, the visual theory, and the magnocellular theory. The visual theory suggests that dyslexia is a visual processing deficit, based on impairment in processing letters and words from a written text. Visual processing problems include poor vergence, unstable binocular fixations and visual crowding. It does not reject the presence of other possible causes of dyslexia (Ramus et al., 2003). According to Hinkley, Schoone and Ondersma, (2011), learning-related vision problems are divided into visual efficiency and visual information processing.

The magnocellular theory aims to combine the above four theories. It advocates that as well as deficits in the visual pathways, the magnocellular dysfunction includes deficits in the auditory and the tactile systems (Ray, Fowler and Stein, 2005; Ramus et al., 2003). Laycock, Crewther and Crewther (2012) shared similar sentiments in their research, which shows evidence for a sizeable magnocellular impairment in some individuals with dyslexia.

It has been suggested that deficits in the transient system of the magnocellular pathway are the cause of dyslexia (Omtzigt, Hendriks and Kolk, 2002; Stein, 2001; Demb, Boynton and Heeger, 1998; Greatrex and Drasdo, 1995). The transient system controls 'where' the eyes should move. Hence, any deficiency in this system may result in poor eye movements during reading. Although the evidence for this theory is diverse (Schulte-Körne and Bruder, 2010; Skottun, 2000), Gori et al. (2016) had recently established a causal relationship between dyslexia and the dorsal pathway deficit.

Besides the above-mentioned theories, the other theories are the naming speed deficit and the double-deficit theories. The naming speed deficit theory demonstrates the speed a person can employ in the rapid automatized naming (RAN) of familiar letters or objects. It is a robust predictor of dyslexia (Denckla and Rudel, 1976). This theory hypothesised that naming speed deficit is detached from the phonological processing deficit. Hence, there are four possible groups of combinations:

- i) individuals with no deficit,
- ii) individuals with phonological processing deficit,
- iii) individuals with naming speed deficit, and
- iv) individuals with double-deficit (both naming speed deficit and phonological processing deficit).

Individuals with double-deficit tend to face more difficulties in reading. Hence, it is essential to distinguish the deficits among children with dyslexia in order to provide the right instructional intervention. If we only provide phonological intervention to children with double-deficit, they will only receive part of what is required (Birsh, 2005).

DYSLEXIA AND THE VISUAL SYSTEM

As it is estimated that 80% of the time, a child learns through the visual channel (Kaplan, 2015), visual difficulties may be a primary or contributory factor in learning disorders (Kemp, Smith and Segal, 2018). Although the impact of visual deficits remained debatable, there is growing evidence that visual factors are associated with dyslexia (Peer and Reid, 2003). The findings and concepts behind surface dyslexia and the visual theory of dyslexia have strongly supported the presence of visual deficits in those with dyslexia.

According to Stein (2014), visual complaints are common in children with dyslexia, which may be caused by the abnormal development of visual nerve cells. The vision-related symptoms include distortion, blurring, merging or moving of letters or words (Stein and Walsh, 1997). Often, this results in a misreading of words, an omission of words and skipping of lines when reading, suggesting the consequence of poor visual processing. Additionally, these symptoms may lead to eye strain and headaches (Wilkins, 1995), as noted above.

Furthermore, Georgiou et al. (2012) found that her sample of children with dyslexia did not have auditory challenges, but around half of them displayed visual processing deficits. Although orthographic and rapid automatized naming (RAN) processing deficits were present in these children, the relationships among them remained unclear. Hence, it is essential to investigate the RAN in children with dyslexia.

Learning-related vision problems are divided into visual efficiency and visual information processing (Hinkley, Schoone and Ondersma, 2011). Visual efficiency includes visual function relating to refractive errors, accommodation, vergence and eye movements, while visual information processing comprises higher brain functions integrated with the motor, auditory, language and attention systems (Borsting et al., 1996). The process includes non-motor aspects of visual perception and cognition. It provides the meaning to what is seen, through organising, structuring, and interpreting visual stimuli.

Regrettably, deficits related to visual information processing are often missed out, only discovered much later when learning issues have surfaced or may remain undiagnosed. Especially in Singapore, these testing of visual information processing skills are rarely practised and almost unheard of. Hence, this study hopes to address this gap, investigating eye movement performance and visual perceptual skills in children with dyslexia.

EYE MOVEMENTS

According to recent studies, reading comes in two main processes, the 'decoding' then the 'comprehension' stage (Muter, 2003; Evans, 2001; Griffin et al., 1997; Rack et al., 1994; Simons and Grisham, 1987). Immature readers rely on decoding through phonetic analysis while mature readers employ both sight analysis and phonetic analysis. Hence, decoding is an essential skill for early readers as we learn to read by recognising the shape of familiar words and by building up our sight-word vocabulary through visual images (Evans, 2001).

As reading deficits start with a problem of decoding of an 'object or text' when reading, eye movements, especially saccadic eye movements, play a significant role in reading (Eden et al., 1994; Poynter et al., 1982). With eye movements forming part of the visual system, it is logical that imperfect eye movements may deter the performance of reading. As a consequence, it hinders comprehension, which develops in the higher orders of the brain and gradually become more vital in learning (Schuhmacher, 2017; Evan, 2001).

There are many subtypes of eye movements. The two core types are the vergence eye movements and the version eye movements. Saccadic eye movements or saccades (2-3 degrees) are rapid shifts in fixation from one point to another, which are important during reading, when the eyes need to move smoothly along a line of print, then back and down to the start of the next line for extended periods. However, assessment of saccadic eye movements is not included as part of the routine eye examination in Singapore. Although eye movement deficits may not be the only contributory factor to reading difficulties, better control of saccadic eye movements can translate to more precise and quicker reading speed (Fischer and Hartnegg, 2000) and reduce the percentage of reading errors (Fischer and Hartnegg, 2008). Therefore, it is of great benefit to investigate the saccadic eye movement performance in children with dyslexia in Singapore, to determine the potential underlying causes which were undiagnosed.

Rapid automatized naming (RAN) involves the involuntary ability to recognise visually presented objects, numbers or letters, and express the verbal label swiftly and precisely (Denckla and Rudel, 1974). It is partly reliant on the automatic visual processing of the stimulus. These processes are essential in identifying and recognising of single words, improving reliability in predicting word identification ability as well as word-level reading difficulties (Meyer et al., 1998a; Meyer et al., 1998b; Fawcett and Nicolson, 1994; Denckla and Rudel, 1976). Hence, RAN emerges as a stronger predictor of reading performance than phonological processing ability, in some studies, and signifies as the second component of the double-deficit hypothesis of reading disability (Wolf et al., 2002; Wolf and Bowers, 1999; Wolf and Obregón, 1992).

Also, slow naming speed could suggest poor automaticity in producing orthographic or visual mental illustrations of letters or words, which is required in rapid word recognition (Becker, Elliott and Lachmann, 2005; Wolf and Bowers, 1999). Since RAN involves visual input, visual dysfunction may be one of the causative factors. Therefore, deficits in RAN have been associated as a risk for reading difficulties which can co-exist with the phonological deficits (Wolf, Bowers and Biddle, 2000).

EYE MOVEMENTS AND READING

During reading, the eyes need to be able to track and search words. Accurate and well-coordinated eye movements such as saccades and visual tracking are highly essential. Visual tracking involves the accurate and synchronised movement of the eyes from one word to another. When saccades are poor, the ability to scan along a horizontal line of text (tracking) may be affected.

The frequency and duration of fixations depend mainly on the level of difficulty of the reading material, word ambiguity and grammatical function. According to Aslin and Salapatek (1975), younger children tend to have large saccadic corrections and higher drift rates during fixation. In addition to immature control, these errors may be due to attention factors (Aslin and Ciuffreda, 1983).

When reading English, a mature reader's saccades can travel six to eight-characters of text within the foveal region, with each fixation lasting approximately 225 milliseconds (Ciuffreda and Tannen, 1995). Occasionally, we need to move our eyes backwards to re-read the same text. The backward shift is called regression and only extends to a few characters. A large right-to-left saccadic eye movement is required during reading, from the end of one line to the beginning of the following line. This type of saccade is known as a return-sweep saccade; it covers approximately 12 to 20 degrees and has a duration of 40 to 54 milliseconds (Ciuffreda and Tannen, 1995). When the eye movement is affected, increased regression may cause loss of place, lead to misrepresentation of information to the brain. Any word additions, omissions, transpositions or substitutions, and/or skipping lines, may trigger text confusion or affect comprehension. In short, good readers tend to have longer saccades, shorter fixation time and fewer regressions than poor readers (Rayner, 2009; Rayner, 1998; Rayner, 1985). When the development of this skill fails, reading and writing abilities are often below expectation (Chivers, 2006).

Various studies had investigated the quality of saccades in individuals with reading difficulties (Solan et al., 1998; Eden et al., 1994; Ygge et al., 1993a; Ygge et al., 1993b; McConkie et al., 1988; Ciuffreda, Kenyon, and Stark, 1985; Pavlidis, 1985; Ciuffreda, Kenyon and Stark, 1983). They found that individuals with reading difficulties tend to have a deprived quality of eye movements, consisting of increased numbers of saccades and longer fixation time. Also, an excessive number of regressions are recorded as these individuals tend to reread, to double-check the correctness of decoded words. The prolonged duration of fixations and higher numbers of fixations indicate impairment of lexical and sublexical pathways (Hatzidaki et al., 2011; Hawelka, Gagl and Wimmer, 2010).

Pavlidis (1981) established that individuals with dyslexia exhibit more right-to-left saccades than normal and have backward shifts when observing a non-text target (a moving dot on a computer screen). Subsequent studies were unable to replicate the results in Pavlidis' study (Black et al., 1984; Brown et al., 1983; Stanley, Smith and Howell,1983), and his findings remain controversial. These may be due to the differences in variable criteria in the subject selection, instructions given to subjects, experimental procedures and stimulus characteristics, which further research would need to resolve.

However, later studies have found poor saccadic control in those with dyslexia (Biscaldi, Gezeck and Stuhr, 1998; Biscaldi, Fischer and Aiple, 1994; Fischer and Weber, 1993; Fischer and Weber, 1990). Any poor eye control may cause gaze problems when reading and copying, as they may miss words out or lose their place.

Hence, this leads to excessive head movements when changing gaze and poor control of reflexive eye movements. Also, Eden et al. (1994) reported that poor fixation stability was observed in children with dyslexia during non-verbal visual tasks. These controversial findings further propose the need to investigate the presence of eye movement deficits in children with dyslexia.

The relationship between saccadic dysfunction and reading difficulties has been well-documented, although it may not be the only cause of reading difficulties, they may further contribute to the learning difficulty (Kulp and Schmidt, 1996; Poynter et al., 1982; Hoffman, 1980; Lefton, Lahey and Stagg, 1978; Sherman, 1973). Nevertheless, whether eye movement deficits are the primary or secondary cause of dyslexia, it is crucial, to identify the presence of the deficits rather than focusing on the cause and effect relationship between eye movements and dyslexia.

VISUAL PERCEPTION

During reading, the visual demands are high. Other than eye movements, visual information processing skills consist of visual perception. Visual perception involves the non-motor visual analysis ability to see, understand and interpret the images seen by the eyes, then act. These processes are served at a high level of executive function in our brain (Schuhmacher, 2017).

According to Groffman (2006), visual perception is an active process of locating/identifying and extracting information from the environment. It brings together visual clues from the surroundings, and interactions between other senses involving higher cortical function. The route can be complicated, linking previous experience, organisation, and elaboration of the nervous system (Solan and Ciner 1989). When addressed separately, visual perception integrates all components simultaneously to enable appropriate interaction and to perform in all daily functions for instant communication, social interaction, mobility and learning. Visual perceptual processing is vital in the progression of visual skills needed for all visual learning, including reading and assimilating information (Goodrich et al., 2007).

There are seven areas of visual perceptual skills classified by Scheiman and Rouse (2006) and Gardner (1996). These include Visual Discrimination (DIS), Visual Memory (MEM), Spatial Relationships (SPA), Form Constancy (CON), Sequential Memory (SEQ), Visual Figure-Ground (FGR) and Visual Closure (CLO).

VISUAL PERCEPTUAL SKILLS AND LEARNING

The capability of the brain to make sense of seen objects and scenarios is necessary for building life skills such as reading and interpreting signs and maps. Through the representation of data, proper visual perception helps one to understand and interpret the data and decode meaning from the information. The ability involves recognising numbers, faces, letters and other visual elements (Meronen et al., 2013). It is from these elements that the brain can decode more information for further understanding.

Previous research studies have established a correlation between visual perception and learning ability in children. Children who have poorly developed visual perceptual skills are likely to be slow learners (Crawford and Dewey, 2008). Even though they may still learn to read and write, the learning process may require excessive cognitive effort.

Cognitive ability can be enhanced through the visual perceptual process, making it easier for one to understand through reading and writing. For instance, when a child reads about an element that he is familiar with, it is easier for him to understand, due to preconceived information acquired through visual perception, making it is easier for one to understand the same scenario or object when it is exposed in class. Also, visual perception prepares one for the understanding of future problems or situations that have a connection or relation to previous and experienced scenarios. For example, visual perception helps in matching the same shapes even when they are made smaller or bigger in size. Knowland et al. (2016) mentioned that the development of these visual perceptual skills is dependent on the magnitude with which a child interacts with his surrounding, especially outdoors. Hence, the relationship that a child makes with his environment is on a par with his visual perceptual ability.

Visual perceptual skills have been shown to correlate with academic performance, particularly in younger children (Goldstand, Koslowe and Parush, 2005; Sortor and Kulp, 2003; Taylor, 1999; Feagans and Merriwether, 1990; Kavale 1982). The areas include learning mathematics, reading, writing and/or spelling. Also, visual perceptual deficits have been documented in numerous studies involving children with learning difficulties including those with reading difficulties (Kovács, 2000) and developmental coordination disorders (Van Waelvelde et al., 2004).

According to Kulp et al. (2004), visual discrimination and visual analysis are vital in performing well in academia, as these skills enable letter or symbol to be perceived and organised correctly in our minds. Additionally, the process of reading is visually demanding, requiring fine spatial discrimination and rapid processing skills (Vidyasagar, 2004).

Goodrich et al. (2007) suggested that visual memory forms the basis of other higher order forms of visual learning. Kulp, Edwards and Mitchell (2002) found that visual memory ability was significantly related to reading, decoding, math, and overall academic achievement. Subsequently, Sortor and Kulp (2003) suggested that low visual perceptual ability may correlate with weak math and reading abilities. Scheiman and Rouse (2006) advocate enhancing visual perception (visual organisation, attention and information processing) in children with perceptual deficits. It can complement the educational process and create building blocks for future academic success. According to Kavale (1982), there is a significant correlation between visual perception and reading. Therefore, visual perceptual skills should be included in the prediction of reading achievement. Hence, it has been proposed that visual perceptual assessment is necessary for those children who struggle in reading or math (Sortor and Kulp 2003).

Studies have shown that better visual span could improve reading and comprehension (Kwon, Legge and Dubbels, 2007; Chung, Legge and Cheung, 2004). Thus, it is imperative to increase efficiency in reading. The various findings suggested that visual processing is highly essential and vital in the development of reading skills.

Stein (2014) has demonstrated the role of the brain and its direct link with dyslexia. Dyslexia is not just about having difficulties with translating letters into sounds; in addition, it involves the challenge of seeing letters and their order. It is important to note that visual perception is different from visual acuity, as one may have sharp vision but still lack good visual perception.

The ability of the mind to make sense of what the eyes see, is salient for various skills such as reading, dressing, writing, painting, answering puzzles, completing math tests, amongst others. These are the everyday skills that everyone takes part in or performs. Meronen et al. (2013) noted that the ability to perform these tasks boosts self-esteem and confidence, leading to positive growth and development. For children, it is essential to have excellent visual perceptual skills as they form the foundation of many other skills that they learn as they interact with the environment. Hence, this study is an opportunity to explore visual processing in children with dyslexia.

METHODOLOGY

Participants

The participants were 30 primary students attending mainstream schools, 19 males (63.33%) and 11 females (36.67%). The majority are Chinese (90%) and the remaining are Malays (10%). Their age ranged from 7-years 9-months to 13-years 5-months, with an average age of 10-years 0-month.

These students had been formally diagnosed with dyslexia by an educational or specialist psychologist. They were recruited from the DAS learning centres, where they were attending intervention programmes. Parents who showed interest in the research gave the consent of participation and provided background information covering medical conditions, history of eye-related examination and diagnoses/treatment. They completed a short questionnaire to highlight whether their child had been assessed previously for visual difficulties related to learning, and if they experienced difficulties which might be related to visual issues.

The Developmental Eye Movement (DEM) Test

The Developmental Eye Movement (DEM) test is a standardised visual-verbal assessment, commonly used to measure eye movement and rapid automatized naming (RAN). It is designed to provide information on vertical and horizontal scanning or tracking behaviour using number-naming task. Under normal circumstances, it is common to take a longer duration for the horizontal task, and this is only relevant to those up to the age of 13. After that, the tasks should take approximately the same amount of time to complete.

The test comprises of digits only to bypass the issue of reversal of letters. It is a quick and non-invasive test to assess children between 6 and 13 years of age who present with reading difficulties. It takes into consideration of one's automaticity skills, ability to see and read aloud (Garzia et al., 1990). Tracking problems and/or automaticity difficulty can be identified by analysing the results. A tendency to lose your place while reading or copying and to use a finger or marker to keep your place when reading and writing are indicators of tracking or oculomotor problems.

The results can be categorised into four types (Table 1).

Table 1: Categorization of Type I to Type IV

CATEGORY	RESULT	INDICATIONS
TYPE I	Normal horizontal time, vertical time and ratio	Normal (no indication of oculomotor or automaticity dysfunction)
TYPE II	Normal vertical time and increased horizontal time with high ratio	Difficulty in horizontal scanning (oculomotor dysfunction)
TYPE III	Increased vertical time and horizontal time with normal ratio	Difficulty in automaticity of number naming (automaticity dysfunction)
TYPE IV	Increased vertical time and horizontal time with high ratio (combination of type II and III)	Oculomotor and automaticity dysfunction

Test of Visual Perceptual Skills (non-motor) 4th edition (TVPS-4)

The Test of Visual Perceptual Skills (non-motor) 4th edition (TVPS-4) is a standardised test that is commonly used by many professionals to assess two-dimensional visual perceptual abilities. The TVPS designs are bold and presented in a multiple-choice format. Also, the forms are not language or culture related. The test only requires minimal verbal or motor (pointing) response. Hence, it is suitable for those with learning difficulties, low intellectual ability, impairments in speech, hearing, motor or neurological functions. It is an easy-to-use and quick to score assessment to provide information about a child's strengths and weaknesses in performing tasks associated with visual information processing (Martin, 2017; Martin, 2006; Gardner, 1996). The latest updated 4th edition (TVPS-4), includes a broader age range for examination, from 5 to 21 years old.

The test consists of seven subtests, visual discrimination, visual memory, spatial relationships, form constancy, sequential memory, visual figure-ground and visual closure. The subtests start from the most fundamental skills to the more advanced skills, with 18 plates in each area. It is administered individually with a built-in easel, so that the examinee can look straight ahead, instead of downward viewing. It is untimed, requiring about 25 minutes to complete.

Both assessments were conducted by the researcher, a qualified optometrist, in English (first language in all mainstream schools), on an one-to-one setting in a quiet room with good lighting. The participants went through the DEM test followed by the TVPS-4. Short and simple verbal instructions were used to improve understanding. Administration of assessments only began when the participant had fully understood the instructions.

RESULTS

Questionnaire

The participants were studying in Primary 2 to Primary 6, where five of them entered primary school one year later than their peers. Four of them were born prematurely. Based on the questionnaires returned by the parents, only 63.33% of the participants had been to an eye exam, excluding eye screening by HPB at school. Eleven (36.67%) of them had an eye examination by either an ophthalmologist or optometrist, with 16.67% by an optician and 10% were not sure who conducted the examination. The remaining participants (36.67%) did not undergo a routine eye examination. Seventeen (56.67%) of them wore glasses. Sixty percent (60%) of the parents noticed that their child tends to leave out or confuse words when reading, and 23.33% of the parents mentioned their child has poor eye-hand coordination.

The Developmental Eye Movement (DEM) Test

In the DEM test, duration data were recorded in seconds. The adjusted vertical time (AVT), adjusted horizonal time (AHT) and ratio (AHT divided by AVT) were calculated and rounded to two decimal places. These results were compared to the corresponding age groups based on U.S. normative data, in the absence of local normative data. According to Richman (2009), a score below the 31st percentile is considered to be a weak performance and at risk. Hence, any score lower than 0.5 standard deviation below the mean was categorised as ‘poor’ performance. Among the participants, 10 (33.33%) and 12 (40%) scored poorly in AVT and AHT respectively. In 9 (30%) cases, the participants displayed a poor ratio.

In relation to the categories in Table 1, 43.33% of the participants had normal eye movement (Type I). 23.33% of them showed difficulty in horizontal scanning (Type II) while 30% had difficulty in automaticity of number naming (Type III). One of them was found to have difficulty in both horizontal scanning and automaticity of number naming skills (Type IV). In terms of the severity of these deficits, 4 participants had percentiles ranks of less than 1, the most severe categorisation on AVT, 2 participants on AHT, and 2 participants on ratio. This suggests that those participants who showed deficits on this test had highly significant impairments, which may well impact severely on their learning.

Test of Visual Perceptual Skills (non-motor) 4th edition (TVPS-4)

For the TVPS-4, a scaled score of 10 indicates that the child's performance lies at the mean score for the sample age group while a scaled score of 7 indicates the child's performance is one standard deviation below the mean for that group. Interestingly the range of scores was broad across each subtest, with scaled scores ranging from a low of 1 to a high of 16. The distribution of scores are presented in Figure 1 to 7. The mean and standard deviation of each subtest are presented in Table 2.

For the overall standard scores, 100 indicates the mean and median with a standard deviation of 15. Figure 8 illustrates the score for the individual participant. Despite this, the overall standard scores are ranged from 93 to 122, and fell within the average to superior range, except for 2 participants.

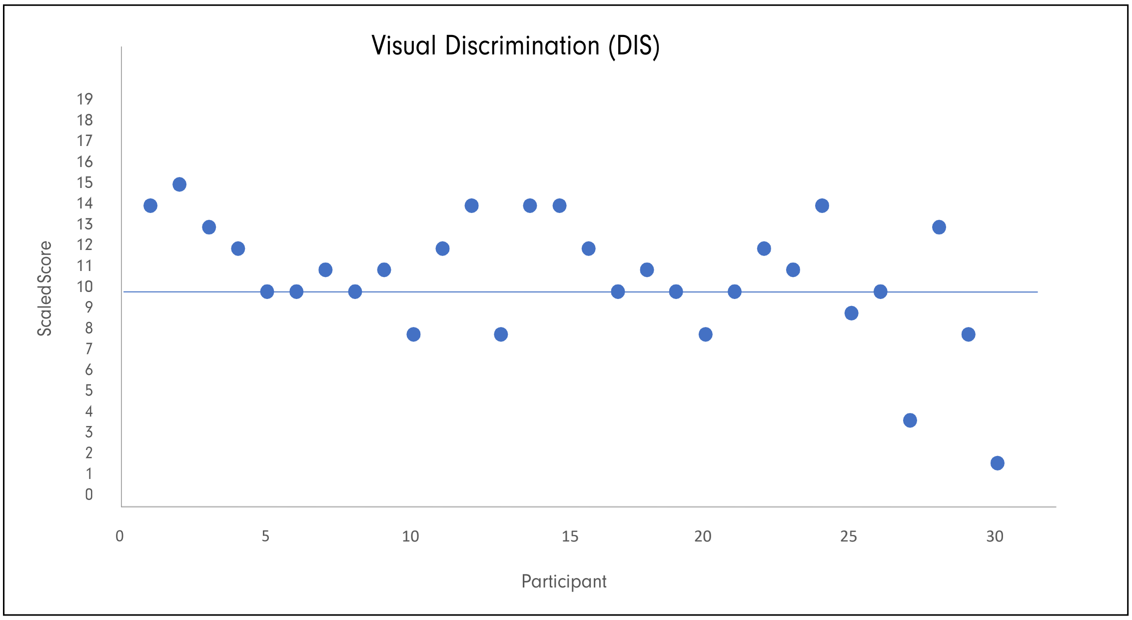

Figure 1: The scaled scores of visual discrimination for individual participants.

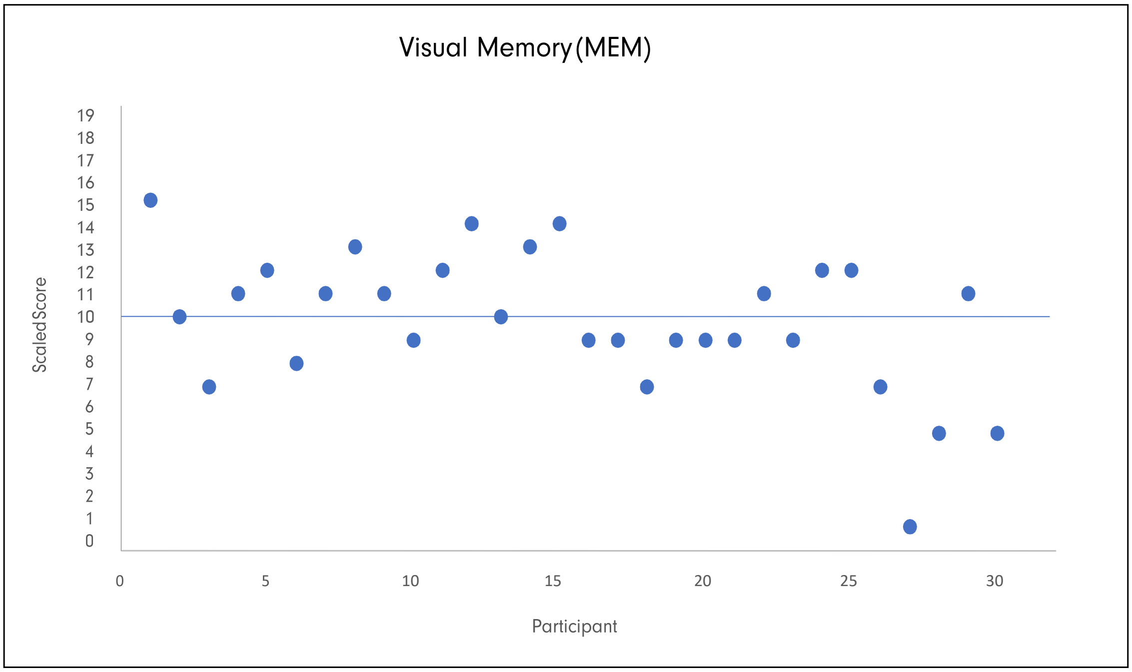

Figure 2: The scaled scores of visual memory for individual participants.

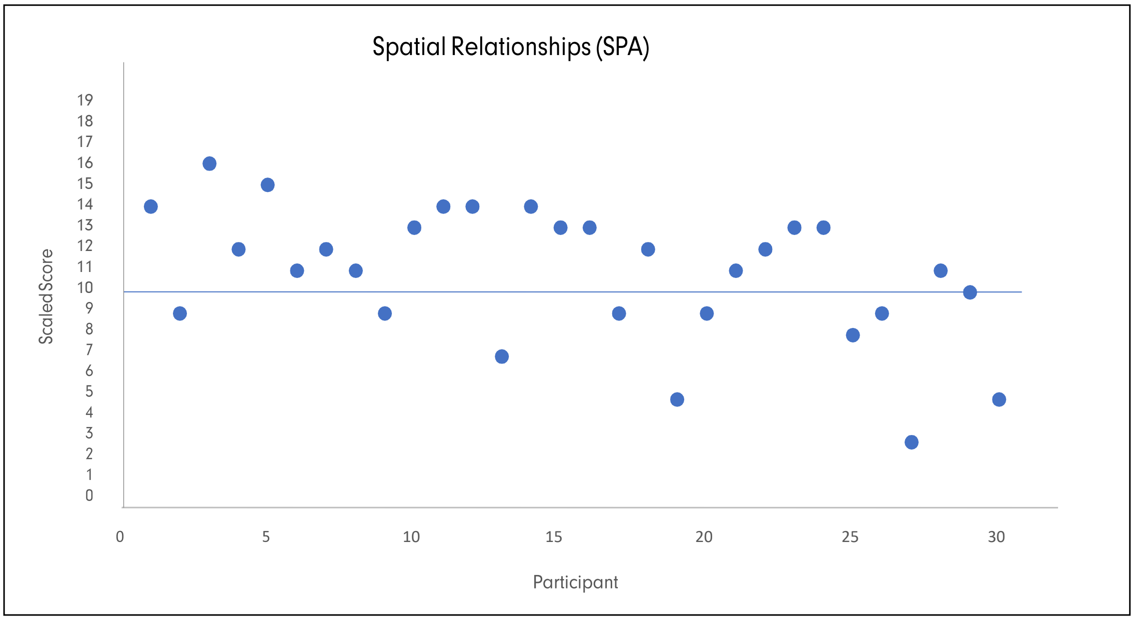

Figure 3: The scaled scores of spatial relationships for individual participants.

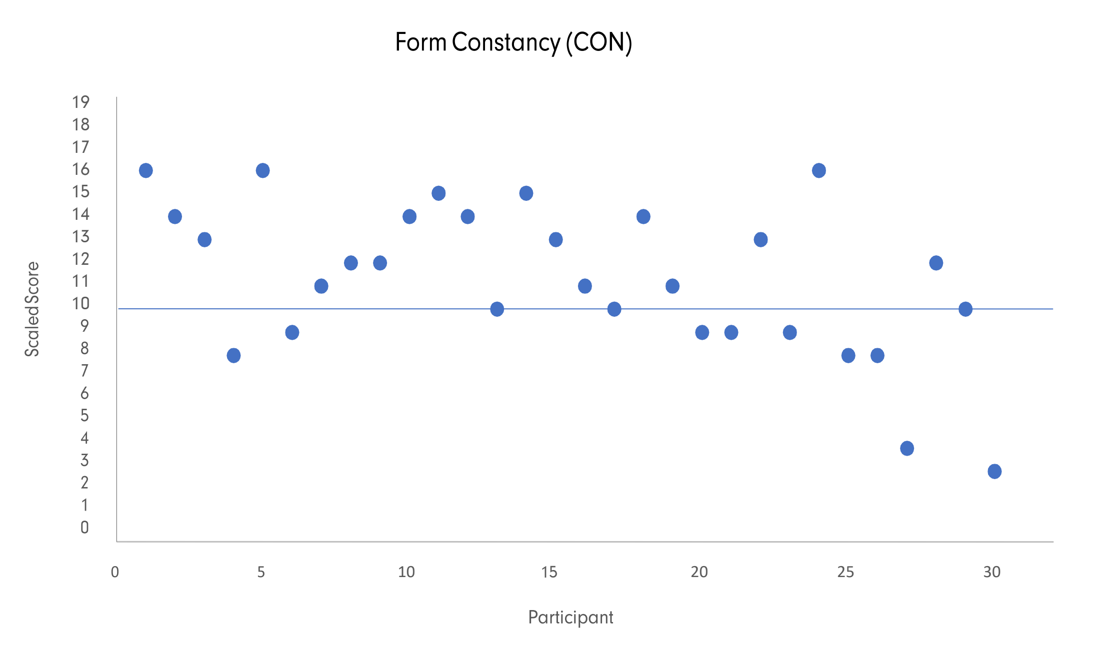

Figure 4: The scaled scores of form constancy for individual participants.

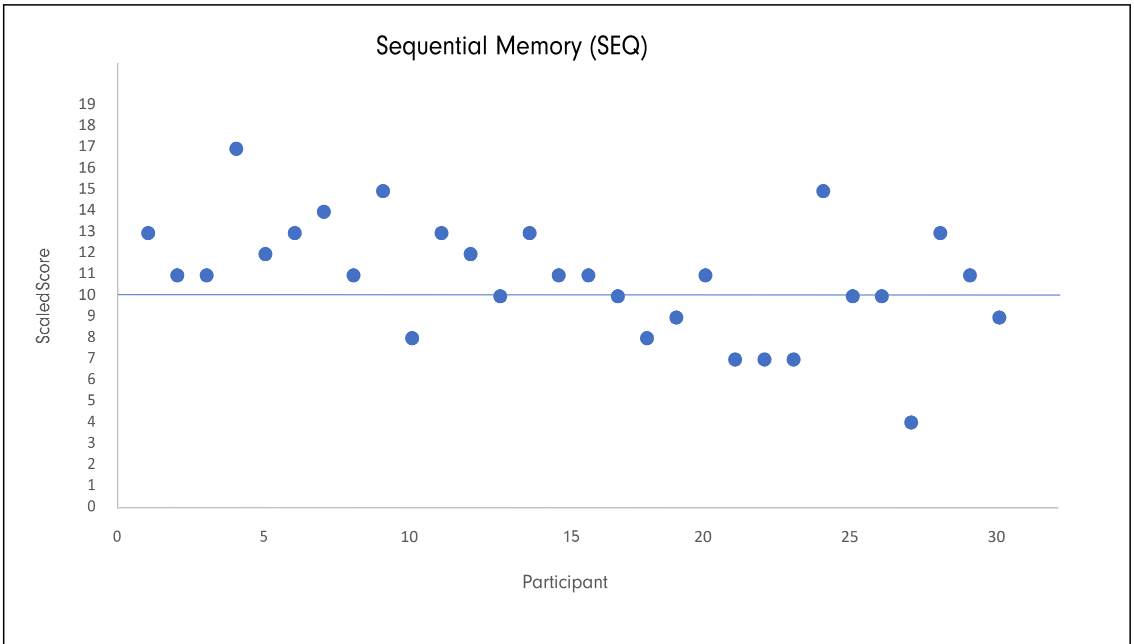

Figure 5: The scaled scores of sequential memory for individual participants.

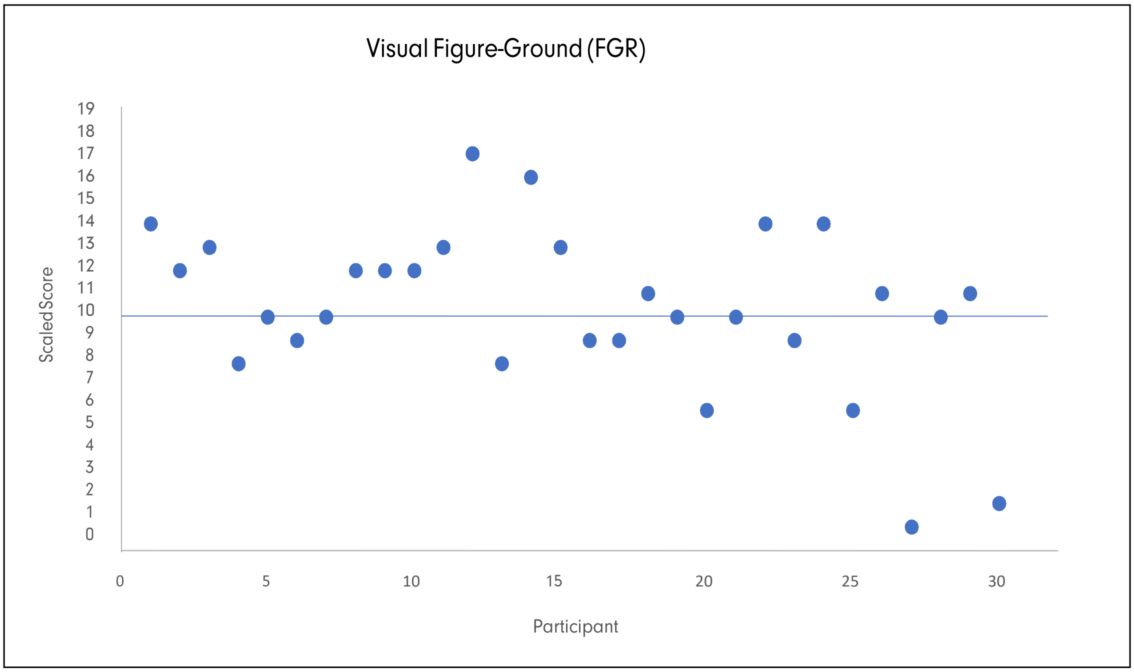

Figure 6: The scaled scores of visual figure-ground for individual participants.

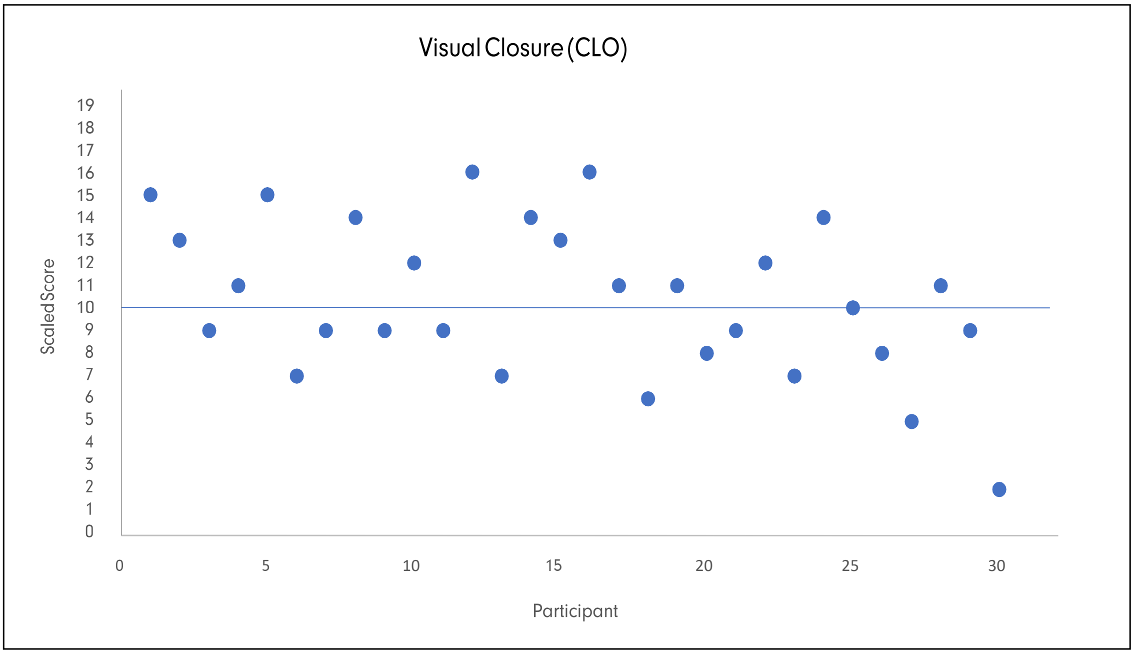

Figure 7: The scaled scores of visual closure for individual participants.

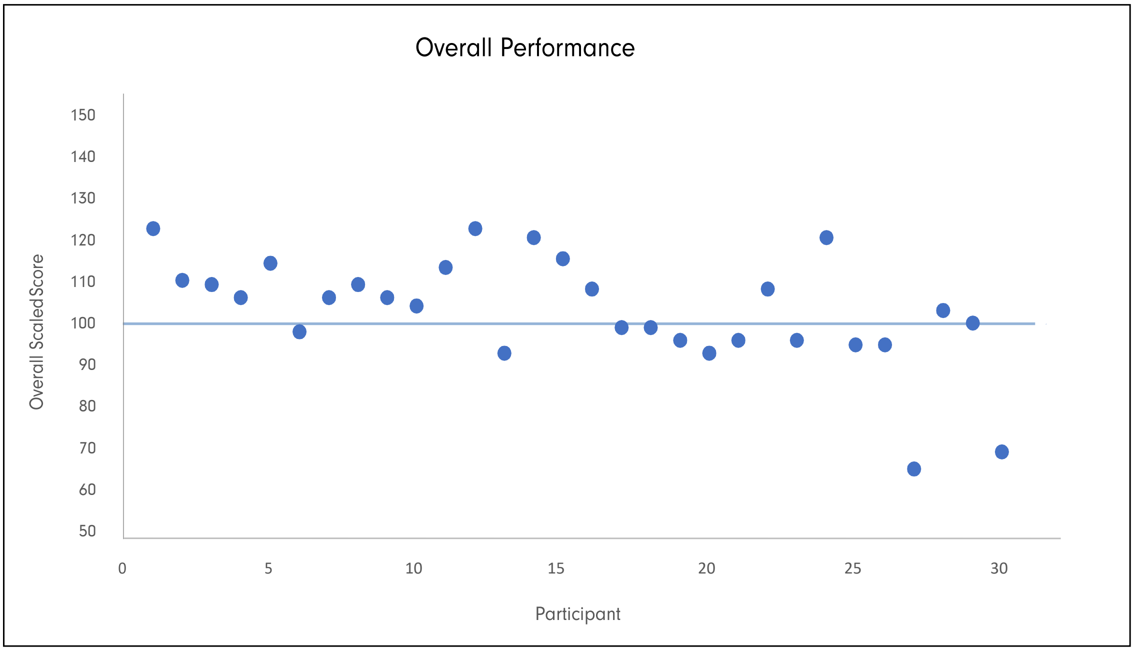

Figure 8: The overall standard scores for individual participants.

Table 2: Mean and standard deviation of the TVPS-4 subtests.

Subtest	**Mean**	**Standard Deviation**
Visual Discrimination (DIS)	10.67	2.92
Visual Memory (MEM)	9.83	3.02
Spatial Relationships (SPA)	10.90	3.12
Form Constancy (CON)	11.30	3.29
Sequential Memory (SEQ)	10.87	2.79
Visual Figure-Ground (FGR)	10.40	3.54
Visual Closure (CLO)	10.40	3.43

DISCUSSION

Visual deficits may potentially be one of the contributing factors which affects the learning ability of a child in a negative manner. Therefore, vision conditions should be taken into account in underachieving children. There has been no research that investigates the possible presence of eye movement or/and visual perceptual deficits in children with dyslexia in Singapore. The results of the questionnaire showed that about two-thirds of the participants had been to an eye examination. Nevertheless, among these, barely half of the eye examinations were conducted by an ophthalmologist or optometrist. This provided the motivation for this study.

The Developmental Eye Movement (DEM) Test

Previous research studies have suggested that RAN is linked to reading abilities in children (Koponen et al., 2013; Norton and Wolf, 2012). However, due to the descriptive nature of this study, a causal relationship between RAN deficits and dyslexia cannot be confirmed. Also, this design does not determine if reduced RAN causes reduced reading ability, or vice versa; as well as taking into consideration if both variables are non-causal correlates.

According to Wolf et al. (2002), phonological processing has been the core area of focus in the reading research, as phonological deficit was anticipated to link to reading difficulties, affecting word recognition skills and reading fluency. However, there are certain parts of reading disabilities that are not entirely explained by phonological awareness alone, for instance, children with reading difficulties are not able to improve despite following phonological-based interventions (Wolf, Bowers and Biddle, 2000).

Rapid naming is dependent on the automatic visual processing of the stimulus, resulting in quick word recognition (Becker, Elliott and Lachmann, 2005; Wolf and Bowers, 1999). A wide range of evidence has started to show that a deficit in RAN is associated with reduced reading ability, forming an alternative theory of reading disability (Wolf and Bowers, 1999). In this double-deficit hypothesis, phonological deficit and RAN deficit are two independent sources of reading difficulties, even though both can arise concurrently. Also, it has been suggested that RAN indicates the automaticity which letter codes are retrieved in memory, coupled with requiring this process to automatize the reading process (Spring and Davis, 1988). The findings of this study coincide with the research mentioned that reduced RAN skills may be associated with dyslexia.

According to Fischer and Hartnegg (2008), 20% to 70% of children with dyslexia (age range of 7 to 17 years old) may have deficits in voluntary saccade control. Their findings are consistent with another research conducted on poor readers in American High schools using the DEM test (Powers, Grisham and Riles, 2008). They found that poor readers may well be at risk for poor saccadic tracking skills. Moiroud et al. (2018), discovered that children with dyslexia have longer fixation durations at the DEM test when compared to children without dyslexia based on chronological age-matched, significantly correlate to the number of words read in one minute with the time taken to read horizontal task. Their study further affirmed that the DEM test is useful in investigating oculomotor behaviour of children with dyslexia.

During the DEM test of this study, 23.33% of the participants did try to use their finger to point or made head movements, especially when reading the letters horizontally, indicating difficulty in saccadic eye movements. One of the participants displayed the two behaviours, struggled to complete vertical task and horizontal task, scoring below one percentile rank in both subtests. Hence, observations of parents or/and educators are important, in spotting any child with these symptoms and subsequently referring them for further assessments. Solan and Ficarra (1990) stated that the eye movement component could not be the only variable in reading problems; they suggested a more inter-disciplinary approach when attempting to improve reading problems.

According to Thaler et al. (2009), children with dyslexia showed different eye movements when compared to children with dyslexia and attentional deficits. They suggested that it is necessary to control comorbid attentional issues in children with dyslexia. Only one participant in this study had comorbid attention deficit hyperactivity disorder (ADHD). However, the participant showed normal eye movement. Hence, comorbidity may not be the factor affecting the DEM test results. Future studies are essential to further investigate the eye movements in these two groups of children.

The DEM test was designed to evaluate saccadic eye movements in a simulated reading setting. When Ayton et al. (2009) compared the validity of the DEM test for measuring the saccadic eye movements with a direct objective eye movement tracker (ReadAlyzer™ or Visagraph™), they suggested that the DEM test did not correlate directly with saccadic eye movements. They found that the DEM test correlates to verbalisation speed, reading performance and visual processing. However, Lack (2005), supported the time scores of the DEM test significantly correlated to Visagraph™ Number Test. Hence, the DEM test remains as a promising measurement to identify potential reading related eye movement deficits.

In this study, even though an experienced examiner administered the DEM test, there are other factors to be considered (Pang, Lam and Woo, 2010). The other possible factors not related to oculomotor or automaticity deficits, which may exist, are intrinsic population characteristics, language differences, educational system and cultural environments (Facchin, Maffioletti and Carnevali, 2012; Baptista et al., 2011; Pang, Lam and Woo, 2010). Thus, these factors must not be overlooked.

In theory, the DEM test is a visuo-spatial test independent of language, to evaluate ocular movements in reading. However, due to a significant component of naming in the test, computable between 64% and 90%, it was suggested that language would influence the test outcome (Facchin, Maffioletti and Carnevali, 2011). Children who experience language difficulties may have reduced RAN skills (Hatch, Pattison and Richman, 1994). A language background other than English may affect the RAN performance (vertical subtests), as recent studies have found that the DEM test results are dependent on language (not only speech) (Facchin, Maffioletti and Carnevali, 2012; Baptista et al., 2011; Pang, Lam and Woo, 2010), rejecting the previous assertion that the DEM test was independent of language (Fernandez-Velasquez and Fernandez-Fidalgo, 1995).

Also, different age of learning to read, reading attainment, educational systems, developmental curve, length of word numbers, cultures and other aspects can result in different test norms. Different normative values may be found among different populations, even with the same language, such as in United Kingdom (English) or Latin America (Spanish or Portuguese) (Facchin, Maffioletti and Carnevali, 2012). Hence, a different normative value is essential for each population to ensure a valid and reliable DEM test result (Facchin, Maffioletti and Carnevali, 2012; Baptista et al., 2011; Pang, Lam and Woo, 2010; Okumura and Wakamiya, 2010).

As compared with those of the U.S., the participants were exposed to different languages, educational system, social practises and other undetermined influences. Under Singapore's Educational system, English is the primary medium of instruction and used in all school subjects except during Mother Tongue lessons (Dixon, 2005).

Although almost all Singaporeans are bilingual, these children may be better at or prefer to use their mother tongue. Thus, from clinical perspectives, it is debatable that the norm for bilingual children may be different from language-specific norms due to language influence. However, the information regarding the preferred language used was not obtained in this study. Based on the present design and findings, the exact factor/s which might account for the DEM test scores are unknown.

Even though the DEM test is reliable, and horizontal time can be used as a global measure of visual processing speed to predict reading problems (Facchin, Maffioletti and Carnevali, 2011; Orlansky, 2011; Richman 2009), caution is necessary when interpreting data from a single test administration. The test results should be analysed together with other clinical findings and patient history, and not used as an independent test purely based on a single pass or fail threshold (Orlansky et al., 2011; Richman, 2009). In the case of suspected learning difficulties, the DEM test could not be used as a definitive diagnosis, and a full evaluation is essential (Facchin, Maffioletti and Carnevali, 2012; Richman, 2009).

Test of Visual Perceptual Skills (non-motor) 4th edition (TVPS-4)

The results found in this study are much better than the previous research study which found 70% of the children with dyslexia scored below average for visual discrimination, visual memory, sequential memory and visual figure-ground (Garje et al., 2015). The mean of each subtest is also above 10, except for visual memory, with a mean of 9.83 and a standard deviation of 3.02. Overall, these results are much higher (better) than the previous findings in children with dyslexia (Fusco, Germano and Capellini, 2015).

In order to consider the importance of the pattern of results, it is important to establish how many children suffer from a deficit with sufficient severity that impact their learning. Four of the five participants who entered primary school one year later than peers, showed poor visual memory. Two of them presented prominent weakness in almost all areas of visual perceptual skills, and scored below the 10 percentiles for overall performance. Their performance may have skewed the results; this may be attributed to other possible underlying difficulties, due to their overall developmental delay rather than dyslexia, which is not within the scope of this study.

Four of the participants were born prematurely, half of them showed visual perceptual weakness in at least one subtest. This is consistent with studies suggesting that children who were born prematurely are at risk for visual-perceptual and visual memory deficits, despite adequate cognitive and motor development (Molloy et al., 2014; Molloy et al., 2013). Although visual perceptual deficits can be subtle (Davis et al., 2005), these children may have poorer academic achievements (Geldof et al., 2012). Hence, early identification and remediation are highly essential and helpful to these children.

Multiple studies have found that the link between visual perception and academic performance occurs in earlier grades. In a meta-analysis of 161 studies, involving the study of visual perception, visual memory and visual discrimination have a more significant impact on reading skills in preschool and primary levels, between 16-30% of the variance. It is insignificant for those children at intermediate levels, supporting that visual perception is more vital to reading ability at earlier grades (Kavale 1982). In a study involving 66 children with learning disabilities over three years, visual discrimination problems were found in some poor readers; it can persist and lead to poor achievement throughout elementary school (Feagans and Merriwether, 1990).

This is evident in those participants who entered primary school one year later than peers, as 80% of them showed weaker visual memory, more prominent than in other participants, which in turn, may have affected their higher order visual perceptual skills. Hence, future studies are necessary to investigate their needs further and take into account other possible underlying causes contributing to their difficulties.

The understanding of the prevalence of reduced visual perceptual skills is invaluable, as functional implications of poor visual information processing skills are related to reading difficulties. Gabrieli and Norton (2012) suggested that visual-spatial mechanisms have a direct influence on the growth of visual coding of print (orthography). Furthermore, Vidyasagar and Pammer (2010) had proposed that dyslexia may be caused by an issue in visual processing other than phonological deficits, as vision depends on normal input from the visual system. Although studies had mentioned that poor visual perceptual skills can be predictors of reading and math abilities, the precise impact remains unclear (Franceschini et al., 2012; Facoetti et al., 2010; Krajewski and Schneider, 2009).

Although studies have shown a correlation between visual perceptual and academic achievement, it is not without some controversy. A few studies have found weak associations when comparing visual perception and academic achievement. In1985, Helveston and colleagues compared academic achievement with visual functions in 1,910 children in grades 1-3 and concluded that there was no significant link between visual functions and academic achievement. However, the incidence of vision problems found in the study was lower than average, and the criteria for the children in reading groups was too simplified and subjective (Stolzberg, 1986). Nevertheless, a more inter-disciplinary approach is widely preferred when evaluating and remediating academic achievement. Auditory and visual perceptual skills are both crucial in the development of reading skills (Johnston et al., 1990). Overall, it has been mainly accepted that many visual factors, including visual perception, contribute to poor academic achievement. Thus, when attempting to remediate reading performance or other poor academic performance, it has been suggested to involve a more inter-disciplinary approach.

In terms of attention, even though a break was given before the test, 36.67% of them did show a sign of loss of concentration and required prompting to stay focused. The lack of focus may be attributed by tiredness, as the assessments were done before or after their lesson at the respective DAS learning centres, after school hours.

When we are fixating on an object, our eyes continue to move, and we are not aware of these fixational eye movements (microsaccades, drifts, and tremor). These fixational eye movements help to stimulate the firing of visual neurons when we fixate to a stationary item, in order to retain our vision. According to Martinez-Conde, Macknik and Hubel (2004), fixational eye movements play an important role in visual perception; when fixational eye movements are hindered, our visual perception fades due to neural adaptation. Although microsaccades are the easiest and biggest to distinguish, these eye movements may occur a few times per second. Hence, it remains challenging to measure fixational eye movements. Future studies with better techniques can further explore the relationship between fixational eye movements and visual perception.

Brown and Peres (2018) suggested that TVPS-4 needs to have other cross-cultural validation to ensure appropriate clinical interpretation of scores when used in other countries. Also, performance in visual perception may be influenced by ethnic, socioeconomic status, as well as different language backgrounds (Lai and Leung, 2012; Dunn, Loxton and Naidoo, 2006). Studies have shown that children from higher socioeconomic backgrounds tend to attain better scores than children from middle and low socioeconomic backgrounds (Dunn, Loxton, and Naidoo, 2006). All participants attended local mainstream schools and have the same education system. However, the information regarding language background at home and socioeconomic status were not obtained. Also, IQ was not controlled in this study.

Based on the findings, the recommendations are as follows:

- Provide training to professionals who are involved in children with dyslexia, to raise their awareness and enable them to identify those who likely to benefit from a further visual investigation.
- Educational psychologists may consider including the DEM test as a screening tool for eye movement and visual perceptual test as part of the assessments for children with dyslexia who display visual difficulties.
- Raise public awareness with regards to the difference between various eye care providers so that they can make a better-informed decision based on the level and type of eye care that they require.
- Routine eye examinations by ophthalmologist or optometrist are recommended for all children with learning difficulties. If vision problems persist, then a more in-depth specialised visual assessment is advised for further investigation.

CONCLUSION

This study gives an insight into the eye movement performance and visual perceptual skills in children with dyslexia in a local context. Also, the results have suggested that both visual deficits are present in this group of children, with 56.67% of them showing eye movement deficits and 46.67% of them displaying visual perceptual weaknesses. These findings are consistent with previous research that children with dyslexia may show deficits in eye movement performance or/and in visual perceptual skills. Hence, eye movement and visual perceptual deficits may be the potential underlying causes of learning difficulties in these children. Although the results may be attributable to a possible bias of parents who showed interest in this study, as 60% of the parents did notice their child seemed to have difficulties, such as a tendency to leave out or confuse words when reading.

Seven of the participants displayed both visual deficits. However, the type of eye movement deficits and the area of visual perceptual weaknesses involved were varied. Also, fixational eye movements were not included in this study. Hence, no correlation can be established between eye movement performance and visual perceptual skills in this study. Nevertheless, it is clear from the current study that a few of the participants who have problems with visual deficits may show a particularly severe pattern of difficulties, which is bound to impact their learning significantly.

LIMITATIONS

As an exploratory study, there were numerous limitations. Firstly, the results and findings obtained may not be generalizable due to the small sample size of 30 participants and the sampling techniques. The participants were recruited through convenience, non-probability sampling. Their participation were not random, and their parents were more likely to give consent for their child to take part in the research as they may have suspected visual difficulties in their child. As more than half of the participants did show visual deficits, future studies are necessary to compare eye movement performance and visual perceptual skills between the normal population (control group) and those with dyslexia.

Secondly, the participants' cognitive, IQ, literacy and phonological abilities were not assessed or available for direct matching due to confidentiality of psychological reports. The participants were from the DAS learning centres, studying in mainstream schools in Singapore, so it was assumed that they had average intelligence. Furthermore, there was no control group for direct comparison. Hence, future studies should include a more comprehensive selection and assessment criteria for both experimental group and control group.

Thirdly, this study was not able to control the actual demographics of the participants. There is no direct matching of the participants to the actual statistical population of children with dyslexia in Singapore. Also, confounding factors such as family background, parental educational levels, language used at home and socioeconomic status were not strictly controlled. These factors may affect both results; hence, future studies may take into account these aspects and address the possible impacts of family background on the children's performance.

Finally, although the participants were required to wear their habitual optical correction if available, other visual factors such as visual acuity, vergence and accommodation were not controlled in this study. Although previous research studies have shown that the DEM test was not related to uncorrected refractive errors, visual acuity and binocularity (Kulp and Schmidt, 1998), other inclusion criteria for future studies include: near monocular and binocular visual acuity better than 20/25 Snellen (or 0.8 decimal) acuity; normal range of amplitude of accommodation and stereopsis; and no obvious binocular anomalies (strabismus or large phoria). The DEM test was published to asses saccadic eye movements, without evaluating fixations. Although it is desirable to measure both components directly when reading, the clinically available instruments are expensive and inefficient to conduct during screening or routine eye examination. Hence, the DEM test remains as a useful screening tool. Nevertheless, future research studies can incorporate fixational eye movements to better understand the relationship between these eye movements and visual perception.

As an exploratory study, no conclusions on any cause and effect as well as relationships could be formulated. The associations observed can only indicate that there is a possibility that eye movement deficits and visual perceptual weaknesses may be present in children with dyslexia, and for some children these will be severe. Therefore, taking into account the above limitations, future studies with better research design and methodology is needed to investigate the actual eye movement performance and visual perceptual skills of children with dyslexia in Singapore. Further research may be considered to investigate the effectiveness of integrating additional accommodations or/and interventions for children with visual deficits. For example, enlarged printed materials, with proper spacing between words and lines, to minimise visual distractions.

This study has highlighted that visual difficulties involving both eye movement and visual perception are prevalent in children with dyslexia in Singapore. The deficits are more prominent among those who were born prematurely and entered school one year later than peers. Hence, this requires immediate attention.

During reading, our eyes are required to scan across the page, along a line of words and move back to the beginning of the following line. These actions require accurate and precise eye movements, and also a timely facility to process information. Any difficulty in this aspect may hinder reading. Hence, a routine eye examination is essential whenever there is any doubt about possible visual deficits. The existing protocols established by The College of Optometrists, British and Irish Orthoptic Society (BIOS), and American Optometric Association (AOA) can be used as a guideline, in setting up our local standards of practice for assessment and management of the visual deficits in children with specific learning difficulties.

Furthermore, visual perceptual skills may influence functional skills and academic outcomes, with increasing evidence that individuals with reading or math learning difficulties have poorer visual perceptual skills. Children who showed significant visual perceptual deficits might benefit from enlarged printed materials, with proper spacing between words and lines, to minimise visual distraction and optimise learning. Scheiman and Rouse (2006) advise that the treatment of underlying perceptual deficits is complementary to any educational process and this should improve the visual organisation, information processing and attention of children who have visual difficulties. By improving visual perception at a young age, we could help create building blocks for future academic success in children with visual perceptual deficits. Hence, visual perceptual training should be incorporated for those in need.

Since visual deficits in children do not disappear as they grow up and tend to remain into adulthood, they may continue to struggle visually when reading; this may have adverse effects on reading motivation and performance. Therefore, the implementation of strategies to deal with visual deficits is likely to enhance the reading fluency as well as the speed of learning. By removing the impact of dyslexia on reading difficulties, it may be beneficial in improving self-esteem (Burden, 2008). In the long-term, this may probably be more cost effective and decrease the amount of time in providing intervention for this group of children.

REFERENCES

Aslin, R. N., & Salapatek, P. (1975). Saccadic localization of visual targets by the very young human infant. *Perception & Psychophysics, 17*(3), 293-302.

Aslin, R. N., & Ciuffreda, K. J. (1983). Eye movements of preschool children: Comment. *Science, 222*, 74–75.

Ayton, L. N., Abel, L. A., Fricke, T. R., & McBrien, N. A. (2009). Eye Movement test: What is it really measuring? *Optometry and Vision Science, 86*(6), 722–730.

Baptista, A. M., de Sousa, R. A., de Morais Guerra Casal, C. C., Marques, R. J., & da Silva, C. M. (2011). Norms for the Developmental Eye Movement test for Portuguese children. *Optometry and Vision Science, 88*(7), 864–871.

Becker, C., Elliott, M. A., & Lachmann, T. (2005). Evidence for impaired visuo-perceptual organisation in developmental dyslexics and its relation to temporal processes. *Cognitive Neuropsychology, 22*(5), 499-522.

Birsh, J. R. (2005). *Multisensory teaching of basic language skills*. 2nd edn. Baltimore: P.H. Brookes Pub. Co.

Biscaldi, M., Fischer, B., & Aiple, F. (1994). Saccadic Eye Movements of Dyslexic and Normal Reading Children. *Perception, 23*(1), 45–64.

Biscaldi, M., Gezeck, S., & Stuhr, V. (1998). Poor saccadic control correlates with dyslexia. *Neuropsychologia, 36*(11), 1189-1202.

Black, J. L., Collins, D. W. K., De Roach, J. N., & Zubrick, S. (1984). A detailed study of sequential saccadic eye movements for normal-and poor-reading children. *Perceptual and Motor Skills, 59*(2), 423-434.

Borsting, E., Ridder III, W. H., Dudeck, K., Kelley, C., Matsui, L., & Motoyama, J. (1996). The presence of a magnocellular defect depends on the type of dyslexia. *Vision Research, 36* (7), 1047-1053.

Brown, B., Haegerstrom-Portnoy, G., Adams, A. J., Yingling, C. D., Galin, D., Herron, J., & Marcus, M. (1983). Predictive eye movements do not discriminate between dyslexic and control children. *Neuropsychologia, 21*(2), 121-128.

Brown, T., & Peres, L. (2018). An overview and critique of the Test of Visual Perception Skills–fourth edition (TVPS-4). *Hong Kong Journal of Occupational Therapy, 31*(2), 59-68.

Burden, R. (2008). Is dyslexia necessarily associated with negative feelings of self- worth? A review and implications for future research. *Dyslexia, 14*(3), 188-196.

Campbell, R. J. (2009). *Campbell's psychiatric dictionary*. New York: Oxford University Press.

Chivers, M. (2006). *Dyslexia and alternative therapies*. London: Jessica Kingsley Publishers.

Chung, S. T., Legge, G. E., & Cheung, S. H. (2004). Recognition and reading speed in peripheral vision benefit from perceptual learning', *Vision Research, 44*(7), 695- 709.

Ciuffreda, K. J., & Tannen, B. (1995). *Eye movement basics for the clinician*. St Louis: Mosby.

Ciuffreda, K. J., Kenyon, R. V., & Stark, L. (1983). Saccadic intrusions contributing to reading disability: A case report. *American Journal of Optometry and Physiological Optics, 60*(3), 242-249.

Ciuffreda, K. J., Kenyon, R. V., & Stark, L. (1985). Eye movements during reading: further case reports. *American journal of optometry and physiological optics, 62*(12), 844-852.

Crawford, S. G., & Dewey, D. (2008). Co-occurring disorders: a possible key to visual perceptual deficits in children with developmental coordination disorder? *Human Movement Science, 27(*1), 154-169.

Davis, D. W., Burns, B. M., Wilkerson, S. A., & Steichen, J. J. (2005). Visual perceptual skills in children born with very low birth weights. *Journal of Pediatric Health Care, 19*(6), 363-368.

Demb, J. B., Boynton, G. M., & Heeger, D. J. (1998). Functional magnetic resonance imaging of early visual pathways in dyslexia. *Journal of Neuroscience, 18*(17), 6939- 6951.

Denckla, M. B., & Rudel, R. G. (1974). Rapid "automatized" naming of pictured objects, colors, letters and numbers by normal children. *Cortex, 10*(2), 186-202.

Denckla, M. B., & Rudel, R. G. (1976). Rapid "automatized" naming (RAN): Dyslexia differentiated from other learning disabilities. *Neuropsychologia, 14*(4), 471-479.

Dixon, L. Q. (2005). The Bilingual Education Policy in Singapore: Implications for Second Language Acquisition. In J. Cohen, K. T. K., McAlister, K., Rolstad, & J., MacSwan, (ed.) ISB4: *Proceedings of the 4th International Symposium on Bilingualism*. Somerville, MA: Cascadilla Press. Available at: http://www.lingref.com/isb/4/047ISB4.PDF (Accessed: 8 September 2018).

Dunn, M., Loxton, H., & Naidoo, A. (2006). Correlations of scores on the developmental test of visual-motor integration and copying test in a South African multi-ethnic preschool sample. *Perceptual and Motor Skills, 103*(3), 951-958.

Dyslexia Association of Singapore. (2018). *Services: Programmes*. Available at: https://www.das.org.sg/services/programmes/main-literacy-programme.html.

Eden, G., Stein, J., Wood, H., & Wood, F. (1994). Differences in eye movements and reading problems in dyslexic and normal children. *Vision Research, 34*(10), 1345-1358.

Eden, G., VanMeter, J., Rumsey, J., Maisog, J., Woods, R., & Zeffiro, T. (1996). Abnormal processing of visual motion in dyslexia revealed by functional brain imaging. *Nature, 382*(6586), 66-69.

Evans, B. J. W. (2001). *Dyslexia and vision*. London: Whurr.

Everatt, J. (2002). Visual processes' in G. Reid, & J., Wearmouth, (eds.) *Dyslexia and Literacy: Theory and Practice.* (pp. 85-98) Chichester: Wiley.

Facchin, A., Maffioletti, S., & Carnevali, T. (2011). Validity Reassessment of Developmental Eye Movement (DEM) Test in the Italian Population. *Optometry & Vision Development, 42*(3), 155-167.

Facchin, A., Maffioletti, S., & Carnevali, T. (2012). The Development Eye Movement (DEM) test: Normative data for Italian population. *Optometry and Vision Development, 43*(4), 162–179.

Facoetti, A., Trussardi, A. N., Ruffino, M., Lorusso, M. L., Cattaneo, C., Galli, R., Molteni, M., & Zorzi, M. (2010). Multisensory spatial attention deficits are predictive of phonological decoding skills in developmental dyslexia. *Journal of Cognitive Neuroscience, 22*(5), 1011-1025.

Fawcett, A. J., & Nicolson, R. I. (1994). Naming speed in children with dyslexia. *Journal of Learning Disabilities, 27*(10), 641-646.

Feagans, L. V., & Merriwether, A. (1990). Visual discrimination of letter-like forms and its relationship to achievement over time in children with learning disabilities. *Journal of Learning Disabilities, 23*(7), 417-425.

Fernandez-Velazquez, F. J., & Fernandez-Fidalgo, M. J. (1995). Do DEM test scores change with respect to the language? Norms for Spanish-speaking population. *Optometry and Vision Science, 72,* 902-906.

Fischer, B., & Hartnegg, K. (2000). Stability of gaze control in dyslexia. *Strabismus, 8*(2), 119-122.

Fischer, B., & Hartnegg, K. (2008). Saccade Control in Dyslexia: Development, Deficits, Training and Transfer to Reading. *Optometry and Vision Development, 39* (4), 181-190.

Fischer, B., & Weber, H. (1990). Saccadic reaction times of dyslexic and age- matched normal subjects. *Perception, 19*, 805–818.

Fischer, B., & Weber, H. (1993). Express saccades and visual attention. *Behavioral and Brain Sciences, 16* (3), 553–610.

Franceschini, S., Gori, S., Ruffino, M., Pedrolli, K., & Facoetti, A. (2012). A causal link between visual spatial attention and reading acquisition. *Current Biology, 22*(9), 814-819.

Fusco, N., Germano, G. D., & Capellini, S. A. (2015). Efficacy of a perceptual and visual-motor skill intervention program for students with dyslexia', *CoDAS, 27*(2), 128-134.

Gabrieli, J. D., & Norton, E. S. (2012). Reading abilities: importance of visual-spatial attention. *Current Biology, 22*(9), R298-R299.

Gardner, M. F. (1996). *Test of Visual Perceptual Skills (Non-Motor)-Revised*. San Francisco: Psychological & Educational Publications.

Garje, M., Vishnu, D., Rashmi, Y., Arpita, A., & Setia M. S. (2015). Study of the visual and perceptual problems in children with learning disability. *Indian Journal of Basic and Applied Medical Research, 4*(3), 492-497.

Garzia, R. P., Richman, J. E., Nicholson, S. B., & Gaines, C. S. (1990). A new visual-verbal saccade test: The Developmental Eye Movement test (DEM). *Journal of the American Optometric Association, 61*(2), 124-135.

Geldof, C. J. A., Van Wassenaer, A. G., De Kieviet, J. F., Kok, J. H., & Oosterlaan, J. (2012). Visual perception and visual-motor integration in very preterm and/or very low birth weight children: A meta-analysis. *Research in Developmental Disabilities, 33*(2), 726-736.

Georgiou, G. K., Papadopoulos, T. C., Zarouna, E., & Parrila, R. (2012). Are auditory and visual processing deficits related to developmental dyslexia? *Dyslexia, 18*(2), 110-129.

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

Goodrich, G. L., Kirby, J., Cockerham, G., Ingalla, S. P., & Lew, H. L. (2007). Visual function in patients of a polytrauma rehabilitation center: A descriptive study. *Journal of Rehabilitation Research & Development, 44*(7), 929-937.

Gori, S., Seitz, A. R., Ronconi, L., Franceschini, S., & Facoetti, A. (2016), Multiple causal links between magnocellular–dorsal pathway deficit and developmental dyslexia. *Cerebral Cortex, 26*(11), 4356-4369.

Greatrex, J. C., & Drasdo, N. (1995). The magnocellular deficit hypothesis in dyslexia: A review of reported evidence. *Ophthalmic and Physiological Optics, 15*(5), 501-506.

Griffin, J. R., Christenson, G. N., Wesson, M. D., & Erickson, G. B. (1997).*Optometric management of reading dysfunction.* Boston: Butterworth-Heinemann.

Groffman, S. (2006). The relationship between visual perceptual problems and learning', in M. Scheiman, & M. W., Rouse, (eds.) *Optometric Management of Learning-Related Vision Problems*. (2nd Revised ed., pp. 241-280). St. Louis: Mosby, 241-280.

Hatch, S. W., Pattison, D., & Richman, J. E. (1994). Eye movement dysfunction vs. language delays in migrant children. *Journal of the American Optometric Association, 65*(10), 715-718.

Hatzidaki, A., Gianneli, M., Petrakis, E., Makaronas, N., & Aslanides, I. M. (2011). Reading and visual processing in Greek dyslexic children: an eye-movement study. *Dyslexia, 17*(1), 85-104.

Hawelka, S., Gagl, B., & Wimmer, H. (2010). A dual-route perspective on eye movements of dyslexic readers. *Cognition, 115*(3), 367-379.

Health Promotion Board. (2018). *Schools: Student Health Centre*. Available at: https://www.hpb.gov.sg/schools/school-health-services.

Helveston, E. M., Weber, J. C., Miller, K., Robertson, K., Hohberger, G., Estes, R., Ellis, F. D., Pick, N., & Helveston, B. H. (1985). Visual function and academic performance. *American Journal of Ophthalmology, 99*(3), 346-355.

Hinkley, S., Schoone, E., & Ondersma, B. (2011). Perceptions of Elementary Teachers about Vision and Learning and Vision Therapy. *Journal of Behavioral Optometry, 22*(1), 3-9.

Hoffman, L. G. (1980). Incidence of vision difficulties in children with learning disabilities. *Journal of the American Optometric Association, 51*(5), 447-451.

Johnston, R. S., Anderson, M., Perrett, D. I., & Holligan, C. (1990). Perceptual dysfunction in poor readers: Evidence for visual and auditory segmentation problems in a sub-group of poor readers. *British Journal of Educational Psychology, 60*(2), 212-219.

Kaplan, M. (2015). *The secrets in their eyes: Transforming the lives of people with cognitive, emotional, learning or movement disorders or autism by changing the visual software of the brain*. London: Jessica Kingsley Publishers.

Kavale, K. (1982). Meta-analysis of the relationship between visual perceptual skills and reading achievement. *Journal of Learning Disabilities, 15*(1), 42-51.

Kemp, G., Smith, M., & Segal, J. (2018). Learning Disabilities and Disorders - Types of Learning Disorders and Their Signs. Available at: https://www.helpguide.org/articles/autism-learning-disabilities/learning-disabilities- and-disorders.htm.

Knowland, V. C., Evans, S., Snell, C., & Rosen, S. (2016). Visual speech perception in children with language learning impairments. *Journal of Speech, Language and Hearing Research, 59*(1), 1-14.

Koponen, T., Salmi, P., Eklund, K., & Aro, T. (2013). Counting and RAN: Predictors of arithmetic calculation and reading fluency. *Journal of Educational Psychology, 105*(1), 162-175.

Kovács, I. (2000). Human development of perceptual organization. *Vision Research, 40*(10-12), 1301-1310.

Krajewski, K., & Schneider, W. (2009). Exploring the impact of phonological awareness, visual–spatial working memory, and preschool quantity–number competencies on mathematics achievement in elementary school: Findings from a 3-year longitudinal study. *Journal of Experimental Child Psychology, 103*(4), 516- 531.

Kulp, M. T., & Schmidt, P. P. (1996). Effect of Oculomotor and Other Visual Skills on Reading Performance: A Literature Review. *Optometry and Vision Science, 73*(4), 283-292.

Kulp, M. T., & Schmidt, P. P. (1998). Relationship between visual skills and performance on saccadic eye movement testing. *Optometry and Vision Science, 75*(4), 284-287.

Kulp, M. T., Earley, M. J., Mitchell, G. L., Timmerman, L. M., Frasco, C. S., & Geiger, M. E. (2004). Are visual perceptual skills related to mathematics ability in second through sixth grade children? *Focus on Learning Problems in Mathematics, 26*(4), 44-48.

Kulp, M. T., Edwards, K. E., & Mitchell, G. L. (2002). Is visual memory predictive of below-average academic achievement in second through fourth graders? *Optometry and Vision Science, 79*(7), 431-434.

Kwon, M., Legge, G. E., & Dubbels, B. R. (2007). Developmental changes in the visual span for reading. *Vision Research, 47*(22), 2889-2900.

Lack, D. (2005). Comparison of the developmental eye movement test, the Visagraph numbers test with a test of the English language arts. *Journal of Behavioral Optometry, 16*(3), 1-5.

Lai, M. Y., & Leung, F. K. S. (2012). Visual perceptual abilities of Chinese-speaking and English-speaking children. *Perceptual and Motor Skills, 114*(2), 433-445.

Laycock, R., Crewther, D. P., & Crewther, S. G. (2012). Abrupt and ramped flicker-defined form shows evidence for a large magnocellular impairment in dyslexia. *Neuropsychologia, 50*(8), 2107-2113.

Lefton, L. A., Lahey, B. B., & Stagg, D. I. (1978). Eye movements in reading disabled and normal children: A study of systems and strategies. *Journal of Learning Disabilities, 11*(9), 549-558.

Martin, N. A. (2006). *Test of Visual Perceptual Skills*. 3rd edn. Novato, CA: Academic Therapy Publications.

Martin, N. A. (2017). *Test of visual perceptual skills*. 4th edn. Novato, CA: Academic Therapy Publications.

Martinez-Conde, S., Macknik, S. L., & Hubel, D. H. (2004). The role of fixational eye movements in visual perception. *Nature reviews neuroscience, 5*(3), 229-240.

McConkie, G. W., Kerr, P. W., Reddix, M. D., & Zola, D. (1988). Eye movement control during reading: I. The location of initial eye fixations on words. *Vision Research, 28*(10), 1107-1118.

Meronen, A., Tiippana, K., Westerholm, J., & Ahonen, T. (2013). Audiovisual speech perception in children with developmental language disorder in degraded listening conditions. *Journal of Speech, Language and Hearing Research, 56*, 211-221.

Meyer, M. S., Wood, F. B., Hart, L. A., & Felton, R. H. (1998a). Longitudinal course of rapid naming in disabled and nondisabled readers. *Annals of Dyslexia, 48*(1), 89- 114.

Meyer, M. S., Wood, F. B., Hart, L. A., & Felton, R. H. (1998b). Selective predictive value of rapid automatized naming in poor readers. *Journal of Learning Disabilities, 31*(2), 106-117.

Mody, M., & Silliman, E. R. (2008). *Brain, behavior and learning in language and reading disorders*. New York: Guilford Press.

Moiroud, L., Gerard, C. L., Peyre, H., & Bucci, M. P. (2018). Developmental Eye Movement test and dyslexic children: A pilot study with eye movement recordings. *PLOS One, 13*(9), 1-11.

Molloy, C. S., Wilson-Ching, M., Anderson, V. A., Roberts, G., Anderson, P. J., & Doyle, L. W. (2013). Visual processing in adolescents born extremely low birth weight and/or extremely preterm. *Pediatrics, 132*(3), e704-712.

Molloy, C. S., Wilson-Ching, M., Doyle, L. W., Anderson, V. A., & Anderson, P. J. (2014). Visual memory and learning in extremely low-birth-weight/extremely preterm adolescents compared with controls: A geographic study. *Journal of Pediatric Psychology, 39*(3), 316-331.

Muter, V. (2003). Early reading development and dyslexia. Chichester: John Wiley and Sons Ltd.

Norton, E. S., & Wolf, M. (2012). Rapid automatized naming (RAN) and reading fluency: Implications for understanding and treatment of reading disabilities. *Annual Review of Psychology, 63*, 427-452.

Okumura, T., & Wakamiya, E. (2010). *Visual Skills in Children with Learning Difficulties*. Tokyo: Meijitosho Shuppan Corporation.

Omtzigt, D., Hendriks, A. W., & Kolk, H. H. (2002). Evidence for magnocellular involvement in the identification of flanked letters. *Neuropsychologia, 40*(12), 1881- 1890.

Orlansky, G., Hopkins, K. B., Mitchell, G. L., Huang, K., Fraizier, M., Heyman, C., & Scheiman, M. (2011). Reliability of the Developmental Eye Movement test. *Optometry and Vision Science. 88*(12), 1507-1519.

Pang, P. C., Lam, C. S., & Woo, G. C. (2010). The Developmental Eye Movement (DEM) test and Cantonese-speaking children in Hong Kong SAR, China. *Clinical and Experimental Optometry, 93*(4), 213-223.

Pavlidis, G. T. (1981). Do eye movements hold the key to dyslexia? *Neuropsychologia, 19*(1), 57-64.
Pavlidis, G. T. (1985). Eye movements in dyslexia: their diagnostic significance. *Journal of Learning Disabilities, 18*(1), 42-50.
Peer, L. (2001). Dyslexia and its manifestations in the secondary school', in Peer, L. & Reid, G. (eds.) *Dyslexia: Successful inclusion in the secondary school.* (pp.1-9). London: David Fulton,
Peer, L., & Reid, G. (2003). *Introduction to dyslexia*. London: David Fulton.
Peterson, R., & Pennington, B. (2012). Developmental dyslexia. *The Lancet, 379*(9830), 1997-2007.
Powers, M., Grisham, D., & Riles, P. (2008). Saccadic tracking skills of poor readers in high school. *Optometry, 79*(5), 228–234.
Poynter, H. L., Schor, C., Haynes, H. M., & Hirsch, J. (1982). Oculomotor functions in reading disability. *American Journal of Optometry and Physiological Optics, 59*(2), 116-127.
Rack, J., Hulme, C., Snowling, M., & Wightman, J. (1994). The role of phonology in young children learning to read words: The direct-mapping hypothesis. *Journal of Experimental Child Psychology, 57*(1), 42-71.
Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., & Frith, U. (2003). Theories of developmental dyslexia: insights from a multiple case study of dyslexic adults. Brain: *A Journal of Neurology, 126*(4), 841-865.
Ray, N. J., Fowler, S., & Stein, J. F. (2005). Yellow filters can improve magnocellular function: motion sensitivity, convergence, accommodation, and reading. *Annals of the New York Academy of Sciences, 1039*(1), 283-293.
Rayner, K. (1985). The role of eye movements in learning to read and reading disability. *Remedial and Special Education, 6*(6), 53-66.
Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*(3), 372-422.
Rayner, K. (2009). Eye movements and attention in reading, scene perception. *The Quarterly Journal of Experimental Psychology and Visual Search, 62*(8), 1457-1506.
Richman, J. E. (2009). *The Developmental Eye Movement Test, Examiner's Manual*, Version 2.0. South Bend: Bernell Corporation.
Scheiman, M. & Rouse, M. W. (2006). *Optometric Management of Learning-Related Vision Problems.* 2nd Revised edn. St Louis: Mosby.
Schuhmacher, H. (2017). *Vision and learning: a guide for parents and professionals. How undiagnosed vision problems cause learning difficulties and what you can do to unlock your child's academic potential.* Columbia: CreateSpace Independent Publishing Platform.
Schulte-Körne, G., & Bruder, J. (2010). Clinical neurophysiology of visual and auditory processing in dyslexia: a review. *Clinical Neurophysiology, 121*(11), 1794- 1809.
Sherman, A. (1973). Relating vision disorders to learning disability. *Journal of the American Optometric Association, 44*(2), 140-141.
Simons, H. D., & Grisham, J. D. (1987). Binocular anomalies and reading problems. *Journal of American Optometric Association, 58*, 578-587.
Skottun, B. C. (2000). The magnocellular deficit theory of dyslexia: the evidence from contrast sensitivity. *Vision Research, 40*(1), 111-127.
Snowling, M. J. (2000). *Dyslexia*. 2nd edn. Oxford: Blackwell.
Solan, H. A., & Ciner, E. B. (1989). Visual perception and learning: Issues and answers. *Journal of the American Optometric Association, 60*, 457-460.
Solan, H. A., & Ficarra, A. P. (1990). A study of perceptual and verbal skills of disabled readers in grades 4, 5 and 6. *Journal of the American Optometric Association, 61*(8), 628-634.
Solan, H. A., Ficarra, A., Brannan, J. R., & Rucker, F. (1998). Eye movement efficiency in normal and

reading disabled elementary school children: effects of varying luminance and wavelength. *Journal of the American Optometric Association, 69*(7), 455-464.
Sortor, J. M., & Kulp, M. T. (2003). Are the results of the Beery-Buktenica Developmental Test of Visual-Motor Integration and its subtests related to achievement test scores? *Optometry and Vision Science, 80*(11), 758-763.
Spring, C., & Davis, J. M. (1988). Relations of digit naming speed with three components of reading. *Applied Psycholinguistics, 9*(4), 315-334.
Stanley, G., Smith, G. A., & Howell, E. A. (1983). Eye-movements in dyslexic children: Comments on Pavlidis' reply. *British Journal of Psychology, 74*(2), 195-197.
Stein, J. (2001). The magnocellular theory of developmental dyslexia. *Dyslexia, 7*(1), 12-36.
Stein, J. (2014). Dyslexia: The Role of Vision and Visual Attention Current *Developmental Disorders Reports, 1*(4), 267-280.
Stein, J., & Walsh, V. (1997). To See but Not to Read; the Magnocellular Theory of Dyslexia. *Trends in Neurosciences, 20*, 147-152.
Stolzberg, M. E. (1986). Visual function and academic performance: A critique. *Journal of the American Optometric Association, 57*(12), 880.
Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education, 2,* 53-55.
Taylor, M. K. (1999). Relationship between visual motor integration skill and academic performance in kindergarten through third grade. *Optometry and Vision Science, 76*(3), 159-163.
Thaler, V., Urton, K., Heine, A., Hawelka, S., Engl, V., & Jacobs, A. M. (2009). Different behavioral and eye movement patterns of dyslexic readers with and without attentional deficits during single word reading. *Neuropsychologia, 47*(12), 2436-2445.
Van Waelvelde, H., De Weerdt, W., De Cock, P., & Smits-Engelsman, B. C. (2004). Association between visual perceptual deficits and motor deficits in children with developmental coordination disorder. *Developmental Medicine and Child Neurology, 46*(10), 661-666.
Vaughn, W., Maples, W. C., & Hoenes, R. (2006). The association between vision quality of life and academics as measured by the College of Optometrists in Vision Development Quality of Life questionnaire. *Optometry-Journal of the American Optometric Association, 77*(3), 116–123.
Vidyasagar, T. R. (2004). Neural underpinnings of dyslexia as a disorder of visuo-spatial attention. *Clinical and Experimental Optometry, 87*(1), 4-10.
Vidyasagar, T. R., & Pammer, K. (2010). Dyslexia: a deficit in visuo-spatial attention, not in phonological processing. *Trends in Cognitive Sciences, 14*(2), 57-63.
Wilkins, A. J. (1995). *Visual stress*. Oxford: Oxford University Press.
Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology, 91*(3), 415-438.
Wolf, M., Bowers, P. G., & Biddle, K. (2000). Naming-speed processes, timing, and reading: A conceptual review. *Journal of Learning Disabilities, 33*(4), 387-407.
Wolf, M., & Obregón, M. (1992). Early naming deficits, developmental dyslexia, and a specific deficit hypothesis. *Brain and Language, 42*(3), 219-247.
Wolf, M., O'Rourke, A. G., Gidney, C., Lovett, M., Cirino, P., & Morris, R. (2002). The second deficit: An investigation of the independence of phonological and naming- speed deficits in developmental dyslexia. *Reading and Writing, 15*(1-2), 43-72.
Ygge, J., Lennerstrand, G., Axelsson, I., & Rydberg, A. (1993a). Visual functions in a Swedish population of dyslexic and normally reading children. *Acta Ophthalmologica, 71*(1), 1-9.

Ygge, J., Lennerstrand, G., Rydberg, A., Wijecoon, S., & Pettersson, B. M. (1993b) Oculomotor functions in a Swedish population of dyslexic and normally reading children. *Acta Ophthalmologica, 71*(1), 10-21.