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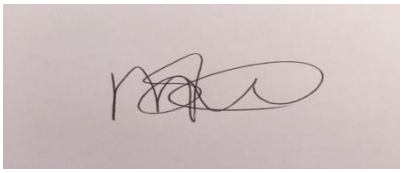
THE EFFECT OF AN OCULOMOTOR-VESTIBULAR-PROPRIOCEPTIVE SENSORY STIMULATION PROGRAMME ON READING SKILLS IN CHILDREN AGED 8 TO 12 YEARS 11 MONTHS

A dissertation submitted to the Faculty of Health Sciences, School of Therapeutic Sciences, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science in Occupational Therapy.

21 November 2016

Declaration

I, *Megan Sylvia Bense* hereby declare that this thesis is my own work. It is being submitted for the degree of Master of Science in Occupational Therapy of the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.



18th Day of November 2016.

Dedication

This thesis is dedicated to Jennifer Lewkowski whose mentorship and lifelong work inspired the exploration of this topic.

I would also like to dedicate this thesis to Ms. Franzsen who has provided guidance and encouragement through the various phases of writing.

A final dedication must be made to my father, mother and brother and the rest of the family and friends who were both patient and supportive throughout this journey.

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Abstract

The oculomotor system plays an important role in reading skills. A sensory stimulation oculomotor-vestibular-proprioceptive intervention programme was provided to primary school children who were based at a remedial school and were identified as poor readers. A sample of 30 children ranging between 8 years and 12 years 11 months formed the final participants for the study. Learners were divided into two groups and the programme was presented in an alternate group design with groups acting as a control when not receiving intervention. The intervention sessions were carried out twice weekly for three weeks. The assessments included the Neale Analysis of Reading, the Developmental Eye Movement test and an informal eye movement test.

The change in oculomotor function and reading over the intervention and control periods for both groups was determined. The results of this study were used to explore the impact of sensory stimulation on oculomotor function and reading skills. Significant positive changes were recorded for both groups but for different components of oculomotor function and reading. Group A had significant change for eye movements across the midline, DEM horizontal scores and rate of reading. Group A continued to improve after the intervention was withdrawn. Group B had significant change for quick localisation, DEM errors scores and reading accuracy and comprehension. Moderate correlations were found between vertical and horizontal scores, accuracy, and rate of reading.

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Operational Definitions

Oculomotor function or visual skills -"include subcategories of binocular vision, and ocular motility" (1).

Oculomotor system –**"**consists of interconnected regions throughout the central nervous system that interact to control various eye movements. It includes different brainstem nuclei, the superior colliculus of the midbrain, and various regions throughout the cerebral cortex" (2).

Oculomotor control - Voluntary or reflex-controlled movements of the eye (3).

Eye movements- includes saccades, smooth pursuit, and fixation and how the afferent (mostly visual and vestibular) and efferent information is processed (1).

Pursuits – "slower tracking movements of the eyes designed to keep a moving stimulus on the fovea. Such movements are under voluntary control in the sense that the observer can choose whether or not to track a moving stimulus" (4).

Fixation – maintaining of the visual gaze on a single location (3).

Saccades – **"**is a quick, simultaneous movement of both eyes between two or more phases of fixation in the same direction" (5).

Binocular vision – "wherein both eyes aim simultaneously at the same visual target; both eyes work together." This includes amongst others "vergence movements which align the fovea of each eye with targets located at different distances from the observer. Convergence is one of the three reflexive visual responses elicited by interest in a near object" (6) (4).

Visual perception - Perceptions based on sensory information received through the eyes and body as one interacts with their surrounding environment and moves one's body through space (7).

Proprioceptive system – Conscious or non-conscious reception, by the brain, of information from muscles, tendons and joints (3).

Vestibular system - The vestibular system contributes to a wide range of functions from postural and oculomotor reflexes to spatial representation and cognition. Vestibular signals are important in maintaining an internal, updated representation of the body position and movement in space (8).

Abbreviations

DEM	Developmental Eye Movements test.
NARA	Neale Analysis of Reading
VOR	Vestibular-ocular-reflex
VT	Vision therapy
LD	Learning disability

CHAPTER 1: INTRODUCTION

1.1 Introduction to the study

The oculomotor system is a system that is involved in the control of eye movements and it is a system that any individual relies on heavily for the performance of day-to-day tasks that require visual input (7). This is particularly so in children learning to read, an important skill which provides the foundation for academic achievement, personal development and communication skills. Literature suggests that children who have trouble when learning to read may have oculomotor dysfunction. These children are likely to continue experiencing reading difficulties into adulthood (9) (10) (11).

The majority of children with poor progress in reading development are referred for specialised education evaluation (9). It has been demonstrated that reading problems can be corrected at an early age when evidence-based practices are applied in a population at risk of or experiencing reading difficulties (10). Occupational therapists, as one of the team members in special education, are concerned with remediating the client factors and performance skills that underlie academic activities like reading and writing (12). Occupational therapy interventions for deficits in sensory processing abilities, perceptual and perceptual-motor performance skills are vital in a child identified with school related difficulties such as poor reading and writing skills (13) (14).

A review of the literature by Goldstand, Koslowe, and Parush (2005) indicates that the best evidence in occupational therapy for problems related to reading and handwriting addresses visual-information processing deficits (14). It would also include intervention for the client factors in visual perception, and the sensory perceptual performance skills of visual-motor integration (15). However, various disciplines, including occupational therapists, are now considering the importance of visual skills in addition to visual-information processing when addressing academic dysfunction. Kulp and Schmidt (1996) found that accurate and efficient oculomotor skills are important for tasks such as reading, copying from the blackboard and taking tests (16). Eden, Stein, Wood and Wood (1995) found the influence of oculomotor function on reading ability is significant even when

attention deficits and language are controlled (17). This was confirmed by Powers, Grisham and Riles in 2008 (11) who showed oculomotor skills well below those expected in high school students in poor readers and Seassau, Gérard, Bui-Quoc, and Bucci (2015) who confirmed oculomotor and binocular deficits in children with dyslexia (18). There is also support in the literature for an association between binocular vision and reading deficits (19).

1.2 Statement of the problem

To provide the best evidence for practice in specialised education evaluation, Schneck (2010) suggested that occupational therapists should assess and consider the role played by basic visual skills. This would include oculomotor and binocular visual function and the impact of these skills on reading ability (15).This is important as visual input is dependent not only on visual perception and visual acuity but also oculomotor control, which may be affected when there is vestibular dysfunction. Deficits in the vestibular-ocular-reflex (VOR) effect the coordination of the eye and head movements (20) used when reading, contributing to gaze instability when following words on a page (21). Furthermore, it has been found that delayed vestibular maturation in children, associated with sensory integration dysfunction, and slow visual processing is also linked to reading disability in primary school children (22).

There is controversy about whether deficits in oculomotor function have a negative effect on school performance, specifically reading (14). Furthermore, there is very little available research on the impact of intervention strategies that include vestibular processing, the contribution of this system to oculomotor function and the effect this intervention may have on aspects of reading skills.

1.2 Purpose of the study

Since occupational therapists assess and treat vestibular processing and oculomotor deficits using sensory stimulation, the role of this intervention will be investigated in relation to a measured outcome of reading performance in primary school learners with identified reading problems.

1.3 Research question

Will an oculomotor-vestibular-proprioceptive sensory stimulation programme have an effect on reading rate, reading accuracy, comprehension and oculomotor function in primary school learners with identified reading problems?

1.4 Aim and objectives

1.4.1 Aims

To establish the effectiveness of an oculomotor-vestibular-proprioceptive sensory stimulation programme on reading rate, reading accuracy, comprehension and oculomotor deficits in primary school learners with identified reading problems.

1.4.2 Objectives

- To determine the effectiveness of a sensory stimulation oculomotor-vestibular-proprioceptive intervention programme on the reading rate, reading accuracy and reading comprehension of primary school learners aged 8 to 12 years 11 months (Grades 2 to 7), using the Neale Analysis of Reading (NARA).
- To determine the effectiveness of a sensory stimulation oculomotor-vestibular-proprioceptive intervention programme on the oculomotor function of primary school learners aged 8 to 12 years 11 months (Grades 2 to 7), using the eye movement section of the Clinical Observation Assessment, adapted from Ayres Sensory Integration Theory, and the Developmental Eye Movements test (DEM).
- To determine the association at baseline and at the final assessment between the reading rate, reading accuracy and reading comprehension and oculomotor function of primary school learners aged 8 to 12 years 11 months (Grades 2 to 7), using the NARA, clinical observation and the DEM.

1.5 Null hypothesis

A sensory stimulation intervention programme to improve oculomotor-vestibular-proprioceptive processing will have no effect on the reading rate, reading

accuracy, reading comprehension and in oculomotor function of primary school learners aged 8 to 12 years 11 months (Grades 2 to 7).

1.6 Justification for the study

This research project aims to determine the effects that sensory stimulation of the vestibular, proprioceptive and oculomotor systems has on reading rate, reading accuracy, comprehension and oculomotor control. In addition to this, the lasting effects of the stimulation on these components will be assessed.

Literature supports that eye movements (oculomotor system) play an important role in reading skills. Occupational therapists address oculomotor function, and thus reading skills, through sensory stimulation. It has been proposed that stimulation of the vestibular system, the proprioceptive system and oculomotor system form the basis of intervention when aiming to improve oculomotor skills (7). Although the research is controversial, literature has suggested that reading more quickly could improve one's ability to better comprehend written text (23).

An alternate group research design was used to provide a sensory stimulation programme for children between the ages of 8 to 12 years 11 months (Grades 2 to 7) with reading problems associated with poor oculomotor function. The programme includes a specific order of vestibular stimulation and a therapeutic activity that involves the whole body. This programme is designed to improve oculomotor function and measure these effects against reading skills. Oculomotor function and reading skills will be measured through the assessments.

1.7 Layout of Dissertation

Chapter 1- Introduction

An introduction to the role of visual function in reading difficulties and concerns in occupational therapy about the assessments and effect of oculomotor and binocular dysfunction. The statement of the problem, the purpose of the study, aim, objectives and justification for the study are included in this chapter.

Chapter 2 Literature Review

This chapter includes a literature review with describes the oculomotor system as well as the association with the vestibular system and proprioceptive system. The effects of vision and oculomotor function on academics and reading are considered as well as the association between oculomotor and related systems and reading proficiency. The assessment of reading proficiency and eye movements in occupational therapy are reviewed as well as vestibular-proprioceptive sensory stimulation programmes in the treatment of oculomotor dysfunction.

Chapter 3 Methodology

A diagram depicting the layout of the methodology is included. An alternate group design was used so the participants could be divided into two groups**.** A longitudinal research design was used to provide the intervention to participants in a sequence. The population for the study, sample selection, including the inclusion and exclusion criteria, sample size, the variables and the five measurement tools are described. The research procedure and the method of data collection are laid out and the ethical considerations and data analysis are explained.

Chapter 4 Results

Areas within the demographics are described into personal demographics that discusse gender, language and age of the participants and the educational demographics. The within-group analysis is divided into results for Group A and Group B. Results of the Clinical Observations and Developmental Eye Movements test for each group is extrapolated under visual and oculomotor function while the results for the Neale Analysis of Reading (NARA) are discussed under reading ability. A between Group Analysis was also carried out, with a discussion on the comparisons of the groups at assessment 1, oculomotor function and reading ability. The associations between change in oculomotor function and reading scores are then explained and this is followed by a summary.

Chapter 5 Discussion

The demographics, the effectiveness of the programme on reading skills, the effectiveness of the programme on oculomotor skills, the associations at baseline and the final assessment between reading skills and oculomotor skills as well as the limitations of the study are discussed and linked to current research.

Chapter 6 Conclusion

This chapter brings the results and the discussion together and includes research and final thoughts on the programme and what can be done in the future.

CHAPTER 2: REVIEW OF THE LITERATURE

2.1 Introduction

This literature review considers the oculomotor system as well as the association with the vestibular system and proprioceptive system. The effects of vision and oculomotor function on academics and reading are reviewed and the association between the oculomotor and related systems and reading proficiency is considered. The assessment of reading proficiency and eye movements in occupational therapy are examined as well as vestibular-proprioceptive sensory stimulation programmes in the treatment of oculomotor dysfunction.

Literature was searched by using keywords such as oculomotor system, vestibular system, proprioceptive system, association of oculomotor function and reading ability, assessment of oculomotor function and vestibular-proprioceptive sensory stimulation programmes. The databases used were Science Direct, Elsevier, EBSCO Host and Ovid Proquest and Pubmed.

2.2 Vision and visual function

Visual function can be divided into visual acuity, visual fields and contrast sensitivity. The visual function looks at how the eye and visual system functions with the outcomes being measured at the eye or organ level.

Functional vision then relates to how the individual uses vision and is measured by the person's visual skills and how they use these skills in functional activities. These include accommodation, binocular vision and ocular motility or oculomotor function, which relate to the coordinated movement of the eyes (24,1).

Visual ability is then a combination of visual function and functional vision, where stimuli relayed to the brain and the processing of the visual input supports one another.

2.3 The oculomotor system and associated systems related to vision

The literature shows that links between the peripheral vestibular apparatus, ocular system, postural muscles, brainstem, cerebellum and cortex have been explored (25). The vestibular system interacts with the visual and proprioceptive input to provide stability within the environment as we negotiate daily activities. Vestibular centres in the brainstem, cerebellum, and cerebral cortex function to integrate sensory information from the peripheral vestibular organs, visual system, and proprioceptive system to allow for proper balance and orientation of the body in its environment (25). This also allows an accurate image to be obtained on the retina, as with head movement, these systems integrate (26).

2.3.1 Vestibular system

The vestibular system is a complex sensory organization that involves communication with many systems and areas within the brain (25) (27). The vestibular system can be divided into the peripheral vestibular system and the central vestibular system.

The peripheral vestibular system is located in the inner ear and is sensitive to movement of the head, gravitational forces and vibration. The five major vestibular structures are located in the inner ear. These five structures consist of two otoliths that are sensitive to linear (or straight line) accelerations; the utricle, in the horizontal plane and the saccule, in the vertical plane, and the three semicircular canals; namely the lateral, superior and posterior semicircular canals, that are sensitive to angular accelerations (head rotations) (25) (27) (28). The central vestibular system is a multimodal central nervous system (CNS) system. This system is integrated with vision and proprioception and has close links with areas within the brain such as the cerebellar, reticular and autonomic systems (25) (3).

The utricle and saccule contain macula and the semicircular duct contains an ampulla which houses crista. The macula signals head position and responds to linear acceleration of the body in the horizontal and vertical plane and when the head is stationary and tilted in either flexion or extension. The primary function of the static labyrinth is to indicate the position of the head relative to the trunk and

contributes to the sense of position of the body in space. Interactions between the visual system, conscious proprioceptive system and vestibular system when sensing body position are reported in the literature (3). The crista signals head movements and are sensitive to angular accelerations. The lateral ampullae are activated by turning the head to the right and left side respectively. Both superior ampullae are activated by flexion of the head and both posterior ampullae are activated by extension of the head. The function of the dynamic labyrinth is to inform compensatory eye movements in response to head movements. The vestibulo-ocular reflex (VOR) forms part of this reaction (27) (3).

The function of the vestibular apparatus includes the detection of head movements and gravitational forces in the body (25) (3). The information received by the vestibular apparatus is processed in the brain, which informs the body to maintain balance and correct spatial orientation during movement and correct processing of visual images whilst in motion (25).

Hair cells on the neuroepithelium of the peripheral vestibular organs carry sensory impulses to primary processing centres in the brainstem and cerebellum. These areas relay this information via ascending and descending fibres to co-ordinate vital reflexes. These reflexes allow for the proper orientation of the eyes and body in response to head movement (25).

The vestibulocollic reflex (head stabilization), reflex control of upright posture, and the vestibulo-ocular reflex (retinal image stabilization) are some of the fundamental reflexes of which the vestibular system forms the basis (27).

The vestibulocollic reflex is the compensatory response of neck muscles to rotation of the head, which aims to stabilise the position of the head so that the gaze can be directed (29). The vestibulospinal reflex is related to the vestibulocollic reflex. The vestibulospinal reflexes are important for maintaining balance, posture and keeping the head horizontal (27) (3). The lateral vestibulospinal tract is linked to antigravity extensor tone. The medial vestibulospinal tract operates head-righting reflexes which aim to keep the head and gaze horizontally when the body is flexed forward or to the side. The eye-righting reflexes also play a role in stabilising gaze in response to movement of the head as the eyeball can turn up to 10 degrees within the eye socket (3).

The vestibule-ocular reflex results in eye movements that aim to stabilize one's gaze despite head movements (30). This reflex provides a stable visual field and enables visual fixation during head movements (27) (30).

The vestibular system also supports many other functional activities. These activities include the following (25) (3) (31) (32):

- being the primary organiser of sensory information,
- integrating sensory input at the brainstem level,
- providing unconscious awareness of a person's movement and position in space,
- maintaining postural control and equilibrium which plays a role in positions held against gravity (extensor tone) and the modulation of body and eye movements relative to gravity,
- contributes to physical and emotional awareness.

2.3.2 Proprioceptive system

Neurologists describe two types of sensation: conscious sensation which is perceived at the level of the cerebral cortex and nonconscious sensation that is not perceived and has reference to the cerebellum. Conscious proprioceptive sensation emanates from within the body with the receptors being linked to the locomotive system (muscles, joints, bones) and the vestibular labyrinth. The position sense of the body when it is stationary (position sense) and when it is in motion (kinaesthesia) is perceived by the cerebral cortex (3) (33). The posterior spinocerebellar tract (lower limb and lower trunk) and the cuneocerebellar tract (upper limb and upper trunk) are concerned with nonconscious proprioception. They run from the spinal cord and terminate in the cerebellum. The posterior spinocerebellar tract receives varied primary afferent information from the muscles, joints, muscle spindle primaries and collateral information from cutaneous sensory neurons. Both of these tracts consist of separate tracts made up of proprioceptive and exteroceptive components. The proprioceptive information carried by the components of these tracts allows for spatial discrimination. However, the information cannot be fully classified as proprioceptive or exteroceptive as they lack modality specificity and carries crude

information regarding spatial discrimination. Information about spatial discrimination aims to keep the cerebellum informed of ongoing movements of one's body within ones' environment (3) (34).

Proprioception includes both sensory and motor pathways. It contributes to postural control, joint stability, and several conscious sensations (35). Therefore, proprioception is important in the development of body schema, motor planning and motor coordination and modulation of behaviour (33). The proprioceptors of skeletal muscle are the muscle spindles that measure length, and Golgi tendon organs that measure force (3) (36). The main central nervous structures processing proprioceptive stimuli are the spinal cord, cerebellum, thalamus, cortex and other parts of the central nervous system. Integration at the level of the cerebellum supports the smoothness of muscle action, is involved in rapid and complex muscle activity and integrates with vestibular input in the timing of actions. Integration at the level of the basal ganglia aids in initiating movements of sustained and repetitive nature and is involved in posture and muscle tone (3) (33) (37) (38).

The proprioceptive system interacts with many systems and can be studied under the proprioceptive vestibular, proprioceptive tactile and proprioceptive visual interactions (39) (32) (33). Interactions between the proprioceptive and vestibular system aid in the correction of one's balance but it is important to note that this differs across various muscle groups and is dependent on various factors (39). Proprioceptive visual interactions have been found to support the central processing of visual information (40).

2.3.3 Oculomotor System

The oculomotor system provides for accurate and effective ocular pursuits, saccades and fixations and includes control of the extraocular muscles. The oculomotor nerves consist of the abducens and trochlear nerve. They provide the motor nerve supply to the four recti and two oblique muscles that control the movements of each eyeball. Two additional sets of neurons supply the upper eyelid and the sphincter of the pupil and the ciliary muscle. The ocular motor units contain type A fibers (fast twitches for saccadic movements), type B fibers (slow

twitches for smooth pursuits) and type C fibers (contractions keeping the visual axes of the two eyes parallel with one another) (3).

Palisade endings (PEs) are specific to the extraocular muscles. While research shows PEs consist of both sensory and motor functions, the exact function is unclear (36) (41). The sensory function of PEs may act as eye muscle proprioceptors and interact with proprioceptive input from the neck muscles, which can be assumed to assist in simultaneous coordinated movement between the eyes and the head (3) (41).

The eyes normally move as a pair. Conjugate eye movements can be divided into scanning, tracking and compensation. Scanning involves looking at a target in high-speed movements in specific directions (right, left, up or down). They are called saccades and can be classified as horizontal saccades (left and right), upward saccades and downward gaze. Automatic scanning eye movements are described as making sideward glances in response to visual stimuli in the peripheral visual field that attracts attention, as well as the movements used when reading. Voluntary scanning movements are initiated in the frontal eye field and are thought to be linked to the facilitation of eye movement linked to the movement of an object (5).

Tracking involves monitoring the position of a moving object, detecting the object's rate of movement, coordination of movement between the eyes and the head and ensuring smooth execution of eye movements. The dynamic labyrinth (vestibular system) and the cerebellum control the smooth execution of eye movements. Compensatory eye movements involve the vestibule-ocular reflex where one's gaze can be held on an object despite head movements.

Accommodation is an additional functional aspect of vision where the ciliary muscle either contracts or is inhibited which results in the suspensory ligament either relaxing or tightening to influence the lens of the eye. This enables focused viewing of an object that is close by (near response) or an object that is far away (far response). Furthermore, the evaluation of the vergence system is an important part of binocular vision testing. Interactions between the accommodative and vergence systems are needed to ensure simultaneous responses in both systems

but the exact relationship between these two systems requires further exploration (5).

2.3.4 Vision and the relationship to the vestibular and proprioceptive systems

According to Knickerbocker, clustered clinical patterns exist where common characteristics are shared between and among the sensory systems. One of these patterns is the Visuo-Vestibular Dyad (31). The main links between these areas are the righting reflexes, maintenance of equilibrium responses and the proprioceptive facilitation of the extraocular muscles (31).

There are many functional aspects of vision. The reflexive protection functions include the teaming and automatic conjugate eye movements, which via the vestibulo-ocular pathways, enables the eyes to remain fixed on a stationary object while the head and body move. Deficits in relation to this function can result in difficulty controlling eye movements during head movements (7).

Deficits which result in a person moving their whole body when having to look at a target are related to the regulation of eye position relative to head position, linked through cranial nerves III, IV and VI. These work in concert with neck proprioceptors and vestibular receptors. According to Moore (2001), the vestibular system is critical for maintaining postural control and equilibrium while performing desired activities, by modulating movements of the body and eyes relative to gravity (7) (15) (42).

The role of the vestibular system includes holding the head stable so that the eyes can focus, contributing to bilateral integration or functioning of the eyes together and smooth eye movements across the visual midline, all of which are required to read (7). The vestibular-proprioceptive awareness of body scheme relative to environmental space is also essential for spatial orientation of the body within the environment and knowing where (8) the body is relative to objects or people. This includes an understanding of laterality and directionality and understanding the concepts like right and left in letters, words and the direction of text on a page.

Proprioceptors in the eyes, neck and body, on the other hand, integrate with the vestibular system to help orientate the head to direct the eyes on the task at hand

and to coordinate movement. Proprioceptive input interacts directly with the vestibular nuclei, as well as the cerebellum, resulting in the integration of all this input at the level of the cerebellum. This aids in the smoothness and timing of rapid and complex muscle activity as well as actions important for the eyes which, are controlled by six muscles (43).

The voluntary-exploratory functions related to complex visual muscle activity include volitional scanning and gaze shifting, which is the voluntary ability to look around the visual field and aid in eye contact and visual orientation. This is also required for visual attention and memory, which is the ability to focus cognitively on a specific set of points in the visual field and remember them in context, which aids in the storing or retrieval of visual information essential for comprehension when reading and the recognition of letters and words. Learning, memory, recall of colours and details forms part of stored visual information so that it can be used for comparison in the future. This supports the recall of visually presented material and details that were viewed sequentially including visual recognition of communication-symbolic language. This translates to a person's ability to read written symbols (7) (15) (43). It is clear that the visual functions provide a strong base for the engagement and achievement in occupational outcomes in learning and reading.

2.4 Role of Visual Skills in Academics

The importance of processing visual information when learning supports the ability to interpret visual stimuli so learners can understand what is seen. While vertical visual skills lead to aspects like perceptual constancy, horizontal skills allow for the clear tracking and scanning of visual information.

Vaughn, Maples, and Hoeneshigh (2006) indicate that a high percentage of functional visual problems go undetected at school resulting in failure and dropping out at a high school level. In their development of a screening instrument for visual function, they found in a sample of 567 high school learners, average age 15 years and referred for visual problems, that only approximately 20% of the students had no problems with visual skills while 40% had dysfunction in more than one area of visual skills.

They report that oculomotor, binocular and accommodation deficits are considered risk factors for academic performance and that when these visual function problems are treated the deficits do improve (43). Visual skills have been therefore been related to learning and deficits in visual skills lead to discomfort and avoidance when needing to use vision in the classroom to achieve academic skills. Learners have problems completing work timeously and may appear to have inattention problems. These deficits affect vocabulary development, reading and comprehension in particular with computer use requiring even more efficient visual skills (44).

Quaid and Simpson (2013) showed that the child receiving individual education plans who presented with poor reading skills had significant differences for visual function skills compared to typical children. The scores for visual function related to vergence, binocular vision and oculomotor function were significantly correlated to their reading speed and the number of eye movements made when reading. They emphasise the importance of completing a full visual function assessment in children with reading problems (45).

2.5 Assessment of Visual skills in occupational therapy

Scheiman (2011) indicates that in the assessment of oculomotor visual function occupational therapists should assess fixation, pursuits and saccades (1). Assessments suggested for use in occupational therapy include the Eye Movement section of the Clinical Observation adapted from J Ayres, which includes fixation by assessing the ability to localise objects, general pursuits and those across the midline, as well as the binocular assessment of convergence (46). This was compiled by the South African Institute for Sensory Integration. The Clinical Observations administration and interpretation booklet was revised in 2005 and includes, among various subtests, a subtest for observing eye movements (47).

Observations of the eye movements subtest determines the ability of the child to establish and maintain visual contact with a target.

The important behaviours for the examiner to note while completing these movements are the following; independent eye from head movements, whether

pursuits are smooth and coordinated, whether the eyes wander and/or can regain contact with the target if lost, if the eyes go ahead or behind the target, if the eyes move in unison, presence of a midline jerk and differences between the left and right eye. The score for each of the above-mentioned movements are in a range for 1 to 3 with 3 being normal, 2 slightly difficult and 1 definite problem (47).

Scheiman (2011) also suggests the use of the Developmental Eye Movement (DEM) test for assessing aspects of visual function. The DEM test involves reading aloud vertical numbers, with no horizontal eye movements, to assess automaticity of eye movements associated with rapid automatized naming (RAN). Rapid automatized naming has been found to be easier for typical children than those with dyslexia and the DEM test takes this component into account when assessing reading (48).

The reading aloud of horizontal numbers requires horizontal oculomotor control. Both the vertical and horizontal scores have a time element and are adjusted according to the number of errors made. A ratio score is obtained by dividing the horizontal and vertical score to determine the type of visual function deficits found. Various authors have recommended the test for determining if there are tracking and saccadic problems related to reading (11) (49).

Other authors feel that the DEM does result in false negative and false positive results when assessing reading (50) and indicate that the test should be used with caution in assessing reading proficiency. Webber pointed out in their study using the DEM that the rate of reading may not be well assessed by the DEM, which may be affected by the cognitive aspects of reading when reading for comprehension (49).

The DEM is, however, simple to administer and takes a few minutes. Norms are available for ages from 5 to 13 years although these were established in the United States of America (USA) (51) Slower horizontal scores before the age of 13years have been attributed to developmental factors and younger subjects do make more errors on the test. The DEM has been used extensively in research to correlate reading proficiency with visual function deficits and identifies these as type I – normal, type II- oculomotor deficits, type III - automaticity deficits and type

IV – mixed deficits with elements of both automaticity and oculomotor dysfunction (51).

No published studies in occupational therapy using this assessment were found, however, this assessment is appropriate to assess eye movements to determine the effect on reading proficiency in children up to 13 years of age.

2.6 The effect of vision on reading and reading proficiency

2.6.1 Reading and visual skills

According to the Progress in International Reading Literacy Study 2006, South Africa's average achievement in reading literacy at Grade 4 and 5 levels was lower than the depicted fixed international average (52). It was furthermore documented that only 17 to 18% of English and Afrikaans learners (combining both grade 4 and 5) reached benchmarks where they could be considered to be competent readers (52). Poor reading skills in South African pupils were reported to be a 'crisis' (53).

The literature has identified that a possible reason for reading difficulties may be related to eye movement deficits (54). The visual pathway plays an important role in visual coordination of posture, oculomotor adaption and the control of eye movements (7). This includes saccades and smooth pursuit eye movements which are two different modes of controlling eye movements. Saccades are primarily directed toward stationary targets whereas smooth pursuit is elicited to track moving targets. In recent years, behavioural and neurophysiological data demonstrated that both types of eye movements work in synergy for visual tracking. This suggests that saccades and pursuit are two outcomes of a single sensorimotor process that aims at orienting the visual axis (55). Deficits in the control of the eye movements can result in losing one's place while reading, turning the head with eye movements and losing the place on the page when copying, affecting both the rate and accuracy of reading (56).

2.6.2 Reading proficiency

Reading is the process whereby an individual is able to draw meaning from written text. While it is possible to separate the act of reading into various components, it is the integration and fluency of various skills that denote the proficiency of the

reader. The prior knowledge of the reader on the specific topic, the reason for the reading and the context in which the reading occurs also influences the proficiency of reading (57).

Many factors put a child at risk of having difficulties with reading. These factors include poverty, speech and hearing difficulties, difficulties with phonological processing, memory difficulties, language barriers and low reading abilities of parents (58) (59). The skills required to be a proficient reader are vast and include phonemic awareness and knowledge of phonetic code, directional tracking and the ability to synthesise, blend and pay attention to details in the print (60). Eye movements have been highlighted as a factor that influences the reading process (59) (58) (60).

Saccades or directional tracking includes scanning from left to right in a straight line and this action supports a reader's ability to get the correct order of letters. Additionally, in a study that explored the predicting factors for developmental dyslexia, visual search was reported as a difficulty for some of the readers (59). While reading is described as a complex process where a number of varying factors are at play, for the purposes of this study, oculomotor function was isolated as an influencing factor on reading proficiency.

Literature suggests that the eye movements of poor readers differ from those of typical children. Rayner (1998) reported a number of authors in a review of 20 years of research, as indicating that children with dyslexia make a greater number of regressive movements related to saccadic problems when reading (61). Eden et al. (1995) monitored eye movements and tracking of 93 Grade 4 children and reported that their reading problems may be a result of poor oculomotor function (17). When using the DEM with children and adults who were proficient and non-proficient readers, Medland, Walter and Woodhouse (2010) felt that it may be the practice related to reading left to right and not eye movements per se that were measured. They did however, find that the DEM scores were associated with reading proficiency (62).

This was confirmed by other studies that have investigated the role of oculomotor function and reading proficiency including Powers Grisham and Riles (2008) on 684 students with an average age of 15.5 years. Students who had been identified

with poor reading performance were assessed using the DEM. The study found that the horizontal scores, which assess saccadic movement, were affected with these Grade 9 students scoring below a Grade 8 level, with error scores at Grade 2 and Grade 3 levels. They reported that the normal vertical scores indicate that rapid atomised naming was adequate for these students which they felt, indicated normal cognitive ability. The ratio scores confirmed the slower horizontal tracking confirming the presence of oculomotor dysfunction in these students. However, they were not formally assessed for reading proficiency (11).

Palomo-Álvarez and Puell (2009) found similar results with 81 poor readers between the ages of 8-10 years in a Spanish study. They found lower scores for rapid alternating movements in younger children and reported that 45.7% of the children fell into the oculomotor type II dysfunction and 30.9% with type IV automaticity and oculomotor skills deficits (63).

Reading requires complex organisation of the sensory input from the eyes, the eyes and neck and the vestibular system. When the visual input is processed in the brain, it is compared and integrated with information from the muscles, joints and the vestibular system to provide information about the environment and the position of objects within it. Processing at all levels of the brain and adequate integration of another sensory input together with visual input is required to support effective and efficient functioning within the environment (64).

Evidence for the relationship between efficient oculomotor function, reading rate and comprehension is however not consistent (23). Furthermore, little is known about how patterns of eye movements may be associated with potential relationships between reading rate and comprehension even though a number of studies have shown that reading more quickly improves comprehension. However, this appears to be controversial (23).

2.6.3 Assessment of reading proficiency

Reading proficiency is a broad term but the end goal is that the individual should be able to understand the text. In order for this to occur, two processes should take place, decoding of written words and processing what meaning should be extracted (65). However varied, the assessment of reading can be separated into

various categories and general principles can be applied when assessing comprehension skills (65). The Neale Analysis of Reading Ability – Second Revised British Edition (NARA II) is considered a well-established test of text reading ability (66). Comprehension, accuracy and rate are scored in this assessment. Reading comprehension is the ability to understand the main narrative of the text, the sequence of events and other details from the contextual cues. Reading accuracy is determined by recording the errors. Errors are any inaccuracies that may appear while reading. Reading rate is the number of words read accurately over a space of time (67).

Although fluency has been considered a fundamental aspect supporting proficient reading, research regarding the factors that facilitate rate and mode of reading fluency are limited (66) (68) (69). Fluent readers read with meaning (69) which would influence their ability to construct meaning from the written text and apply this knowledge. Reading fluency can be separated into an accuracy and speed component (66). Reading rate has also been identified as a key factor in reading comprehension (66) (68) (69). Although the NARA does not measure fluency, the rate score does represent words read accurately per minute aloud (66) (67).

The NARA II consists of a set of graded passages used to assess the Rate, Accuracy and Comprehension of oral reading. The NARA II can be used for children aged 6 to 12 years 11 months and provides reading ages and standardised scores for two parallel sets of passages, based on fully representative national samples. The test materials consist of a manual for schools, a reader and individual record forms. The test material is presented as a book and comprises of short, graded narratives. Each narrative contains a limited number of words and has a central theme, action and resolution. Pictures accompanying each narrative are used to set the scene and not give details to the narrative (67).

Comprehension is assessed in terms of questions that require the child to use all of the contextual clues. The questions assess the understanding of the main idea of the narrative, the sequence of events, other details and some limited inference. Accuracy in reading is assessed by recording the child's errors. The term errors, in this case, are used to describe any inaccuracies in reading. The errors are used

for normative purposes to obtain an objective measure of the accuracy with which a child recognizes words. There are six error categories which include mispronunciations, substitutions (real words that are used instead of the real word in the narrative), refusals (child pauses for 4-6 seconds and does not make any attempt at a word), additions (words or parts of words inserted in the text), omissions (words omitted from the text) and reversals ('no' for 'on'). Rate is determined by recording the time it takes for the child to read the passage. Words per minute are then calculated by dividing the number of words read in the passage by the time it took to read the passage and then multiplying that by 60 (67).

2.7 Critical review of the association between oculomotor and related systems and reading proficiency

Some of the most important human brain systems are dedicated to the maintenance of the balance between the self and the external environment, by processing and integrating many different bodily sensory stimuli (70) (71).

Visual processing was traditionally thought of as an isolated process affecting only eyesight or the ability to see clearly. However, it is not insular; it is a dynamic and interactive processing system as shown in the literature. The functional aspects of vision are varied and support a number of activities required to participate within one's environment.

It is clear that reading is a complex process and any intervention strategy would have to incorporate various schools of thought to address it. Although controversial, reading rate has been identified as a factor that influences comprehension (66). It can therefore be inferred that smooth oculomotor control could then positively influence the speed at which written words can be processed and in turn influence accuracy, if vocabulary knowledge (68) is intact.

This study recognises the concept of a bottom-up approach to learning. This holistic approach looks at patterns of clinical behaviour which are seen between and among groups of sensory systems. In recognising these patterns, one is able to establish a comprehensive and interconnected foundation for therapy (31). This concept supports the idea that the sensory systems form the foundation of a

proposed hierarchy that ensures successive educational achievement in various academic outcomes.

2.8 Intervention using a vestibular-proprioceptive sensory stimulation programme

While optometrists use vision therapy (VT) to address eye movements and the coordination to improve oculomotor skills, occupational therapists utilise sensory stimulation aimed at the integration of the senses at brainstem level. This allows a child to make an adaptive response that integrates the sensations and facilitates the organization of sensory information required for skills such as reading (7) (16) (42).The facilitation of the vestibular system and proprioceptive system are a major component of intervention. These systems, which the literature has shown to be closely linked to the visual system in terms of oculomotor and binocular visual function, have been found to impact on reading ability (15) (16).

“Man does not develop visual perception through his eyes alone, nor does he see by his visual cortex alone. Meaningful vision is produced only by integrated action among many parts of the brain, involving, in addition to visual stimuli, other sensory stimuli, especially somatosensory and vestibular, and related motor behaviour.” Ayres 1972 pg. 201 (72).

An intervention programme that uses sensory stimulation of the auditory, vestibular and visual systems as the basis for the engagement in tasks is the Astronaut Training programme. This programme is a sound activated, vestibular-visual protocol for moving, looking and listening. The protocol is to be used by therapists that are training or are trained in sensory integration techniques and aid in understanding the influence of the Vestibular-Auditory-Visual Triad on meaningful engagement in daily tasks (73). The programme requires the client to engage in the specific head, body and eye activities, while listening to specified music and space sounds.

The programme includes preparation activities to prepare the client for rotary and linear movement. Specific rotary movements are applied and are paired with a set of eye movements i.e. counterclockwise and clockwise rotation in sitting paired with horizontal saccadic eye movements and horizontal smooth pursuits eye

movements and left and right side lying followed by vertical saccadic eye movements and vertical smooth pursuit eye movements, and a set of eye movements that are supported by the vestibular system i.e. horizontal- vertical- diagonal saccades, figure eight smooth pursuits, horizontal, vertical and circular head movements, near-far eye training and peripheral vision. These three phases are then followed by at least one linear/ core movement activity (73).

The vestibular system links up with the visual and auditory system and supports our understating of three-dimensional space. The vestibular system must be activated by the musculoskeletal system, which also includes the tactile and proprioceptive sense (73). The vestibular system supports daily tasks by providing an understating of our head and body position in gravity bound space. There are a number of ways that activation of the vestibular system aids in performance in day to day tasks and is central to our survival and ability to function (73) (74).The vestibular system activates the core postural muscles which provide a solid base for keeping the eyes steady on a target when the body is in motion. Inadequate processing of the vestibular system would result in poor participation of the oculomotor system in tasks such as reading, writing, copying and ball sense skills, an inability to orientate oneself and navigate through one's environment and the inability to mentally visualize objects, which supports advanced cognitive skills (73).

The oculomotor-vestibular-proprioceptive intervention programme was compiled from a number of sources. Bundy, Lane and Murray outlined the main elements of the oculomotor, vestibular and proprioceptive system for an intervention programme (7) and this was adapted for the oculomotor-vestibular-proprioceptive intervention programme. The Astronaut training programme, among other things, showed strong links between the systems and included strong activities and descriptions of the oculomotor elements. Activities were sourced from the Astronaut Training programme and incorporated with the proposed outline by Bundy, Lane and Murray to form the oculomotor-vestibular-proprioceptive intervention programme.

2.9 Summary

It is clear that common characteristics are shared between and among the sensory systems (31) and it is the integration of sensory information that allows us to actively engage in and achieve success in our daily activities. The vestibular system is associated with balance, coordination, development of muscle tone, proximal joint stability, postural control and plan of action. In a study that aimed to improve motor abilities of children, it was found that when vestibular stimulation was included, the results of motor abilities were more efficient (63). Furthermore, this system is closely linked to the extra ocular muscles thus aiding in the development of visual motor integration and the sense of spatial relationships of an individual within an environment. (73).

Visual skill deficits have been linked to poor academic performance including reading deficits and should be considered by occupational therapists when assessing and treating children referred for problems related to the occupation of education. At present, research linking the oculomotor system and comprehension skills is controversial (9) (10). In addition to this, research exploring the effectiveness of sensory stimulation in occupational therapy specific intervention does not make clear links to occupational performance areas. Bundy, Lane and Murray proposed an oculomotor, vestibular and proprioceptive system for an intervention programme (7) and apart from this, the researcher was unable to find studies that measured the results of sensory stimulation against oculomotor skills and furthermore, research that made links to comprehension skills, within the practice of occupational therapy.

Reading skills are one of the cornerstones of academic achievement and success in the school-going child, and assessment should include visual skills. If deficits are found, intervention protocols administered by the occupational therapist may include existing theories and vestibular-visual treatment protocols that support the stimulation of the sensory systems.

CHAPTER 3: METHODOLOGY

3.1 Research Design

The study was an alternate group method research design/ experimental quantitative design. It is classified as outcome research. An alternate group design was used so the participants could be divided into two groups, both of which received the intervention at different times and both of which acted as a control group at different times. This allows for all participants in the study to receive the intervention. This design was chosen as a control group is required and this is more commonly referred to as a 'comparison group'. A non-equivalent control group design was used which was appropriate as the two groups were randomly selected and the results were compared (Figure 3.1).

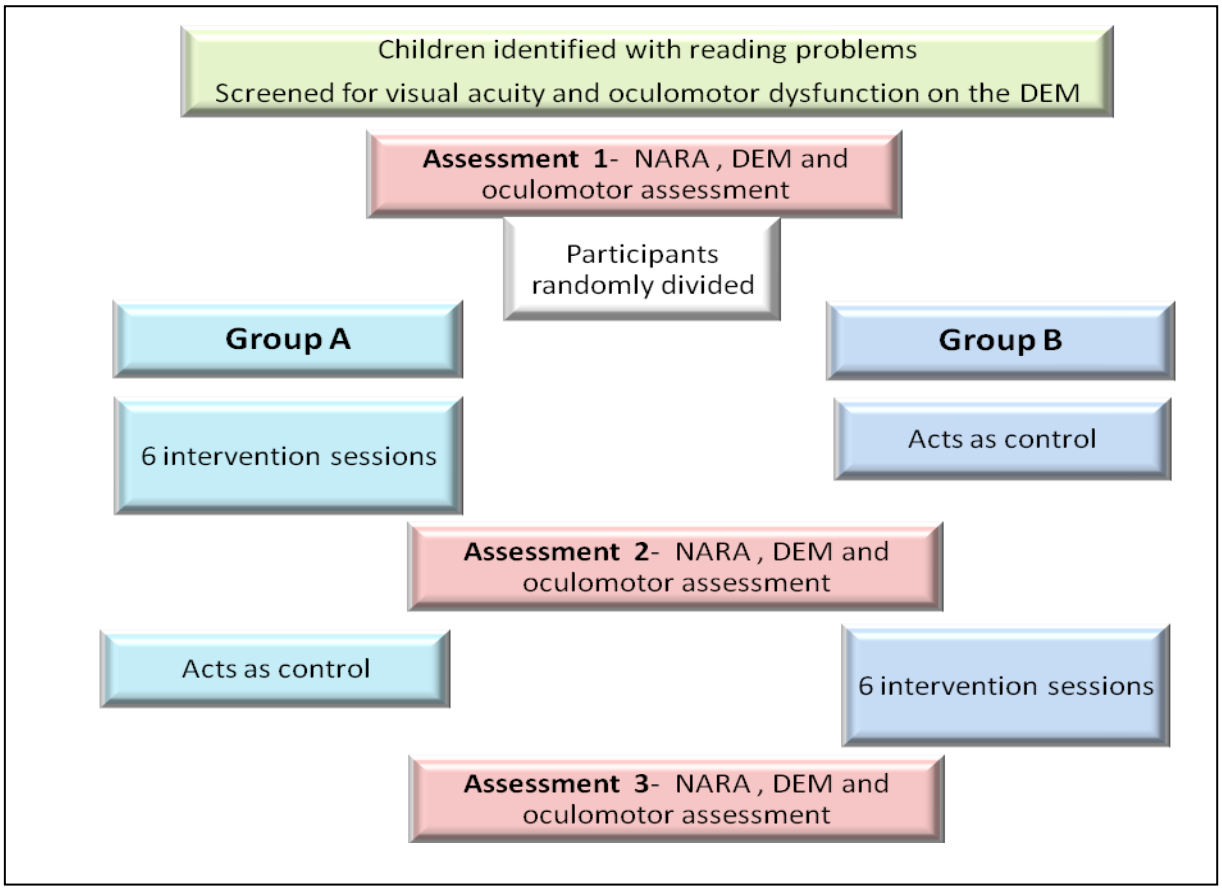


Figure 3.1 Layout of methodology

This involved using a longitudinal research design to provide the intervention to participants in a sequence. Participants were randomly assigned to Group A or Group B. Group A received the intervention first with Group B acting as a control group. Thereafter Group B received the intervention while group A acted as the control group.

The alternate group design requires that both groups receive the same length of intervention for the same length of time i.e. sessions were the same for both groups, 15-20 minutes, conducted twice weekly over a three-week period. A three-period design was used with an intervention/control period, a washout period and then a second intervention/ control period in which the groups were swapped. All participants were assessed before the initial intervention/control period and at the end of both intervention/control periods.

3.2 Selection of subjects

3.2.1 Population

The population for the study consisted of children attending Flamboyant School in White River. Flamboyant School is an independent remedial school which offers education in small classes to learners with one or more barriers to learning. The school offers the services of a specialised multidisciplinary team for learners including that of an occupational therapist, speech therapist educational psychologist and remedial therapists.

3.2.2 Sample selection

The participants for the study were sourced from children between the age of 8 and 12 years 11 months attending the Flamboyant School in White River. The researcher had access to therapy rooms on the school premises and the practice had the necessary suspension and specialised equipment required for the intervention used in this study.

Inclusion criteria

Learners who

- were identified as ‘poor’ readers by teachers and/or support staff ,

- obtained below the 16th percentile on the Developmental Test of Eye Movements (DEM),
- presented with no visual acuity deficits on the Snellen chart,
- were male or female in Grades 2 to 7,
- had the ability to understand English instructions.

Exclusion criteria

Learners with:

- low tolerance for vestibular stimulation e.g. suffers from car sickness after short distances (Appendix A),
- a history of visual difficulties following a visual examination e.g. low vision or blindness (Appendix A),
- a history of specific medical conditions following evaluation from a medical practitioner e.g. epilepsy (Appendix A). This will be obtained from the demographic questionnaire.

3.2.3 Sample Size

A sample size of 30 children, 15 per group, was required based on a 5% significance level at 80% power. This was based on the assumption that learners in both groups would achieve a change of 12.3 seconds (SD 11.9) on the DEM after the six intervention sessions. As this intervention has not been done before, the sample size was calculated based on the assumption that this is the average difference between competent and poor readers in Grade 3 to Grade 5 found by Palomo-Alvarez & Puel (63). Approximately 40 children with reading problems have been identified in the four grades to be used in the study.

3.2.4 Variables

The independent variable for this study was the intervention: a sensory stimulation programme for vestibular and oculomotor function. The dependent variables were the eye movements (automaticity, saccades and observation of oculomotor function) and reading (speed, accuracy and comprehension).

3.3 Measurement tools

3.3.1 Demographic Questionnaire

The demographic questionnaire (Appendix A) was designed by the researcher and consisted of demographic information including age and gender as well as background information. Questions to determine the learner's tolerance for vestibular stimulation e.g. suffer from carsickness after short distances, history of visual difficulties and specific medical conditions, were included.

3.3.2 Neale Analysis of Reading (NARA)

The NARA II (Appendix B) is a standardized and widely used assessment tool and allows an individual child to be compared to the population. It is a useful tool and widely used in education and learning in English-based countries (75). It consists of a set of graded passages for testing the rate, accuracy and comprehension of oral reading. It is both an attainment test and a diagnostic test. The NARA II can be used with children aged from 6 to 12 years 11 months (67).

The NARA II provides standardised scores and reading ages for two parallel sets of passages, which are based on fully representative national samples. Furthermore, the national percentile rank and stanine scores can be calculated for the accuracy, comprehension and rate.

The raw score for accuracy is obtained by subtracting the number of errors made in the passages from 16 (for passages 1-5) and from 20 (for passage 6). The raw score for comprehension is obtained by giving one point for every question that the child answers correctly. There are four comprehension questions for passage 1 and eight questions each for passage 2 to 6. The raw score for rate is calculated by adding the time (in seconds) for all of the passages that were read. The total number of words for the read passages are then divided by the total time and multiplied by 60 and this provides the words per minute. Once the raw scores have been calculated, the scores are converted to standardised scores using the conversion tables provided in the manual (67).

Standardised scores enable one to compare the tested child's score to a large, nationally representative sample. The average nationally standardised score is set at 100 and this measurement makes it easier to determine whether the child is

above or below the national average. The measure of the spread of scores is known as the standard deviation and is set at 15. This means that irrespective of the difficulty of the test, about 68% of the pupils in the national sample would score within one standard deviation of the average (between 85 and 115) and 95% would score within two standard deviations of the average (70 and 130). The standardised scores are found by locating the pupil's raw score and reading across the row to the column that includes their age. Standardised scores from most educational tests cover the same range from 70 to 130 or 140 and so scores from more than one test can be meaningfully compared or added together. (67).

Percentile ranks enable the child's performance to be compared to those in the national standardization sample. The percentile rank of the child is defined as the percentage of pupils in the sample of the same age who gained a score at the same level or below that of the child's score. If the child reached a score at the 25^{th} percentile, it would indicate the child as well as or better than 25 percent of the sample. There is also a constant relationship between standardised scores and percentile ranks when the same average score and standard deviation are used (67).

Stanines represent broad units with each stanine equal to one-half of a standard deviation in width. Normally distributed scores are divided into 9 units. A stanine of 5 correlates to a standard score of 100 and a percentile rank of 50. Stanines are useful for reporting differences in broad general terms (67).

Reading ages are the age at which a given raw score was the average. This type of scoring has been criticised but with the use of the confidence intervals (confidence bands), the score can be considered as a normative score. The reading age should not be seen as a fixed score but rather provide insight into reading as a learned behaviour. A low reading age may not imply any kind of immaturity or under development of a general nature and should rather be used to matching reading material for any programme that would be developed for the child (67). Reading ages are obtained by using the conversion tables in the manual.

Two measures of reliability are available for the NARA II, parallel form reliability calculated for all three measures and internal consistency for the accuracy and

comprehension measures. Parallel form reliability indicated that accuracy (0.89) and comprehension scores (0.82) have high levels of reliability. Levels of reliability for the measurement of rate was lower (0.66). Internal consistency for the accuracy (all above 0.8) and comprehension (all above 0.9) measures indicated that the reliability of both of these measures is good (67).

Validity is based on the content of the test, the relationship to other measures and evidence about the construct being tested. Content validity is recognised for reading aloud and the ability to answer comprehension questions but not for silent reading. Criterion-related validity can be separated into concurrent and predictive aspects. Both the concurrent and predictive validity of the NARA II has been thoroughly investigated. Construct-related validity was also proven as there was a consistent rise in mean scores over the age groups (67).

3.3.3 Clinical observation of oculomotor function

The Clinical Observation (Appendix C) has been adapted from Ayres Sensory Integration Theory (47). The assessment has a number of subtests and these subtests allow the assessor to identify recurring themes so that a conclusion regarding the functional level of the client can be determined. The subtest that was used in this study was the eye movement subtest. This clinical observation does not have reliability and validity scores.

Observations of the eye movements subtest determine oculomotor function or the ability of the child to establish and maintain visual contact with a target. A pencil with a rubber or target at the end is needed and the time taken to administer the test is 3-5 minutes. The child must sit facing the examiner and is then instructed to watch the top of the pencil with their eyes only. The child's head can be stabilised by the examiner if excessive movement is observed. The pencil is moved across the visual field and can be repeated as many times as needed (47). Scored movements include:

- Pursuits in general; where the pencil is moved in an arc in front of the child's face in all of the planes i.e. vertical, horizontal, diagonal and circular, maintaining a distance of +/-15cm from the child's face,

- Across midline; moving the object across the midline a number of times during the pursuits with both eyes and then each eye independently,
- Convergence; moving the pencil in the midline toward the child's nose and holding it 10 cm away for a few seconds which assesses binocular vision,
- Quick localisation; the examiner moves the pencil to different positions, holds it there and instructs the child to look at the examiner's nose and then look at the pencil to assess fixation.

The score for each of the above-mentioned movements are in a range for 1 to 3 with 3 being normal, 2 slightly difficult and 1 definite problem (47).

3.3.4 Developmental Test of Eye Movements (DEM)

The Developmental Eye Movement (DEM) (Appendix D) test was developed on the basis that poor eye movements are a major cause of reading difficulties (62). The test determines saccadic eye movement efficiency based on the speed and accuracy that a series of single digit numbers can be located, recognized and verbalised rapidly. Oculomotor performance is judged on the basis of the time needed to complete the test as well as the level of accuracy. It is important to note that the test is not measuring reading but rather indirectly measuring similar eye movements required in the act of reading (76).

Subtest A and B are referred to as the Vertical Test of the DEM. This serves as a baseline assessment for naming speed. Subtest C, the Horizontal Test of the DEM, requires number naming in a horizontal layout and measures number calling ability in a horizontal spatial array. Both the vertical and horizontal subtests require rapid and continuous naming speed.

Vertical time score is determined by adding the time to complete tests A and B. The vertical time score helps to determine the child's automaticity of number calling ability. Horizontal time score is determined by adjusting the time to complete test C by compensating for errors. The time is adjusted upward when numbers are omitted and downward when more than 80 numbers are read. The errors include substitutions (saying a number in place of the written number), omissions (leaving out a number), additions (adding a number) and transpositions.

The Ratio score is determined by dividing the adjusted Horizontal Time by the Vertical Time. Ratio scores, which are higher than the expected normal values, suggest number calling with horizontal eye movements is more difficult for the child as compared to calling the same amount of numbers in a vertical array. From the Ratio score, four clinical response types have been identified:

- Type I Behavior: Essentially normal performance in Horizontal Time, Vertical Time, and Ratio,
- Type II Behaviour: Characterized as abnormally increased time to complete the Horizontal Test in the presence of normal performance on the Vertical Test. The Ratio would be abnormally high in this case. Type II behaviour is characteristic of oculomotor dysfunction,
- Type III Behaviour: Typified as an abnormal increase in both the Horizontal Test and Vertical Test times, but with a normal Ratio. In the presence of a normal Ratio, the Horizontal Test time is influenced and increased because of an abnormal baseline. This represents a case of difficulty in automaticity in number calling skills, not an ocular motility deficit,
- Type IV Behaviour: Increased Horizontal and Vertical Test times, and an abnormally high Ratio. This case is a combination of Type II and Type III behaviour patterns. There are deficiencies in automaticity/oculomotor skills.

All of the scores are calculated on a computer using the provided scoring software. The total time for the vertical test, the adjusted horizontal time, the horizontal/vertical ratio and an analysis by age and grade are provided. Standard scores, Z-scores and percentile scores for vertical, horizontal, horizontal/vertical ratio and error categories is provided in the age and grade analysis and the type classification is given. For the purposes of this study, the analysis by age was used. A standard score of 85 (z score of -1.00 or 16^{th} percentile) would be considered as an at risk for eye motility. A standard score of 78 (z score of -1.5 or 7^{th} percentile) and below would indicate that there are problem areas in visual motility.

The DEM is typically used as an evaluative tool to determine if there are learning-related visual problems. DEM subtests have good test-retest reliability (ICC >0.75) and validity (51). Ayton et al. (2009) found that although there is controversy about

what aspects of visual function the DEM actually measures, the test helps predict children at risk of reading problem (50).

3.3.5 Snellen Chart

A Snellen Eye Chart is an eye chart used by eye care professionals and others to measure how well a person can see at various distances. The chart is printed with eleven lines of block letters. The first line consists of one very large letter, an E. Subsequent rows have increasing numbers of letters that decrease in size. A patient taking the Snellen Eye Chart test covers one eye, and reads aloud the letters of each row of the Snellen Eye Chart, beginning at the top. The smallest row that can be read accurately indicates the person's visual acuity in that eye (77).

Scoring for the Snellen Eye Chart is based on a distance of 20 feet and is represented as a fraction. The numerator is 20 (for the distance) and the denominator is the number listed to the right of each row on the eye chart. They must read the whole line in order to receive that score. The number listed to the right of each line on the Snellen Eye Chart is the normal distance at which people with "normal" vision can read a letter of that row's size. For instance, if they can read row 5 of the eye chart but not row 6, their vision would be scored as 20/30, meaning they can read letters at a distance of 20 feet that most people can read at a distance of 30 feet. 20/20 vision is considered "normal" vision (77).

The ability to interact visually requires more than visual acquity but, it is the appropriate place to start when assessing vision (67). Visual acuity testing using Snellen-based letter charts remains the principal measure of functional visual integrity used routinely to assess acuity, despite the well-documented limitations of these charts (77). Poor reliability and reproducibility of the scores obtained when using the Snellen chart have been reported (78).

3.4 Research procedure

Following ethical clearance, obtained from the Human Research Ethics committee at the University of the Witwatersrand, as well as permission from the principal of the school (Appendix F), the teachers and/or remedial team at the schools were

approached to aid in identifying ‘poor’ readers in their applicable classrooms. Once these learners had been identified, they were then further assessed for inclusion in the study.

3.4.1 Screening for oculomotor and binocular function and visual acuity

The teachers and/or remedial team at the schools were approached and asked to identify the learners who are observed to be ‘poor’ readers according to set guidelines set up by Neale (1997) the developer of the NARA (67) (Appendix G). The selection process continued by screening the learners identified by teachers as ‘poor’ readers, and who fell within the age range, using the Developmental Eye Movement test (DEM) and the Snellen chart. The number of learners that were screened was 40. The number was low as the school is a private remedial school and the number of pupils is lower than in a mainstream school. The screening took place at the therapy rooms on the school premises and was organised during periods where formal teaching did not take place and where available, some of the learners were seen during after school hours. The researcher screened all of the learners.

The 30 children were selected from the screened learners. This was based on the DEM analysis by age when the learner scored below the 16th percentile in either the Vertical or Horizontal scores. Furthermore, the learners were screened using the Snellen chart, 20/20 vision is considered "normal" vision. The learners who did not show any visual acuity deficits in scores obtained from the Snellen chart were selected to form the final participants for the study.

3.4.2 Procedure

Once the participants who met the inclusion criteria were identified from the screening described above, they were invited to take part in the study by the researcher and permission letters along with the demographic questionnaire were sent to the respective parents/caregivers (Appendix A, H, I). Only a quarter of the permission letters were returned before the first group of participants were scheduled for the intervention sessions. The intervention for both groups and the second and third assessments were scheduled to take place over the 8-week

period in the second term. This was discussed with the headmistress and, it was decided that due to the tight timeframe, intervention took place after caregivers were contacted telephonically and verbal consent was received. Once permission, either verbal or written, was received, the respective participant was asked to give signed assent to participate in the study (Appendix J).

In cases where the demographic questionnaire was not completed, the teachers and current therapist (occupational therapist) were contacted to determine if the participant was suspected to have a poor tolerance for vestibular stimulation. The researcher used this information to make an informed decision as to whether or not the participant met the inclusion criteria.

3.5 Data collection method

3.5.1 Training of research assistant

The research assistant was another occupational therapist who had experience within the field. An observation session was carried out before the assessment process began. The research assistant attended an information session with the researcher where the various assessments were explained and the manuals were discussed. The research assistant was then asked to practice the assessment on two learners of her choice; these learners did not have to attend the school. Following this, the researcher observed and commented on a session where the research assistant had to assess a learner and complete the record form. As the research assistant appeared competent and the scoring of the templates was correct, it was decided that a further observed assessment session was not necessary.

3.5.2 Assessment

The second step of the process was the assessment of all of the participants. This took place at the school. All of the assessments were completed during school hours allocated to therapy or after school as arranged with the parents/caregivers. This assessment included the NARA, the DEM and the eye movement's subtest of the Clinical Observation. The research assistant completed the assessment of each participant and each assessment took between 35 and 45 minutes.

Following the assessment, the participants were randomly divided into groups A and B. Group A was be taken through the intervention process first with Group B acting as a control group. Group A received six intervention sessions. Once Group A completed the intervention, Groups A and B were assessed using the NARA, DEM and the eye movement's subtest of the Clinical Observation again. The research assistant, who was blinded as to which group the participants were in, completed the assessments.

In the second intervention period, Group A acted as a control group and did not receive intervention while Group B was taken through the intervention process. Once group B completed the intervention, Groups A and B were assessed by the research assistant using the NARA, DEM and the eye movement's subtest of the Clinical Observation for a third time by the research assistant, who was blinded as to which group the participants were in.

3.5.3 Intervention

The intervention took place at the practice based at the school. The intervention took 15-20 minutes to complete with each participant. Intervention was carried out for 15-20 minutes twice weekly over a three-week period and the participants were seen individually. Attempts to keep each participant's session consistent throughout the intervention process was made e.g. the time and day on which the intervention will be carried out remained the same.

The programme was developed by the researcher from a number of sources that commented on the role that sensory stimulation has on oculomotor control. The main outline of the programme was based on a proposed oculomotor-vestibular-proprioceptive intervention strategy from Bundy, Lane and Murray (7). Activities were added to this outline and were sourced from the astronaut-training programme (73) (Appendix K).

After completing the localization and tracking exercises, learners then engaged in a whole body activity that included a strong oculomotor component (Appendix L). When vestibular stimulation is used, it is important to monitor for signs of overload. Specific guidelines related to this type of programme were followed (Appendix M).

3.6 Ethical considerations

Ethical clearance was obtained from the Human Research Ethics Committee at the University of Witwatersrand (Appendix N). Permission was obtained from the relevant authorities (Appendix F).The parents/legal guardians were provided with an information sheet that explained the research procedure. They were asked to give verbal consent and sign informed consent for the learners to participate (Appendix H and I). The study was explained to the learners and they were asked to sign witnessed informed assent (Appendix J). The learners and their parents/legal guardians were made aware that they can terminate their participation at any time without consequence.

Participation in the study did not influence the learners' school commitments. The precautions for sensory overload were followed and the learners were observed carefully at all times.

Confidentially was ensured as far as possible and all identifying information was locked away in a secure location. Only codes were used on the data collection forms. On request, feedback was provided to parents/legal guardians after both intervention periods were been completed.

Feedback was also provided to the remedial team at the school with the parents/legal guardians' permission.

3.7 Data analysis

Demographic data and scores from the assessments were analysed using descriptive statistics including percentages, means and standard deviations.

Demographic information was divided into personal information (gender, age, home language) and education (grade). The chi-square test was used to determine significant differences in demographics between gender and language. The Fischer's exact test was used to determine significant differences for age and grade.

The three assessments tools provided much data on the groups and each individual. Due to this, it was decided to select specific data from the Clinical

observation of oculomotor function, the Neale Analysis of Reading (NARA) and the Developmental Eye Movements test (DEM).

The specific data included was as follows. The:

- scores for each subheading of the Clinical observation of oculomotor function i.e. general, across midline, convergence, quick localization.
- standard scores for each component of the NARA i.e. comprehension, accuracy and rate,
- standard scores each subheading of the DEM i.e. vertical, horizontal, horizontal/vertical ratio and errors.

A between-group analysis was conducted to establish significant differences using a nonparametric Mann-Whitney U test because of the small sample size, ordinal scales and because the data was not normally distributed. The Wilcoxon signed-rank test for matched pairs non-parametric test was used to compare the within-group results.

Effect sizes were calculated to determine the clinical implications of the intervention. Cohen's D was included in a study that reviewed 5 methods of calculating effect sizes and the conclusion was that effect sizes proved a better illustration of treatment effects than just looking at P values in isolation (79).

Effect size is a statistical calculation that can be used to compare the efficacy of different agents by determining the size of the difference between treatments. Cohen's *d* is most useful for assessing magnitude of effects and is calculated from two mean values and their standard deviation (SD) (79). A Cohen's *d* score of zero indicates that the treatment and comparison agent have no difference in effect. A conventional rule is to consider a Cohen's *d* of 0.2 as small, 0.5 as a medium, and 0.8 as large (79). Effect sizes can be equated to standard deviations.

A Spearman's correlation coefficient was established between the scores for the eye movement test, the DEM standard scores and the NARA standard scores to determine the association between the constructs of oculomotor function and reading ability in this study. Correlations were set as 0.0 - 0.19 - low or no correlation, 0.2 – 0.39 - weak correlation, 0.4 – 0.59 - moderate correlation, 0.6-

0.79 - strong correlation and 0.8 and above – excellent correlation (80). This was based on principles and methods currently used in medical research (80).

An intention to treat analysis was stipulated to be used but none of the participants was lost over the course of the study.

3.8 Summary

A diagram depicting the layout of the methodology illustrates the screening process and the assessment procedure. The population was sourced from a remedial school and the screening allowed the researcher to form the final participants based on the inclusion and exclusion criteria.

Following the screening, the participants were randomly divided into two groups of 15 participants each. An alternate group design was chosen so that the two groups could be formed and every participant would receive the intervention. Group A and Group B received the intervention at different times, which allowed the results to be compared both within the group and between the groups, which is in line with a non-equivalent control group design.

Five measurement tools were used to gather information through the process. The demographic questionnaire provided information regarding the age, language, grade and level of vestibular tolerance of the participants. The Snellen Chart was used in the screening process as part of the inclusion and exclusion criteria. This chart measures visual acuity and is commonly used despite well-documented limitations and poor reliability (77) (78). The Neale Analysis of Reading (NARA) measures reading accuracy, rate and comprehension showing high levels of reliability for scores within reading accuracy and comprehension and lower levels of reliability for rate (67). Validity for this assessment has been thoroughly investigated (67). The clinical observation of oculomotor function was adapted from Ayres Sensory Integration Theory (47). This assessment gathers information regarding the ability of the participant to maintain visual contact with a target. Although this assessment is used in occupational therapy undergraduate training and forms the basis of occupational therapy assessments in practice, there are no validity and reliability scores. The Developmental Test of Eye Movement (DEM) provides information on the efficiency of saccadic eye movements. The DEM has

good test-retest reliability and validity and although there is controversy surrounding the use of the test, it does help to predict children at risk of reading difficulties (50).

In a quantitative study, validity is defined as the extent to which a concept is accurately measured (81). This study aims to measure the effectiveness of a sensory stimulation programme on reading speed, reading accuracy, comprehension and oculomotor deficits in children aged 8 to 12 years 11 months. The study is valid as the NARA, DEM and clinical observation of oculomotor function are measurement tools that provide information on each of these aspects. Reliability of the measurement tools, the NARA and the DEM have been established (81). From the results, a conclusion on whether or not the programme was effective was drawn.

The second measure of quality is reliability, which is the accuracy of an instrument (81). Reliability of the study was maintained by not changing the researcher and the research assistant throughout the process and training the research assistant in the use of the measurement tools. During the intervention, the details of the sessions were the same for each participant by following a systematic intervention programme, using the same therapy space and equipment for all of the sessions and ensuring that the participant attended the same or very similar time for each of their individual sessions.

The research procedure and the method of data collection were followed in accordance with the ethical considerations. The chi-square tests and Fischer's exact test were used to analyse the demographic information. The Mann-Whitney U test was used for the between-group analysis and the Wilcoxon signed-rank test was used to compare the within group results. The Cohen's *d* was used to calculate the magnitude of the effect sizes and a Spearman's correlation coefficient established correlations between oculomotor function and reading ability.

CHAPTER 4: RESULTS

4.1 Introduction

The results in this chapter were analysed based on the 30 participants included in the study. All participants attended Flamboyant school, were identified with reading problems, primarily by their teachers. The Developmental Eye Movements test (DEM), to identify oculomotor problems, and the Snellen chart, used to determine adequate visual acuity, were used for the screening. The results of the Snellen chart were used as inclusion criteria only.

The 30 participants were randomly divided into two groups of 15 participants, Group A and Group B. Oculomotor function was assessed using clinical observations and the DEM, and reading skills were assessed with the Neale Analysis of Reading (NARA). Each participant was assessed three times and underwent a period of intervention, using a programme designed to improve binocular and oculomotor function, as well as a period when they acted as a control group.

According to the research objectives and the study design, intervention for Group A occurred between assessment 1 and 2 with no intervention between assessment 2 and 3. No intervention was provided for Group B between assessment 1 and 2 but was implemented between assessment 2 and 3. No participants were lost to the study over the period the research was completed.

4.2 Demographics

4.2.1 Personal

Demographics were compared for Group A and B for age and language as well as gender and grade to establish if the participants in the groups were comparable for these demographic variables. As many of the questionnaires were not returned when the intervention was scheduled to start, basic information was compiled from the learner's school files and collateral information from the teaching staff.

4.2.1.1 Personal demographics

No significant difference was seen in Group A and B for gender so the groups are comparable for gender. However, one third more males than females were recruited for the study because there were more male learners in the school than female learners.

No significant difference was seen in Group A and B for age. The groups were comparable for age. The participants were however slightly older in Group B.

Table 4.1 Demographics of the sample Group A and Group B

	Group A		Group B				
	n (%)		n (%)		Chi-square	df	p value
Gender							
Male	9 (60)		10 (66)		0. 144	1	0.70
Female	6 (40)		5 (34)				
Language							
Eng	12 (80)		11 (73)		0.186	1	0.66
Other	3 (20)		4 (27)				
Age years	**n (%)**		**n (%)**		**p value**		
8	8	4		1	0.27		
9	9	5	9	5			
10	10	1	10	4			
11	8	4	11	4			
12			12	1			

No significant difference was seen in Group A and B for language and the groups were therefore comparable in this area.

4.2.2 Educational demographics

Table 4.2 Demographics of the sample Group A and Group B

	Group A		Group B		p-value
Grade	**n (%)**		**n (%)**		0.07
2	2	4	3	6	
3	3	3	4	3	
4	4	8	2	6	

No significant difference was seen in Group A and B for the grade. The groups were comparable for the grade.

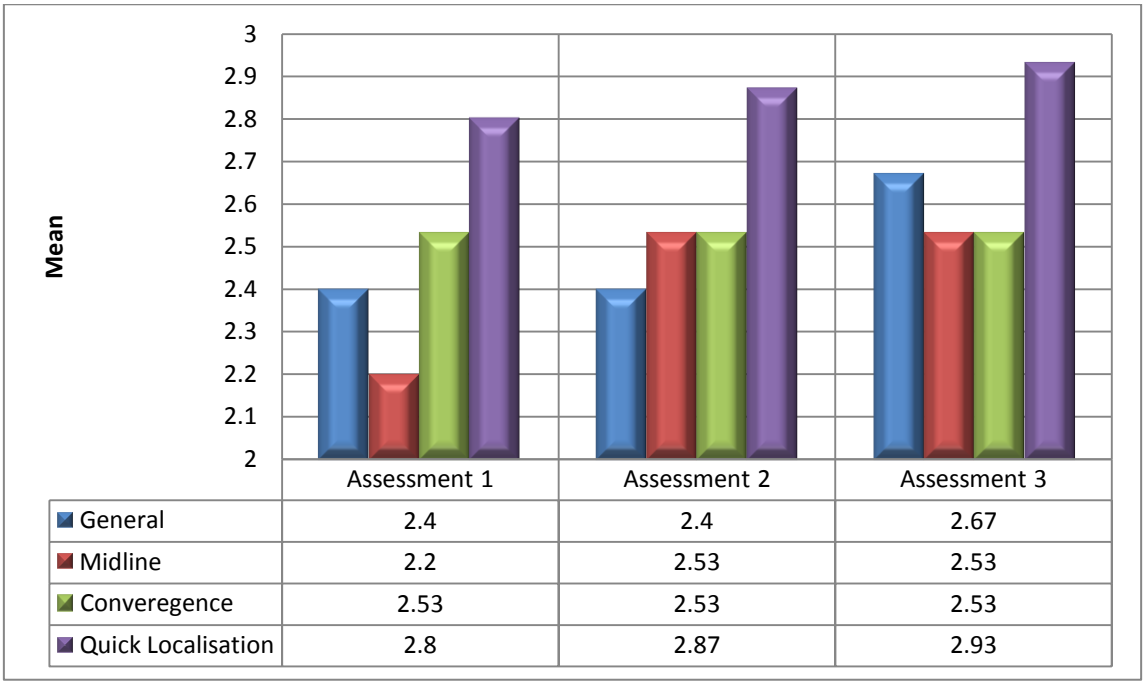
4.3 Visual and oculomotor Function- Within Group Analysis -

4.3.1 Group A

4.3.1.1 Clinical Observations based on Sensory Integration Theory - subtest for eye movements

The results for the eye movement Clinical Observations, based on sensory integration theory, included pursuits in general as well as scores for convergence, quick localization and eye movements across the midline (47).

While the convergence remained unchanged for Group A over the three assessments, the midline eye movements improved between assessment 1 and 2, stayed the same between assessment 2 and 3 and showed an overall improvement between assessment 1 and 3 (Figure 4.1).



	Assessment 1	Assessment 2	Assessment 3
General	2.4	2.4	2.67
Midline	2.2	2.53	2.53
Converegence	2.53	2.53	2.53
Quick Localisation	2.8	2.87	2.93

Figure 4.1: Standard scores for Clinical Observation of Eye Movement for three assessments for Group A (n=15)

The general eye movements stayed the same between assessment 1 and 2 and improved at assessment 3 following the consolidation period when intervention was withdrawn. Changes were also positive for quick localization which improved during the intervention period between assessments 1 and 2 and continued to improve between assessment 2 and 3 when the intervention was withdrawn

The Wilcoxon matched-pairs signed-rank test is a non-parametric method to compare matched objects. It indicated that there were no statistically significant differences in the clinical observation of eye movements for Group A between assessment 1 and 2 when intervention was received or between assessment 2 and 3 when intervention was withdrawn or overall between assessments 1 and 3 (Table 4.3).

Table 4.3: Within group scores of the Clinical Observation of eye movements Group A (n=15)

	Assess 1	Assess 2	Change 1-2	*p-value*	Assess 3	Change 2-3	*p-value*	Change 1-2	*p-value*	Effect size 1-3
	Mean (SD)				Mean (SD)					
General	2.40 (0.82)	2.40 (0.50)	0.00	*1.00*	2.67 (0.48)	0.27	*0.14*	0.27	*0.14*	0.42
Midline	2.20 (0.77)	2.53 (0.51)	0.33	*0.16*	2.53 (0.51)	0.00	*1.00*	0.33	*0.06*	0.55
Convergence	2.53 (0.51)	2.53 (0.63)	0.00	*1.00*	2.53 (0.51)	0.00	*1.00*	0.00	*1.00*	0.00
Quick Localisation	2.80 (0.41)	2.87 (0.35)	0.07	*0.59*	2.93 (0.25)	0.06	*0.14*	0.13	*0.17*	0.39

Significance $p \leq 0.05$*
$p \leq 0.01$**

All the scores on the Clinical Observation of eye movements for Group A showed small to moderate effect size with clinically relevant change except for the convergence component which remained unchanged.

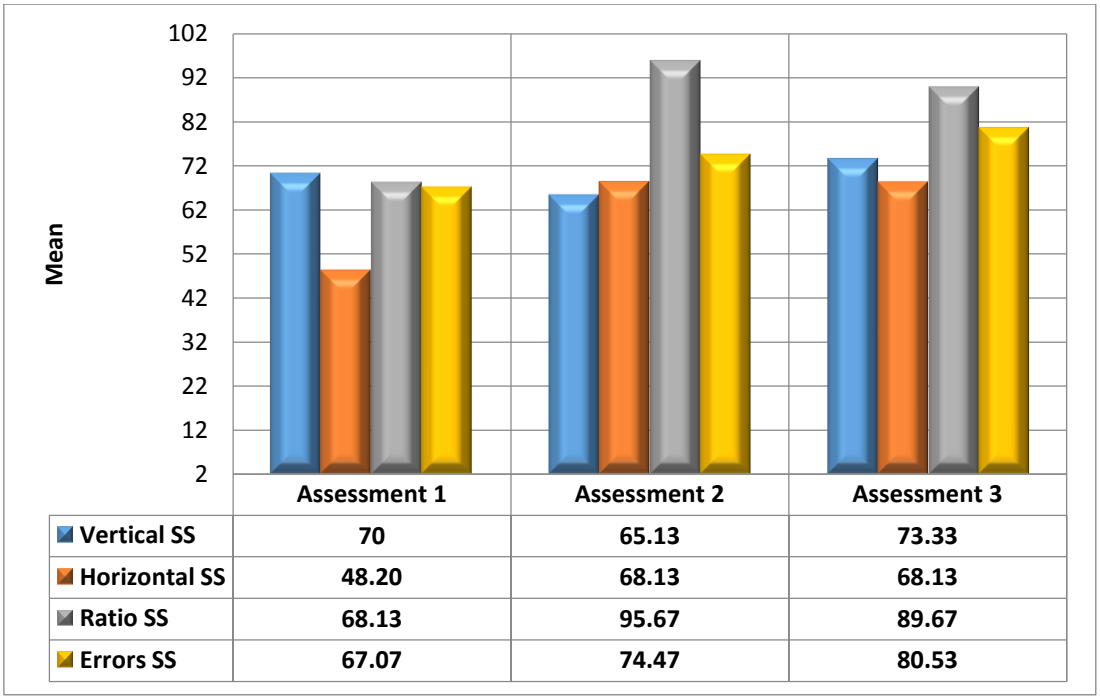
4.3.1.2 Developmental Eye Movements test (DEM)

The scores for the DEM include standard scores for horizontal and vertical times and ratio and errors categories. A standard score of 85 (z score of -1.00 or 16th percentile) would be considered as at risk for eye motility. A standard score of 78 (z score of -1.5 or 7th percentile) and below would indicate that there are problem areas in visual motility.

Assessment 1 for vertical time standard score of 70 (4th percentile) and horizontal time standard score of 47 (0 percentile) showed that all members of Group A would be considered as displaying a problem with a mixed automaticity and oculomotor vision dysfunction. The oculomotor horizontal component was more

affected. This was confirmed by the ratio score which also fell below 78 at the 4th percentile.

Following the intervention from assessment 1 to 2, the vertical time standard score indicating automaticity dropped to 65 (3rd percentile) while an improvement was seen in the horizontal time standard scores which increased to 68 (4th percentile) and which is related to oculomotor function. Both of these aspects were consolidated further during the period when intervention did not occur between assessments 2 and 3, where the vertical standard scores improved to 73 (5th percentile) and the horizontal standard scores remained the same. The ratio scores which fell above 87 after intervention and the period without intervention, confirm similar function for automaticity and oculomotor function at both these assessment periods.



	Assessment 1	Assessment 2	Assessment 3
Vertical SS	70	65.13	73.33
Horizontal SS	48.20	68.13	68.13
Ratio SS	68.13	95.67	89.67
Errors SS	67.07	74.47	80.53

Figure 4.2: Standard scores for Developmental Eye Movement test for three assessments for Group A (n=15)

Overall changes between assessment 1 and 3 horizontal standard scores related to an increase in oculomotor function of 20.86 (Figures 4.4).

The assessment errors standard scores also indicated problem areas for Group A but these were considered separately as the reliability of this score is not confirmed. This score may indicate visual inattention (82), and improved from 67 (3rd percentile) to 74 (5th percentile) on assessment 2 after the intervention, and to a further improvement with a standard score of 80 (6th percentile) on assessment 3.

The results above were confirmed when the change in the standard scores of the three assessments were compared (Table 4.4).

Table 4.4: Within group scores of the Developmental Eye Movement test Group A (n=15)

	Assess 1	Assess 2	Change 1-2	*p-value*	Assess 3	Change 2-3	*p-value*	Change 1-3	*p-value*	Effect size 1-3
	Mean (SD)				Mean (SD)					
Vertical time Standard Score	70.00 (26.32)	65.13 (38.03)	-4.87	*0.53*	73.33 (32.70)	8.2	*0.07*	3.33	*0.43*	0.11
Horizontal time Standard Score	47.27 (32.8)	68.13 (28.50)	20.86	*0.02**	68.13 (38.48)	0	*0.53*	20.86	*0.06*	0.58
Ratio Standard Score	68.13 (34.36)	95.67 (11.38)	27.54	*0.00**	89.67 (19.90)	-6.00	*0.31*	21.54	*0.09*	0.79
Errors Standard Score	67.07 (35.70)	74.47 (29.59)	7.40	*0.64*	80.53 (52.09)	6.06	*0.35*	13.46	*0.15*	0.51

Significance $p \leq 0.05$*
$P \leq 0.01$**

Standard scores for horizontal values improved significantly in assessment 2 indicating a significant improvement in oculomotor function during the intervention phase. The moderate effect size confirmed the clinical significance of this change. The change was maintained at assessment 3 after no intervention where the vertical and horizontal scores were similar with significantly higher ratio scores, indicating Group A participants now presented with mixed visual dysfunction. Although overall improvements were seen for error standard scores, indicating possible less visual inattention, the difference was not statistically significant

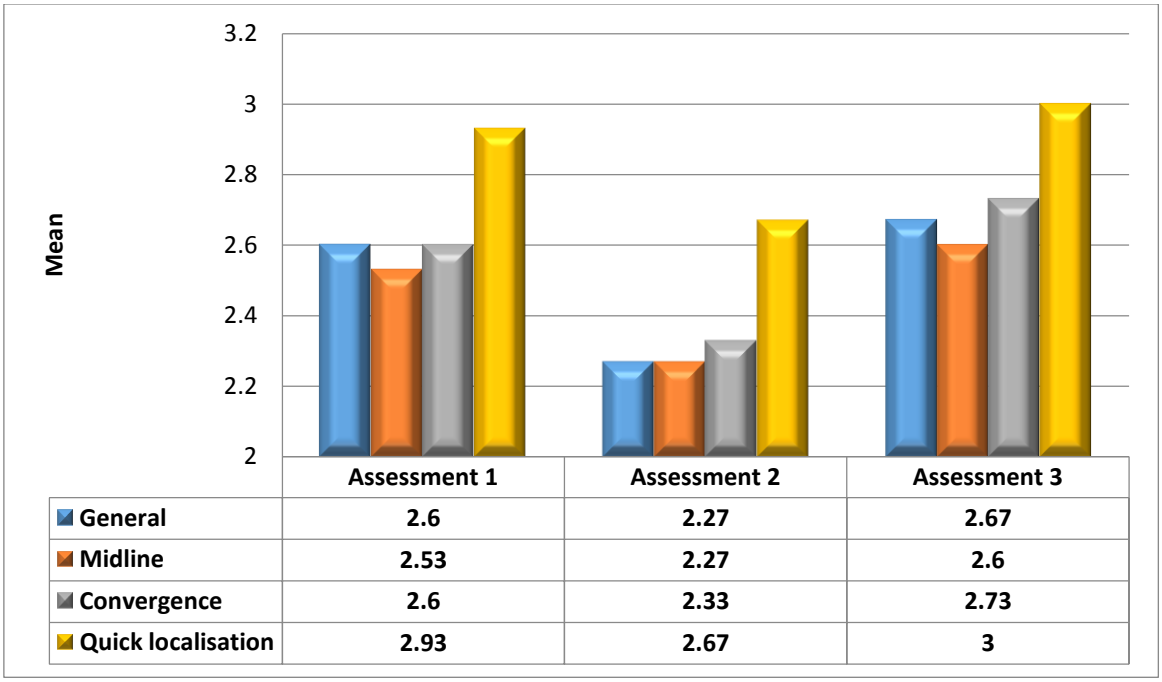
although, the moderate effect size showed an improvement of approximately half a standard deviation overall.

4.3.2 Group B

4.3.2.1 Clinical Observations based on Sensory Integration Theory - subtest for eye movements

In Group B, all the aspects observed decreased from assessment 1 to assessment 2 in the period when no intervention was received (Figure 4.5). The mean scores for general eye movements, midline eye movements, convergence and quick localization were all lower on assessment 2.

The improvement was seen for general eye movements, midline eye movements, convergence and quick localization in assessment 3, when compared to assessment 2, following the intervention. An overall change in all of these areas was positive in relation to assessment 1.



	Assessment 1	Assessment 2	Assessment 3
General	2.6	2.27	2.67
Midline	2.53	2.27	2.6
Convergence	2.6	2.33	2.73
Quick localisation	2.93	2.67	3

Figure 4.3: Standard scores for Clinical Observation of Eye Movement for three assessments for Group B (n=15)

When the scores between the three assessments were compared statistically, no significant change was seen in the clinical observation for eye movement scores for general, across midline, convergence and quick localization components

between assessments 1 and 2, despite the decrease in scores in assessment 2 when no intervention was received.

Table 4.5: Within group scores of the Clinical Observation of eye movements Group B (n=15)

	Assess 1	Assess 2	Change 1-2	*p-value*	Assess 3	Change 2-3	*p-value*	Change 1-3	*p-value*	Effect size 1-3
	Mean (SD)				Mean (SD)					
General	2.60 (0.63)	2.26 (0.45)	-0.34	*0.09*	2.66 (0.48)	0.40	*0.03**	0.06	*0.72*	0.10
Midline	2.53 (0.51)	2.26 (0.45)	-0.27	*0.21*	2.60 (0.50)	0.34	*0.09*	0.07	*0.40*	0.13
Convergence	2.60 (0.63)	2.33 (0.61)	-0.27	*0.14*	2.73 (0.45)	0.40	*0.04**	0.13	*0.59*	0.24
Quick Localisation	2.93 (0.25)	2.66 (0.48)	-0.27	*0.07*	3.00 (0.00)	0.44	*0.04**	0.07	*0.48*	0.56

Significance $p \leq 0.05$*
$P \leq 0.01$**

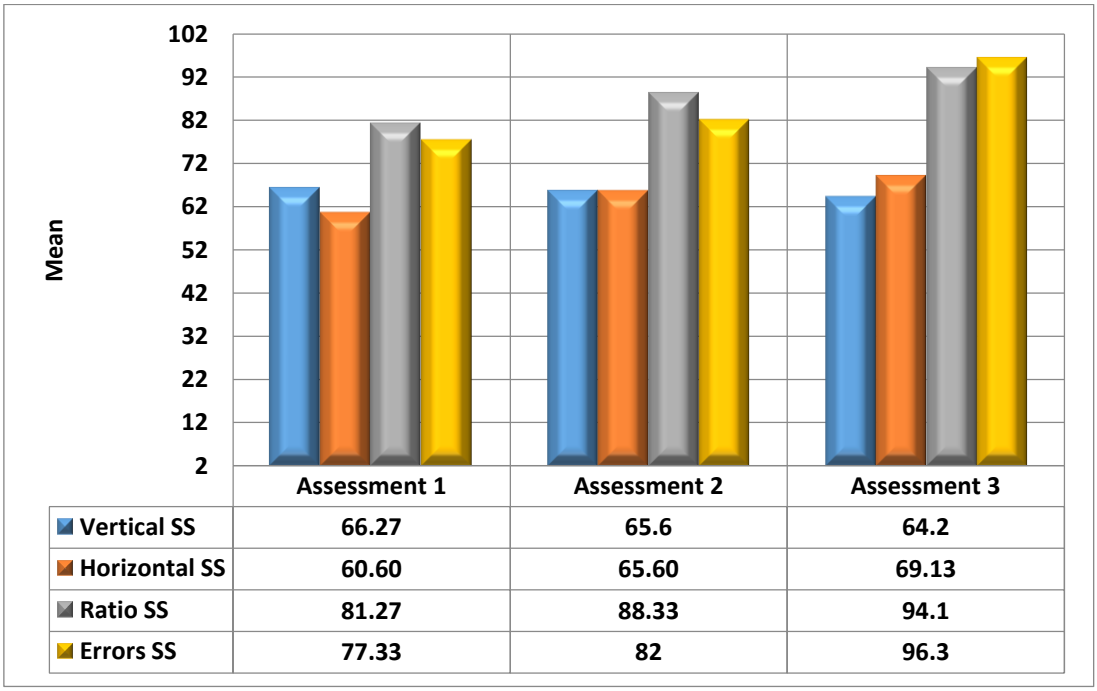
Statistically significant improvement for general eye movements, convergence and quick localization was found between assessments 2 and 3 after the intervention, and although midline eye movements did improve, the change was not significant. Overall, between assessment 1 at baseline and the final assessment 3, all four aspects improved in Group B, but this improvement was not statistically significant (Table 4.5). Effect sizes were small except for quick localization, which had a moderate effect size and showed clinically relevant change.

4.3.3.2 Developmental Eye Movements test (DEM)

According to assessment 1 vertical and horizontal standard scores, all members could be regarded as having mixed visual dysfunction. The vertical standard scores 66 (3rd percentile) were slightly higher and the lower horizontal scores 54 (1st percentile) indicated more oculomotor dysfunction in this group as well. The ratio score 81 (6th percentile) confirmed the difference between the oculomotor and automaticity problems in these participants.

The vertical scores decreased slightly but remained at the 3rd percentile in assessment 2 preceding the intervention and assessment 3 following the intervention.

The horizontal scores 60 (2nd percentile) increased to 65 at assessment 2 (3rd percentile) when no intervention had been given and increased again in assessment 3 to 69 (4th percentile) (Figures 4.4). Ratio standard scores fell in the normal range at assessment 2 and 3, indicating that the vertical and horizontal scores were similar at both assessments and that the participants presented with a mixed visual dysfunction.



	Assessment 1	Assessment 2	Assessment 3
Vertical SS	66.27	65.6	64.2
Horizontal SS	60.60	65.60	69.13
Ratio SS	81.27	88.33	94.1
Errors SS	77.33	82	96.3

Figure 4.4: Standard scores for Developmental Eye Movement test for three assessments for Group B (n=15)

The assessment errors standard scores also indicated problem areas for Group B. The errors score increased from 77 at assessment 1 (5th percentile) to 82 (6th percentile) on assessment 2 after no intervention, to a standard score of 96 (9th percentile) on assessment 3 indicating no problem at that stage and an improvement in visual attention.

A decrease in vertical time standard scores was seen at all three assessment periods. Although positive changes were seen for horizontal, ratio and errors

standard scores, significant statistical difference was only seen for errors standard scores after intervention between assessment 2 and assessment 3. Ratio and errors standard scores showed overall significant statistical improvement between assessment 1 and assessment 3 (Table 4.6).

Table 4.6: Within group scores of the Developmental Eye Movement test Group B (n=15)

	Assess 1	Assess 2	Change 1-2	*p-value*	Assess 3	Change 2-3	*p-value*	Change 1-3	*p-value*	Effect size 1-3
	Mean Standard scores (SD)				Mean Standard scores (SD)					
Vertical time Standard Score	66.27 (30.09)	65.60 (38.99)	-0.67	*0.71*	64.20 (38.89)	-1.4	*0.54*	-2.07	*1.00*	-0.06
Horizontal time Standard Score	60.80 (26.62)	65.60 (28.11)	4.80	*0.50*	69.13 (28.49)	3.53	*0.18*	12.2	*0.07*	0.30
Ratio Standard Score	81.27 (21.58)	88.33 (18.95)	7.06	*0.55*	94.13 (17.45)	5.8	*0.29*	12.86	*0.02**	0.64
Errors Standard Score	77.33 (29.60)	82.00 (25.38)	4.67	*0.46*	96.33 (14.63)	14.33	*0.05**	19	*0.02**	0.85

Significance p ≤ 0.05*
P ≤ 0.01**

The effect size for vertical and horizontal time scores for Group B were small but a large effect size for ratio and errors scores indicated the clinical relevance of the improvement in this area.

4.4 Within Group Analysis - Reading Ability

4.4.1 The Neale Analysis of Reading (NARA)

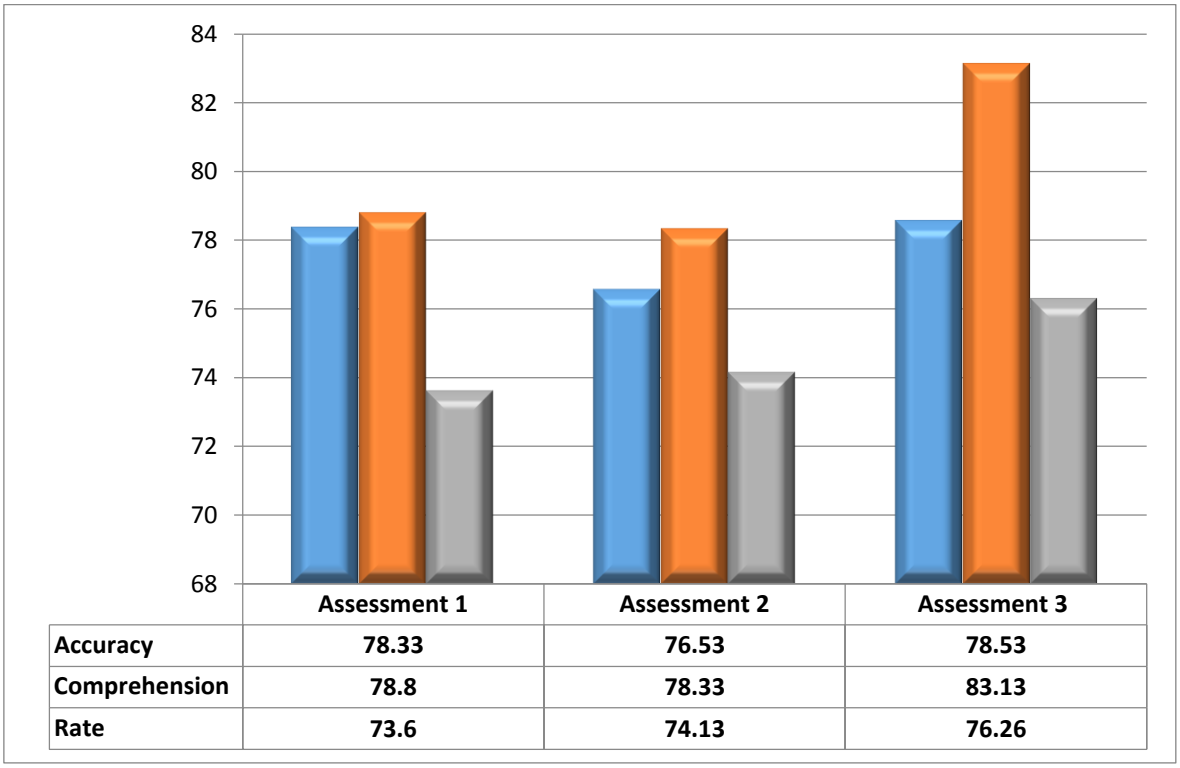
The results for the accuracy, comprehension and rate scores of reading on the NARA were recorded over the three assessments for Group A and Group B.

4.4.1.1 Group A

The results indicate a National Percentile Rank (NPR) of between 6% and 10% and standard scores between 74 and 79 for assessment 1 for the accuracy,

comprehension and rate on the NARA. The scores for accuracy and comprehension were similar with rate having a lower score and all the participants fell into a “below average” category for reading.

The standard scores for accuracy and comprehension on the NARA were lower at assessment 2 following the intervention while the scores for rate improved slightly (Figures 4.5).



	Assessment 1	Assessment 2	Assessment 3
Accuracy	78.33	76.53	78.53
Comprehension	78.8	78.33	83.13
Rate	73.6	74.13	76.26

Figure 4.5: Standard scores for Neale Analysis of Reading Accuracy, Rate and Comprehension for three assessments for Group A (n=15)

On assessment 3, improvements were seen in all three components. Overall change in the standard score for accuracy was small with a change in the percentile scores of 1.2%. It would appear that during the consolidation phase comprehension increased the most with a standard score of 83 or a 5.47% change in the percentile scores, while rate improved to a standard score of 76 and a change in the percentile scores of 3.6%. However, all the standard scores were still below 87, indicating below average levels of reading compared to the national norm reference sample.

The above results were confirmed when the assessments were compared. Accuracy and comprehension standard scores decreased after the intervention

while there was a small increase in the rate of reading. Accuracy, comprehension and rate improved significantly in the consolidation period when the participants did not receive intervention between assessment 2 and 3 (Table 4.7).

Table 4.7: Within group change of scores for Neale Analysis of Reading Group A (n=15)

	Assess 1	Assess 2	Change 1-2	*p-value*	Assess 3	Change 2-3	*p-value*	Change 1-3	*p-value*	Effect size 1-3
	Mean Standard scores (SD)				Mean (SD)					
Accuracy Standard Score	78.33 (8.28)	76.53 (8.13)	-1.8	*0.06*	78.53 (9..47)	2	*0.02***	0.2	*0.84*	0.14
Comprehen-sion Standard Score	78.80 (8.18)	78.33 (9.45)	-0.47	*0.92*	83.13 (8.79)	4.8	*0.00***	4.33	*0.01***	0.51
Rate Standard Score	73.60 (7.24)	74.13 (8.18)	0.53	*0.55*	76.26 (9.49)	2.13	*0.08*	2.66	*0.09*	0.32

Significance p ≤ 0.05*
p ≤ 0.01**

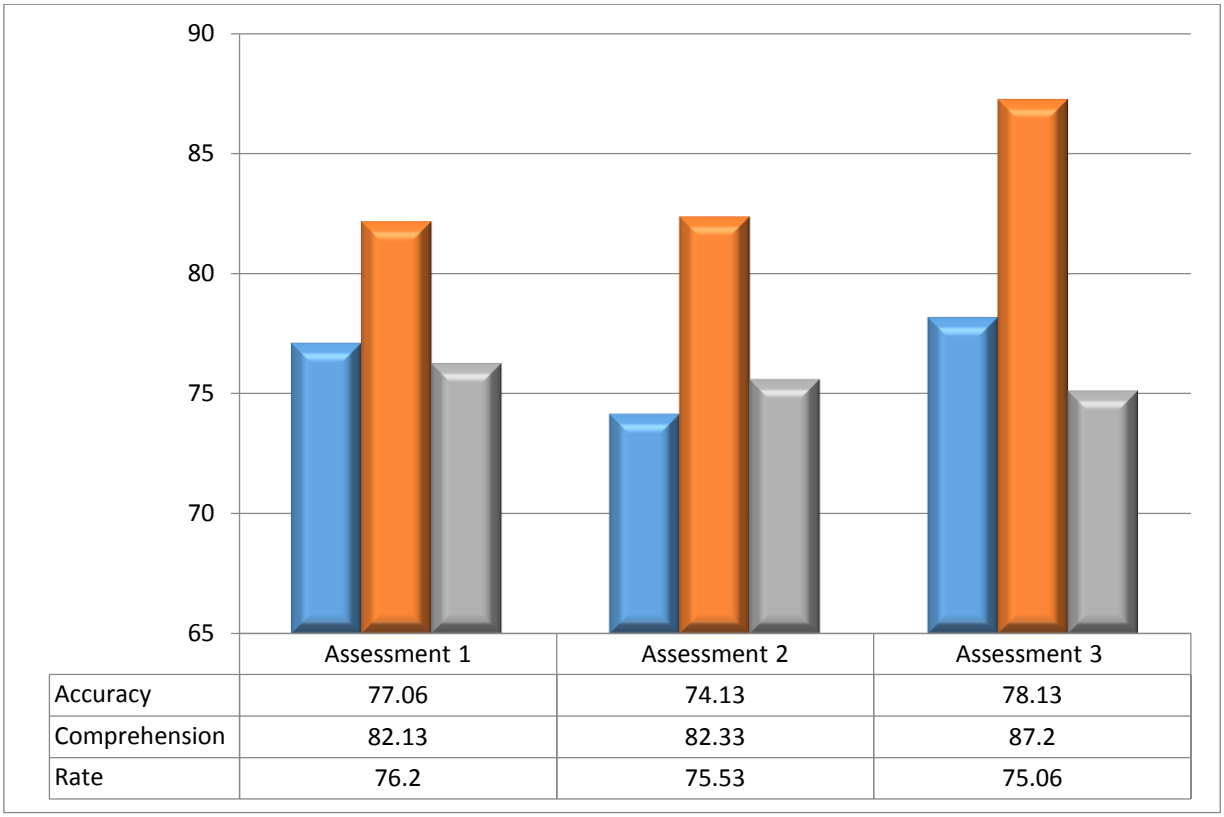
Overall, rate and comprehension scores improved but statistically significant difference and clinically moderate effect size was only observed for the comprehension standard scores from assessment 1 to 3.

4.4.1.2 Group B

The results for the accuracy and rate scores on the NARA indicated the participants fell into a “below average” category for reading performance.

Accuracy and rate standard scores were slightly lower in assessment 2 preceding the intervention. The comprehension standard scores increased slightly at assessment 2.

The NPR for accuracy and comprehension on the NARA improved after the intervention at assessment 3. An overall change in the percentile scores of 0.73% for accuracy and 8% for comprehension were seen. While the rate changed compared to assessment 2, it remained the same as the baseline assessment and therefore there was no overall change.



	Assessment 1	Assessment 2	Assessment 3
Accuracy	77.06	74.13	78.13
Comprehension	82.13	82.33	87.2
Rate	76.2	75.53	75.06

Figure 4.6: Changes in Standard scores for Neale Analysis of Reading Accuracy, Rate and Comprehension Group B (n=15)

Although the standard scores for accuracy increased, it was still below 87, indicating below average levels of reading accuracy compared to the national norm reference sample. The standard scores for comprehension increased to 87, placing this aspect in the normal range for this group. Positive change in standard scores for accuracy and comprehension were seen in assessment 3 (Figure 4.6).

The above results were confirmed when the assessments were compared using the Wilcoxon signed-rank test. Statistically significant difference was seen for accuracy standard scores in assessment 2 preceding the intervention. The scores were significantly lower.

Accuracy and comprehension scores both increased significantly following the intervention with a slight decrease in the rate of reading. The standard scores for accuracy and comprehension increased at assessment 3 and statistically significant difference was seen for accuracy and comprehension standard scores (Table 4.8).

Table 4.8: Within group change of scores for Neale Analysis of Reading Group B (n=15)

	Assess 1	Assess 2	Change 1-2	*p-value*	Assess 3	Change 2-3	*p-value*	Change 1-3	*p-value*	Effect size 1-3
	Mean Standard scores (SD)				Mean (SD)					
Accuracy Standard Score	77.06 (8.42)	74.13 (7.26)	-2.93	0.01**	78.13 (7.76)	4.00	0.00**	1.07	0.38	0.13
Comprehen-sion Standard Score	82.13 (9.30)	82.33 (8.65)	0.20	0.75	87.20 (9.54)	4.87	0.00**	5.07	0.00**	0.53
Rate Standard Score	76.20 (8.24)	75.53 (10.42)	-0.67	0.50	75.06 (10.24)	-0.47	0.45	-1.14	0.48	-0.10

Significance $p \leq 0.05$*
$P \leq 0.01$**

Accuracy and comprehension showed overall improvement between the baseline assessment 1 and assessment 3 but a positive statistical significant difference was only seen for comprehension standard scores. No significant difference was seen for rate scores which decreased between assessment 1 and 3. The change in reading for Group B indicated small effect sizes for accuracy, a moderate effect size for comprehension equal to a half a standard deviation and a small negative effect size for rate.

4.5 Between Group Analysis

4.5.1 Comparison of the groups at baseline Assessment 1

A comparison of Group A and Group B for the Clinical observation scores, the DEM standard scores and the NARA standard scores using the Mann-Whitney U test showed no significant difference between the groups on any test. The p values for the baseline scores of the two groups ranged from 0.30 to 0.80. Since there was no significant difference between the groups, they were considered comparable at baseline Assessment 1.

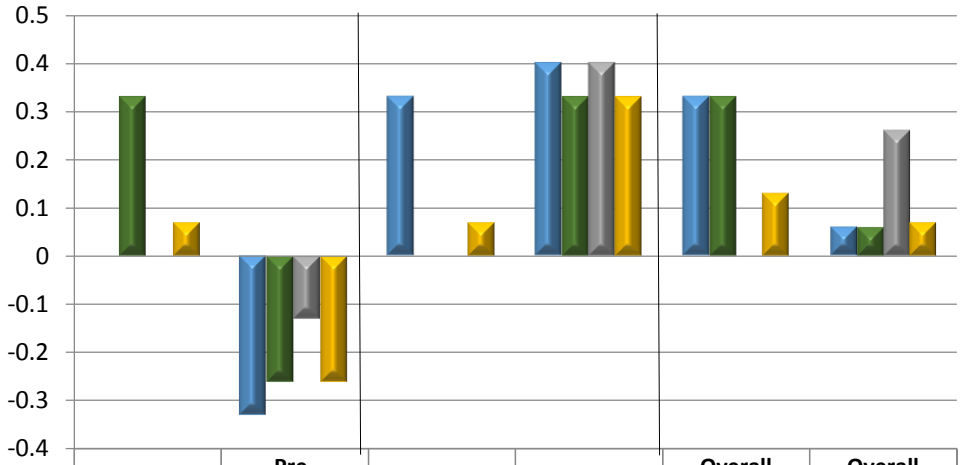
When comparing group A and B, the change in scores was considered for the pre-intervention period for Group B, at the end of the intervention for both groups and

after consolidation phase where intervention was withdrawn for Group A. This was to determine the effect of the proposed oculomotor-vestibular-proprioceptive intervention strategy had on oculomotor function and reading ability.

4.5.2 Oculomotor Function

4.5.2.1 Clinical Observations based on Sensory Integration Theory - subtest for eye movements

Group B showed a decrease in eye movements in the pre-intervention period. Group A showed an improvement in midline scores after the intervention and a slight change in quick localization. Group B showed an improvement in all four aspects of eye movements scores following the intervention while Group A continued to improve for general eye movements and quick localization but otherwise, scores were maintained in the consolidation withdrawal of intervention period from assessment 2 to 3 (Figure 4.7)



	Intervention Group A	Pre-intervention Group B	Withdrawl Group A	Intervention Group B	Overall change Group A	Overall change Group B
	Assessment 1-2		Assesment 2-3		Assessment 1-3	
General	0	-0.33	0.33	0.4	0.33	0.06
Midline	0.33	-0.26	0	0.33	0.33	0.06
Convergence	0	-0.13	0	0.4	0	0.26
Quick Localisation	0.07	-0.26	0.07	0.33	0.13	0.07

Figure 4.7: Change in clinical observation scores pre-intervention, after intervention and after a withdrawal of intervention consolidation phase.

Group A continued to improve for general eye movements and quick localisation but otherwise, scores were maintained in the consolidation withdrawal of intervention period from assessment 2 to 3. The mean change or Group A showed a significant improvement in the midline aspect after intervention, compared to Group B in assessment 1 to 2 (Table 4.9).

Table 4.9: Change in Clinical Observation scores from assessment 1-2 and 2-3 for Group A and B (n=30)

	Mean Change Assessment 1-2				Mean Change from Assessment 2-3			
	Group A	Group B	p-value	Effect size	Group A	Group B	p-value	Effect size
	Mean (SD)				Mean (SD)			
General	0.00 (0.76)	-0.33 (0.61)	0.22	0.47	0.40 (0.50)	0.33 (0.48)	0.72	0.14
Midline	0.33 (0.81)	-0.26 (0.70)	0.04*	0.73	0.33 (0.61)	0.00 (0.65)	0.16	0.51
Convergence	0.00 (0.53)	-0.13 (0.63)	0.53	0.22	0.40 (0.63)	0.00 (0.65)	0.13	0.61
Quick Localisation	0.07 (0.46)	-0.26 (0.45)	0.06	0.67	0.33 (0.48)	0.07 (0.46)	0.14	0.56

Significance $p \leq 0.05$*
$P \leq 0.01$**

There was also a large clinically relevant effect size for improvement in the midline and quick localization aspects for Group A compared to Group B, when Group A received intervention and Group B was in the pre-intervention phase. The results for Group B showed moderate clinically relevant effect sizes for the midline, convergence and quick localization aspects after intervention relative to Group A during their consolidation withdrawal phase, but these changes were not statistically significant. Since Group A continued to improve for general eye movements during this phase, the effect size for change between the groups was small.

When the overall change between assessments 1 and 3 was considered for Group A and Group B greater change was seen in Group A, except for in convergence, as Group B scores had decreased at assessment 2 and then increased. Group A continued to improve during the consolidation withdrawal phase. There was no

significant difference between the groups for overall change with small effect sizes indicated in all aspects of eye movements between the two groups (Table 4.10).

Table 4.10: Change in Clinical Observation scores from assessment 1-3 for Group A and B (n=30)

	Mean Change from Assessment 1-3			
	Group A	**Group B**	**p-value**	**Effect size**
	Mean (SD)			
General	0.33 (0.48)	0.06 (0.70)	0.12	0.44
Midline	0.33 (0.61)	0.06 (0.59)	0.31	0.44
Convergence	0.00 (0.65)	0.26 (0.79)	0.37	-0.36
Quick Localisation	0.13 (0.35)	0.07 (0.26)	0.61	0.19

Significance $p \leq 0.05$*
$P \leq 0.01$**

4.5.2.2 Developmental Eye Movements test (DEM)

The change in ratio scores were not included in the comparison between Group A and Group B as the within-group results indicated that both groups moved from oculomotor dysfunction to mixed dysfunction in visual motility.

When the groups were compared, Group A showed the greatest change in horizontal and error scores following the intervention. Following the consolidation period, vertical, horizontal and error scores improved further. Group B showed a positive change in horizontal and errors scores during the pre-intervention period and both scores continued to improve following the intervention at assessment 3. Overall, both groups showed improvement in horizontal scores and error scores with only Group A showing overall positive change for vertical times (Figure 4.8).

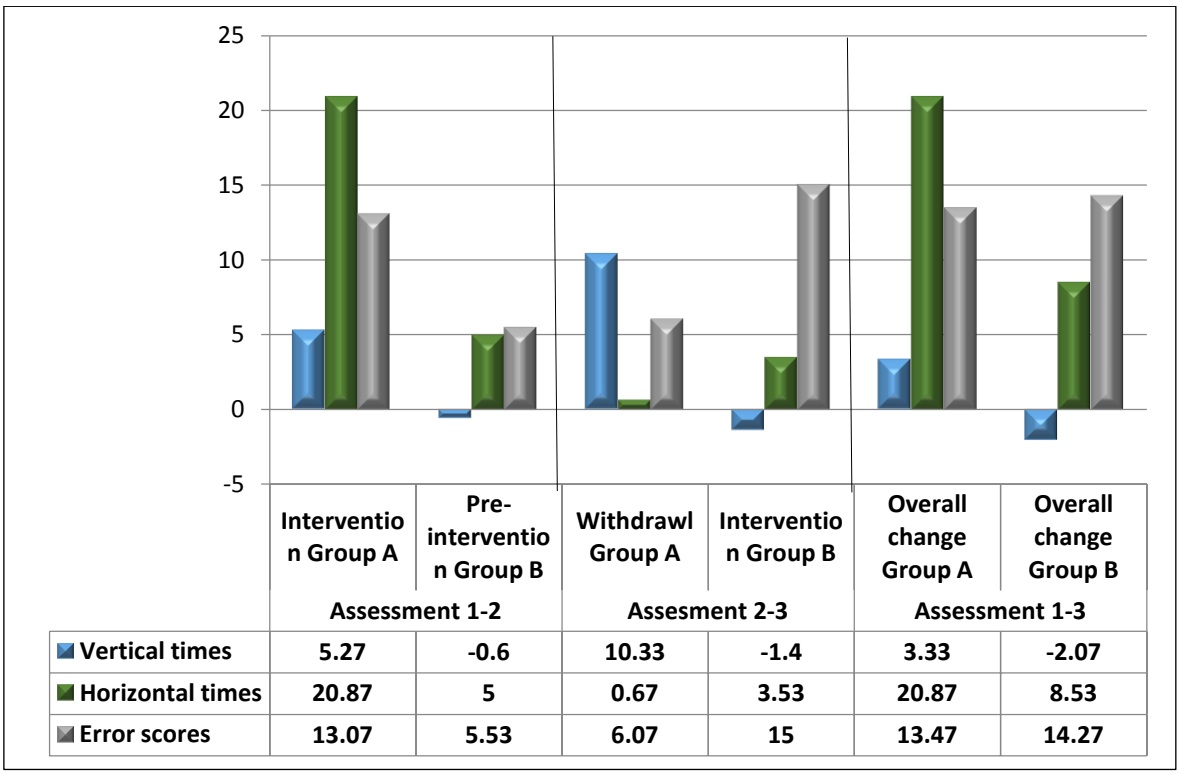


Figure 4.8: Change in Developmental Eye Movement test scores for Group A and B (n=30)

No significant differences were shown for the mean change in the DEM scores between Group A and Group B at assessment 1 and 2. Moderate effect sizes indicated that Group A showed clinically relevant improvement compared to Group B for vertical and horizontal time as well as error scores after Group A received intervention.

Group B did have a significantly greater change in horizontal time scores following the intervention comparative to Group A between assessment 2 and 3 although, this was not reflected in the effect size which was small (Table 4.11).

Table 4.11: Change in Developmental Eye Movement Test scores from Assessment 1-2 and 2-3 for Group A and B (n=30)

	Mean Change Assessment 1-2				Mean Change from Assessment 2-3			
	Group A	Group B	p-value	Effect size	Group A	Group B	p-value	Effect size
	Mean (SD)				Mean (SD)			
Vertical time	5.27 (19.68)	-0.60 (14.55)	0.66	0.34	10.33 (14.02)	-1.40 (14.57)	0.03*	-0.77
Horizontal	20.87	5.00	0.57	0.00	0.67	3.50	0.02*	0.16

time	(32.22)	(23.23)			(24.30)	(10.7)		
Errors	13.07 (36.57)	5.53 (25.34)	0.68	0.24	6.07 (42.24)	15.00 (25.63)	0.66	0.26

Significance p ≤ 0.05*
P ≤ 0.01**

A negative effect size indicated a clinically relevant decrease with a large effect size in vertical time for Group B compared to Group A. Although the errors score improved after the intervention compared to Group A, it was not statistically significant and the small effect size meant it was not clinically relevant as the errors score for Group A continued to improve in this consolidation withdrawal phase.

When the overall change was considered, there was no statistical significance difference between the groups, with small effect sizes shown. However, Group A improved more than Group B in vertical and horizontal time. Group B improved more in the error scores indicating a decrease in visual inattention (Table 4.12).

Table 4.12: Change in Developmental Eye Movement Test scores from Assessment 1-3 for Group A and B (n=30)

	Mean Change from Assessment 1-3			
	Group A	**Group B**	**p-value**	**Effect size**
	Mean (SD)			
Vertical time	3.33 (18.20)	-2.07 (17.04)	0.56	0.31
Horizontal time	20.87 (38.55)	8.53 (17.65)	0.09	0.44
Errors	13.47 (43.79)	14.27 (26.94)	0.79	-0.02

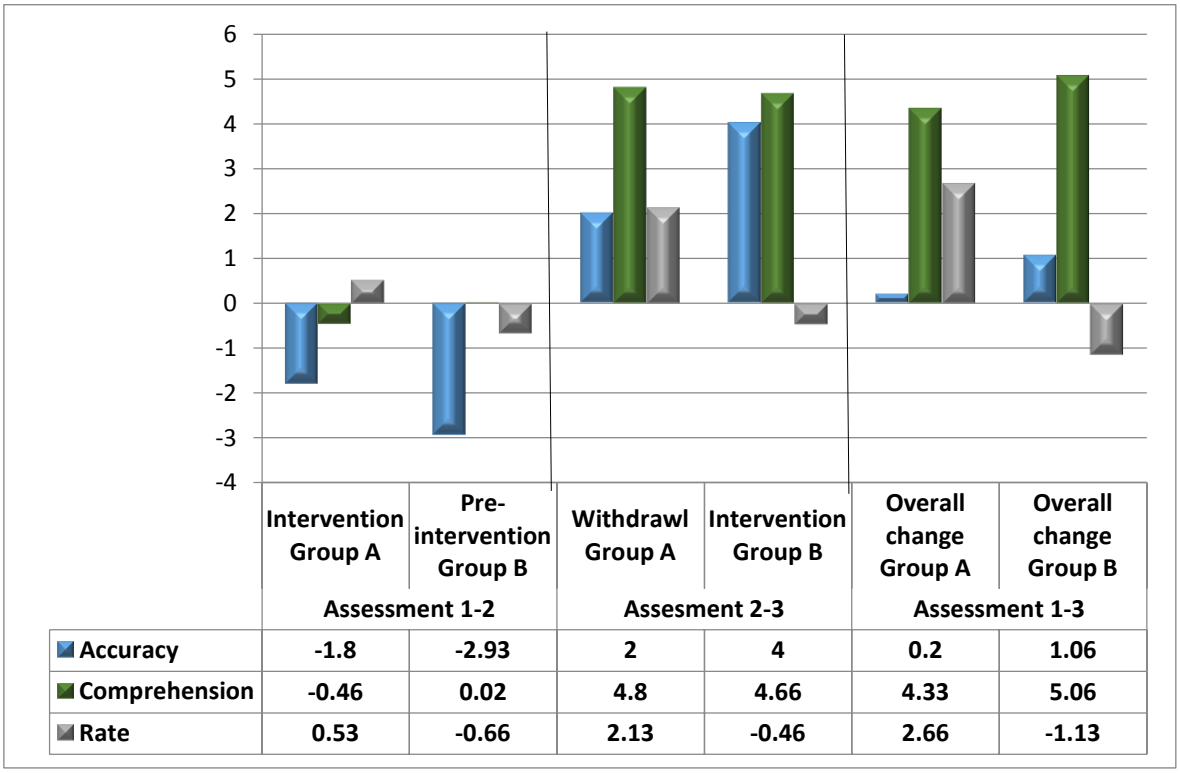
Significance p ≤ 0.05*
P ≤ 0.01**

4.5.3 Reading Ability

4.5.3.1 The Neale Analysis of Reading (NARA)

The NARA scores for Group A, except for rate, were negative following the intervention but all three improved when therapy was withdrawn in the consolidation phase. While the scores decreased or remained the same for Group B in the pre-intervention phase, positive improvement in accuracy and comprehension was seen following the intervention. An overall positive change for

comprehension was found for both groups, with improvement in rate for Group A and a small change in accuracy for Group B (Figure 4.13).



	Intervention Group A	Pre-intervention Group B	Withdrawl Group A	Intervention Group B	Overall change Group A	Overall change Group B
	Assessment 1-2		Assesment 2-3		Assessment 1-3	
Accuracy	-1.8	-2.93	2	4	0.2	1.06
Comprehension	-0.46	0.02	4.8	4.66	4.33	5.06
Rate	0.53	-0.66	2.13	-0.46	2.66	-1.13

Figure 4.9: Change in Neale Analysis of Reading test scores for Group A and B (n=30)

A significant difference was seen for accuracy between assessment 1 and 2 for Group A and B. Although both groups had decreased scores at this time, the decrease for Group A after intervention was less. Group A also had a decrease in comprehension scores compared to a small increase in Group B, resulting in a significant change between the groups. Rate did increase for Group A following the intervention, compared to the decrease seen in rate for Group B during their pre-intervention phase. Effect sizes were small when Group A was compared to Group B indicating the change was not clinically relevant.

Between assessment 2 and 3, both groups improved for accuracy and comprehension, Group A in their consolidation withdrawal phase and Group B directly after the intervention (Table 4.13).

Table 4.13: Change in Neale Analysis of Reading Test scores from assessment 1-2 and 2-3 for Group A and B (n=30)

	Mean Change Assessment 1-2				Mean Change from Assessment 2-3			
	Group A	Group B	p-value	Effect size	Group A	Group B	p-value	Effect size
	Mean (SD)				Mean (SD)			
Accuracy	-1.80 (3.94)	-2.93 (4.06)	0.00**	0.29	2.00 (2.29)	4.00 (4.48)	0.00**	0.59
Comprehension	-0.46 (6.92)	0.02 (4.42)	0.00*	-0.08	4.80 (5.44)	4.66 (4.25)	0.76	0.05
Rate	0.53 (4.43)	-0.66 (6.19)	0.27	0.22	2.13 (4.13)	-0.46 (4.11)	0.08	-0.62

Significance p ≤ 0.05*
P ≤ 0.01**

A statistically significant change with a moderate clinically significant effect size was indicated for accuracy with Group B benefitting from the intervention for this aspect. While rate continued to improve for Group A in their consolidation withdrawal phase it decreased for Group B following the intervention, with the change showing a negative moderate effect size compared to Group A.

Overall, Group B showed a significantly more improvement in accuracy and comprehension scores in comparison to Group A but, the small effect sizes indicated that this change was not clinically relevant. Group A had a clinically relevant increase with a moderate effect size in rate of reading compared to Group B (Table 4.14).

Table 4.14: Change in Neale Analysis of Reading Test scores from Assessment 1-3 for Group A and B (n=30)

	Mean Change from Assessment 1-3			
	Group A	Group B	p-value	Effect size
	Mean (SD)			
Accuracy	0.2 (3.48)	1.06 (4.57)	0.00**	0.17
Comprehension	4.33 (5.66)	5.06 (4.77)	0.00**	0.14
Rate	2.66 (5.31)	-1.13 (5.35)	0.24	-0.71

4.6 Association between change in Oculomotor Function and Reading Scores

The scores from the three tests were correlated to determine the association between the tests and reading ability for baseline at assessment 1 and the final scores after both groups had had intervention at assessment 3.

There was no correlation between the eye movement scores and the standard scores from the DEM for the baseline or final assessments.

Table 4.15: Correlations between the oculomotor test scores and reading scores for Assessment 1 and Assessment 3 (n=30)

	NARA Accuracy		NARA Comprehension		NARA Rate	
	rho		rho		rho	
	Assess 1	Assess 3	Assess 1	Assess 3	Assess 1	Assess 3
Clinical Observation						
General	0.35	0.32	0.13	0.05	0.36	0.13
Midline	0.28	-0.06	-0.03	-0.21	0.25	-0.09
Convergence	0.17	**0.41**	0.09	**0.43**	0.24	0.20
Quick Localisation	0.22	-0.00	0.32	0.00	0.31	-0.40
DEM						
Vertical time	**0.57**	**0.56**	0.36	0.39	**0.56**	**0.62**
Horizontal time	0.36	**0.58**	0.18	0.39	**0.51**	**0.58**
Ratio	-0.07	0.25	-0.21	0.08	0.10	0.22
Error	0.11	0.20	0.17	0.10	0.19	0.30

The eye movement scores did not correlate with the reading scores at baseline but convergence scores had a moderate correlation with accuracy and comprehension at assessment 3. This indicates this component of eye movements may be associated with these aspects of reading. This result was seen in Group B where these three components improved more than for Group A.

The DEM vertical scores correlated moderately with accuracy and rate scores on the NARA at baseline assessment 1. In the final assessment 3, both the vertical and horizontal scores correlated moderately with the accuracy and rate of reading. This supports the results for Group A where improvement in both the vertical and horizontal time on the DEM and the accuracy and rate of reading was found. The

stronger correlation between the vertical time on the DEM and rate on the NARA supports the results for Group B where a decrease in both components was found.

The correlations do not support the findings for comprehension, which showed the greatest improvement in both groups.

4.7 Summary

Group A showed improvement in three of the four areas assessed in the clinical observation of eye movements, with convergence remaining the same. Although the changes were not statistically significant, the most change occurred in the consolidation withdrawal period for eye movements between assessment 2 and 3 with overall improvements in general eye movements of 0.27, movements across the midline of 0.33 and quick localisation of 0.13 between assessment 1 and 3. Moderate effect sizes were observed apart for the convergence component. For the clinical observation of eye movements, Group B showed a decrease in scores for all areas of the eye movements before the intervention. At assessment 3, all areas improved following the intervention with statistically significant change noted for general eye movements, convergence and quick localisation. However overall, effect sizes were small apart from quick localisation, which displayed a moderate effect size.

For the DEM scores, the ratio and horizontal scores showed statically significant improvement following the intervention. Despite the drop in the vertical scores at assessment 2, the vertical, ratio and error scores all improved further in the consolidation period, this shows carry over even when intervention was withdrawn. In the case of the DEM, three areas increased in score before the intervention and these areas continued to increase in assessment 3 following the intervention. Overall statistically significant change was observed for horizontal, ratio and errors scores. Large effect sizes were observed for errors and ratio categories. The null hypothesis for change in oculomotor function was therefore rejected significant change or moderate effect sizes were seen for horizontal, ratio and error components of eye movements in one or other of the groups as well as the subtest of the DEM except for vertical time.

The reading accuracy and reading comprehension scores for the NARA decreased following the intervention, while rate of reading improved slightly. However, all three areas improved following the consolidation period when intervention was withdrawn with comprehension and accuracy displaying statistically significant change. Significant difference and a moderate effect size was only observed for comprehension from assessment 1 to 3.

For the NARA, the decrease in the accuracy scores preceding the intervention was statistically significant. Accuracy and comprehension scores improved significantly following the intervention, with rate scores decreasing at assessment 2 and 3. Accuracy and comprehension scores improved overall but only the comprehension score was significant. The null hypothesis could not be rejected for all components assessed by the NARA as rate did not show any significant change in either group. The null hypothesis could be rejected for accuracy and comprehension however.

The findings, except for comprehension, were supported by the correlations between scores. A moderate correlation was noted between convergence, accuracy, and comprehension on assessment 3. Correlations were also found between vertical and horizontal scores, accuracy, and rate of reading but a stronger correlation existed between vertical time and rate.

CHAPTER 5: DISCUSSION

5.1 Introduction

Although the literature is controversial, a relationship can be identified between eye movements and reading ability (83) (10). The results of the study demonstrated that a positive change in oculomotor function can have a positive influence on reading accuracy, rate and comprehension.

This chapter will consider the demographics of the sample as well as their deficits in eye movements and reading. The change in eye movements and reading is discussed for Group B in a pre- intervention phase, an intervention phase for both Group A and B after a three-week period of intervention as well as a post-intervention phase for Group A, after a consolidation period during which intervention was withdrawn. The changes in reading and oculomotor function for both groups at these three assessment times, as well as the correlation between the changes in eye movements and reading ability for the baseline and final assessments, is considered.

5.2 Demographics

The sample groups displayed no significant differences between Group A and B as the participants were all similar in age, gender, and educational background and language skills. Flamboyant School is a remedial school for learners with learning disabilities. Research indicates that learning disabilities occur in a ratio of three to two in males and females, particularly for reading (84). More males attend the school and therefore more males were recruited in the study. There was no significant difference in age or grade between Group A and Group B (Table 4.1).

Addressing reading in this age group was appropriate as research is mounting about the mature brain having a greater capacity for plasticity than previously thought (85). Individuals make dramatic gains in successful cognitive control from childhood to adolescence (commonly occurring between the ages of 10 to 16 years) with the adolescent period described as a unique period important in establishing adult-level stability of cognitive processing (86).

5.3 Changes in oculomotor function and reading ability in relation to a sensory stimulation programme

The first two objectives which considered the effectiveness of a sensory stimulation oculomotor-vestibular-proprioceptive intervention programme on oculomotor function and on the reading rate, reading accuracy and reading comprehension and of primary school will be considered together.

The sensory stimulation oculomotor-vestibular-proprioceptive intervention programme used in this study directly targeted visual function and vestibular function which included volitional visual tracking exercises and a whole body activity with a strong oculomotor component. Activities required divergence and convergence, monitoring of the periphery while maintaining central vision on a target as well as visual fixation and quick localization of a visual target. Therefore, changes in oculomotor function before and after the intervention will be discussed as well as the change found for reading ability.

Both Group A and Group B had DEM scores below the 16th percentile on the first assessment with reading scores that fell between the 6th percentile and the 12th percentile and the groups were comparable with no significant differences for Assessment 1. The horizontal scores on the DEM were lower, indicating oculomotor dysfunction, which was confirmed by the scores on the Clinical Observation, which centred around 2.5. Furthermore, participants in both groups were assessed to fall into a below average to very low category for reading ability. These results could be used to support the relationship that has been explored in literature, which is that reduced eye movements would have a negative impact on reading ability (54) (45). Similar findings were found by Palomo-Álvarez C (2009) (63), that more learners between the ages of 8-10 years with poor reading skills in their study presented with oculomotor type II dysfunction on the DEM than automaticity and oculomotor skills deficits (63).

5.3.1 Pre intervention phase

Group B was assessed at the start of the study (Assessment 1) and was assessed again three weeks later (Assessment 2). In this period, they formed the control group while Group A received intervention.

During this pre-intervention phase, there was a decrease in all four of the eye movement scores on the Clinical Observation between the two assessments for Group B. The changes were between 0.27 and 0.34 (Table 4.5). This may be related to the observational nature of the tests and small scale for scoring as there are no clear definitions of what a normal, slightly difficult and a definite problem is.

It was important to use a standardised test to further assess oculomotor dysfunction. The DEM was used and on this test, there was an increase in three of the four standard scores between assessment 1 and 2. The horizontal and error standard scores increased which affected the ratio scores. This could be due to test-retest reliability of the DEM as Tassinari and Paul DeLand (2005) did find differences in the reliability, especially for error scores and ratio scores on a retest in schoolchildren, which they attributed to a less than best performance on the first attempt at the test. A small learning effect has also been reported when the test is presented for the second time where scores may be faster on the horizontal and vertical scales. Familiarity with the test may also have resulted in fewer errors in the second administration (87).

Unlike the results reported by Tassinari and Paul DeLand (2005), no learners in this group had a change in diagnostic category with the change in results (87). The results still all fell as a dysfunctional percentile and the horizontal scores increased from the 2nd to the 3rd percentile and the errors scores from the 5th to the 6th percentile (Figure 4.4)

The difference in the results for the eye movements on the Clinical Observations, which decreased, and the scores on the DEM, which increased, are supported by a study conducted by Ayton et al. (2009) which showed, that although the DEM scores correlate well with reading ability they do not correlate with assessment of eye movements measured with optic eye movement spectacles (50).

Therefore, the slight increase in comprehension scores in the pre-intervention phase on the NARA reading scores for Group B, was congruent with the increase in the DEM scores. The NARA rate and accuracy scores decreased significantly for Group B. The reason for the decrease in accuracy is not clear in view of the decrease seen in error scores but the decrease in rate may be related to the increase in comprehension scores as the participants slowed down in order to

better understand what they were reading. The positive change in comprehension could also be because awareness of this group of participants in terms of reading was increased just by being included in the study even if they did not receive intervention. Comprehension is a concept that is tested and used daily in the school environment and they may have been more aware of its importance in view of the study. This difference was small and both scores were dysfunctional and fell at the 12th percentile. Therefore, most scores for oculomotor function and reading for this group in the pre-intervention phase showed some deterioration, with the exception of the comprehension score as well as the horizontal score and error score on the DEM, which increased by one percentile on the second assessment.

Group A received intervention during the period that Group B was in the pre-intervention phase (Assessment 1-2). No significant difference was seen in any of the assessments between the groups in this phase. Moderate effect sizes that were clinically relevant were found for Group A for the change in eye movements across the midline and general eye movements on the Clinical Observation when compared to Group B. However, except for eye movements across the midline, there was minimal or no change for Group A on the Clinical Observation assessment. Changes relative to Group B were not based on improvement in Group A but deterioration in all eye movements found for Group B (Figure 4.7 and Table 4.9).

Group A did however have significant improvement in horizontal and ratio standard scores although this was also not significantly different when compared to Group B, due to the increase Group B presented within the pre-intervention phase (Figure 4.8). Group A did show greater improvement between assessment 1 and 2 than Group B horizontal standard scores and Group B improved more in the errors score. The changes in the scores between the groups were also not clinically relevant (Figure 4.8 and Table 4.11).

The change on the DEM did relate to changes in reading standard scores in Group A as the improvement in horizontal scores on the DEM reflected in an increase in rate on the NARA. This increase in rate was accompanied by a decrease in accuracy and comprehension. The difference between Group A and Group B was

significant for accuracy and comprehension, this was due to more deterioration of accuracy in Group A and comprehension in Group B (Table 4.13).

Significant differences and clinically relevant differences with moderate effect sizes between Group A and B at this stage were found for all the Clinical Observation scores except convergence (Table 4.9). This indicated the effectiveness of the sensory stimulation oculomotor-vestibular-proprioceptive intervention programme for this component only. There was no clinically relevant difference in the DEM or NARA scores between the groups as the effect sizes between the groups was small due to the small sample size and large variation in change resulting in large standard deviations (Table 4.9 and Table 4.11). Although accuracy and comprehension were significantly different for Group A and B, this difference supported the small effect size as accuracy showed deterioration in both groups and comprehension improved in Group B, which was the control group, indicating no effectiveness in improving reading which could be attributed to the programme at this stage.

5.3.2 Intervention phase

When the intervention phase for the two groups was analysed between Assessment 1-2 for Group A and Assessment 2-3 for Group B, change for eye movements across the midline on the Clinical Observation was found in both groups. Following their three weeks intervention period, the difference was significant for Group A but not Group B. Group B showed positive significant change for general, convergence and quick localization. This improvement made up for the decrease in eye movements in Group B that occurred in the pre-intervention phase and this group had an increase in all four scores to levels above those seen in Assessment 1 (Table 4.5).

The improvement in the Clinical Observation of eye movements during the intervention phase was not clearly supported by the improvement in the DEM scores. Group A had significant changes in the horizontal scores from the 0 percentile to the 4th percentile as well as improvement in the error standard scores from the 4th to the 5th percentile during this phase. The immediate improvements found for Group A after the intervention, were also seen in Group B after the intervention for horizontal standard scores, which improved from the 3rd to the 4th

percentile. Group B had a significant improvement in errors standard scores from the 6th to the 9th percentile.

There was little change in the vertical standard scores, which measure automaticity, with a decrease from the 4th to the 3rd percentile for Group A and a small decrease for Group B where scores remained at the 3rd percentile. This was not unexpected as this aspect was not fully addressed in the intervention programme. The changes in the ratio scores for both groups were influenced by the improvement in the horizontal and error standard scores and a decrease in vertical scores and are therefore congruent with these results.

The results thus indicate a change for horizontal standard scores after the intervention phase in both groups indicating improvement in the oculomotor function assessed by the horizontal score in the DEM component, which was addressed by the intervention (50). Since improved standard scores in horizontal times and ratio scores have been linked to decreased difficulty in oculomotor scanning using horizontal eye movements (51), the significant changes in the horizontal and therefore the ratio standard scores in Group A can be assumed to indicate an improvement in oculomotor function. This cannot, however, be linked to the significant change in eye movements across the midline (50) where improvement was also greater in Group A. This area requires further investigation.

The change in the errors standard scores, while not considered as reliable as the vertical and horizontal scores in the DEM, were significant for Group B and as these scores are linked to improvement in visual inattention, this was a more likely outcome for this group (88). Improvement in Group B was also greater for convergence and quick localization in eye movement assessed by the Clinical Observation but this was not clearly linked to improvement on the DEM (50). Both these aspects need further investigation as no correlations were found between the DEM and eye movement scores in this study.

The effectiveness of the sensory stimulation oculomotor-vestibular-proprioceptive intervention programme differed for the two groups so definite conclusions about which components of eye movements are best treated with this programme cannot be drawn. The small group's sizes may have resulted in the different results but it

can be confirmed that the programme had no effect on the vertical scores of the DEM.

Eye movements across the midline and quick localization eye movements, both related to saccadic movements, are needed for reading and the oculomotor function assessed by the DEM has been associated with reading ability in various studies (50,62). Therefore, with the improvement in eye movements and DEM horizontal and error standard scores, a positive change in reading scores was expected in both groups on completion of the intervention phase.

However, for Group A the accuracy and comprehension standard scores for the NARA decreased following the intervention and while comprehension remained at the 10th percentile, accuracy was reduced from the 10th percentile to the 8th percentile. Rate of reading improved but remained at the 6th percentile. This improvement may be aligned to the significant increase in horizontal scores found on the DEM, which is related to faster reading of horizontal numbers, but does not reflect the decrease in errors related to better visual attention also found for the DEM for this group.

For Group B there was a significant improvement in accuracy which improved from the 6th to the 9th percentile and comprehension which improved from the 11th to the 19th percentile. The rate of reading decreased slightly but remained at the 6th percentile for this group which may be due to the attention paid to accuracy while reading which could result in a slower reading rate. These findings are congruent with the significant change found for error scores on the DEM. This improvement in visual attention was probably related to their more accurate reading, which could assist with comprehension but did not account for the improvement in horizontal scores on the DEM, which could result in increased rate.

Thus for Group A, the significant change in horizontal scores related to oculomotor function does appear to have assisted in the rate of reading while in Group B the significant change in error scores was associated with visual attention and resulted in better accuracy and comprehension while reading. All the scores for the DEM and NARA remained below a standard score of 85 indicating definite dysfunction for both groups except the comprehension score for Group B, which was 87 and placed the group at risk of dysfunction above -1SD following the intervention.

5.3.3 Post intervention consolidation phase

Group A was assessed for a third time three weeks after the intervention to determine if there were further improvements on any of the assessments once intervention had been withdrawn. Some areas only improved following the period when intervention was removed.

For the Clinical Observation the scores for general and quick localization eye movements improved while the midline and convergence scores remained the same (Figure 4.7). No significant difference was observed overall, the effect size was small, and although not significantly different to Group B, the positive change in eye movements was greater in Group B who received intervention at this time. This indicates that eye movements did improve more for both groups in the intervention phase with a small improvement in the consolidation phase for Group A for general and quick localization eye movements.

The improvement in eye movements assessed on the Clinical Observation could not be aligned with changes in the DEM scores (50). During this consolidation period, the vertical standard scores of the DEM showed improvement from the 1st to the 4th percentile for Group A. The reason for this increase in automaticity was not clear and needs more investigation.

The horizontal scores remained unchanged and with the increase in the vertical scores this resulted in lower ratio standard scores (Figure 4.8). The error standard scores improved from the 5th to the 9th percentile and this demonstrates carry over for improvement in visual attention related to the error scores even when intervention was withdrawn.

A possible reason for the changes during the post-intervention consolidation phase may be explained by ‘memory consolidation’. Memory is most commonly divided into two categories declarative memory (consciously accessible memories of fact based information) and nondeclarative memory (unconsciously accessible memories of procedure i.e. ‘the how’ learning of actions, habits and skills) although, these categories rarely operate in isolation. Memory consolidation is a period where memories become more stable in the absence of more practice, which appears to occur largely during wake hours and, and where memories are enhanced, occurring primarily during sleep (7). A study that investigated the role of

sleep on consolidation of sensorimotor (various stimulus input and motor responses) skill learning in a task that cannot depend on rote learning, found that sleep-dependent consolidation extends to more complex, naturalistic behaviours where performance recovered and stabilized following sleep (89)

When reading ability was reassessed following the consolidation period when intervention was withdrawn, at assessment 3, all three areas of reading improved for Group A. There was a significant improvement in comprehension from the 10th to the 14th percentile and for accuracy from the 8th to 9th percentile, indicating the need for further time in this group before the effectiveness of the intervention programme was seen. This improvement in comprehension and accuracy was accompanied by an improvement in error scores on the DEM, which was similar to the findings for Group B. In this group, rate continued to increase from the 6th to the 7th percentile although, the horizontal scores on the DEM did not increase which may be related to the increase in vertical scores at this stage (Figure 4.9).

The improvement in the consolidation phase for Group A still had a significantly less positive change in their accuracy scores than Group B but the change in their comprehension scores was similar to Group B. The change in reading rate was clinically greater than that of Group B with a moderate effect size (Table 4.13).

Therefore, it was clear that even though the horizontal scores did not continue to improve when intervention was withdrawn, other aspects assessed by the DEM did and particularly the automaticity related to the vertical scores and visual attention related to error scores. This was accompanied by an increase in reading accuracy and comprehension that was not found immediately following the intervention. Thus carry over does result after the intervention is withdrawn which adds to the effectiveness of the programme even after the short period of implementation.

5.3.4 Change overall

A study that indicated that poor readers in high school may be at risk for poor saccadic tracking skills suggested that if the deficit is due to poor saccadic tracking, convergence and accommodation ability, the skills can improve through optometric therapy and reading should then improve (11). This was supported by

the results of the study as participants in Group A improved in all aspects related to eye movements, except convergence, on the Clinical Observation and reading, with comprehension showing a significant difference and moderate effect size. Participants in Group B improved in all aspects related to eye movements, except vertical scores, on the DEM and accuracy and comprehension in reading with comprehension scores also showing a significant difference and moderate effect size.

The overall results, which compared the difference in scores from the initial assessment to the final assessment (Assessment 1 to Assessment 3), showed that Group A had more positive change than Group B on the Clinical Observations, except for in convergence. The change in eye movements across the midline and general eye movements were also found to have clinically relevant higher scores with moderate effect sizes when Group A was compared to Group B. A similar result was found for the horizontal scores on the DEM, which was significantly better for Group A. These differences appear to support the rate change seen for Group A which also showed clinical relevance and a moderate effect size when compared to Group B.

This is supported by Palomo-Alvarez and Puell (2009) who found that the horizontal DEM test can be used to predict speed in below average readers as there are increased spatial demands in this component of the test (63). The vertical scores for Group A were significantly higher than Group B. The higher vertical scores for Group A can also be linked to improved rate in reading. According to Garzia et al. (1990) the vertical test can be linked to automaticity skills required for fluency when reading (51). The reason for these higher scores can be attributed to the further improvement, which occurred during the consolidation period after the intervention phase (Table 4.10, 4.12 and 4.14).

Results for the DEM indicated greater change for Group B for error scores (Table 4.12) and although the difference was significant but not clinically relevant when compared to Group A, it appears to support the greater change in accuracy and comprehension when reading which was significantly better than for Group A although the effect sizes were small.

Despite the fact that not all of the components in oculomotor function and reading ability improved directly after the intervention or at the same time, the results demonstrate that the intervention strategy did support positive changes in these areas. Oculomotor skills assessed by the Clinical Observation of eye movement showed improvements with the results following the proposed hypothesis. The results for the DEM were however varied, with vertical scores only improving after the consolidation period. Overall improvements in reading accuracy and comprehension were observed following the intervention with rate only improving in Group A. The role of the Clinical Observation scores could not be directly linked to the improvement in the reading scores and correlations were therefore used to determine if links exist.

5.4 The association between the reading rate, reading accuracy and reading comprehension and oculomotor function

The association between reading and oculomotor skills has been shown especially between eye movements, DEM results and reading ability and thus correlations between the changes in the NARA and oculomotor function scores (90) were considered to establish if they supported the suggested associations between the changes discussed above. The Clinical Observation scores and DEM scores were correlated with the NARA scores for the initial assessment and the final assessment.

Correlations were found between vertical and horizontal scores and rate of reading on assessments 1 and 3. This correlation supported the results of this study for Group A and for Group B, except for the change in horizontal scores from the 3rd to the 4th percentile. This may be accounted for by the higher horizontal scores and reading rate in Group B on the initial assessment and the fact that the change in Group A brought them up to an equivalent level in assessment 3. This finding is supported by a study that revealed that the reading rate of poor readers significantly correlated with the DEM horizontal times, with low scores being linked to a lower reading rate (63). Furthermore, associations have been made between visual skill level and reading outcomes such as fluency and comprehension (24).

The moderate correlation for accuracy in reading on the NARA and the DEM vertical scores at Assessment 1 indicate that poor vertical scores were congruent with poor accuracy scores on the initial assessment. This confirmed a link that was not obvious in the change of scores reported in this study where vertical scores did not change during the intervention but accuracy scores for Group B did change. The vertical and horizontal scores on the DEM also showed moderate correlations with accuracy on Assessment 3 and supports the findings for Group A in the consolidation phase where an improvement in accuracy occurred in conjunction with improvement in vertical scores. The reason for this is not clear and needs further investigation especially in view of the small decrease in vertical scores and a small increase in accuracy found in Group B on Assessment 3.

Convergence on the Clinical Observation did correlate moderately with both accuracy and comprehension on the final assessment, which also supports the change in comprehension and accuracy seen in Group B, where convergence improved after the intervention. This finding does not apply to Group A where convergence did not change and therefore further investigation is needed.

These results once again confirm the association between reading and DEM scores for some aspects but indicate that for others, there is no clear association between reading and eye movement assessments scores even though oculomotor deficits have been linked to reading (17).

CHAPTER 6: CONCLUSION

6.1 Introduction

Learning disabilities (LD) are seen in both public and private school settings. While LD is not a single disorder, most of the information relating to learning disabilities relates to reading abilities and many of the children with LD primarily struggle with basic reading skills (91). Occupational therapists assess and treat vestibular processing and oculomotor deficits using sensory stimulation. This study explored the impact of sensory stimulation on oculomotor function and reading skills.

6.2 Oculomotor function and reading skills

The idea that visual information processing underlies academic functioning is not universally accepted (14). Despite this, professionals across multiple disciplines have emphasised that oculomotor function and binocular function should be considered as these aspects influence reading ability even when language and attention deficits are controlled for but the relationship between visual skills and academics remains to be a controversial topic (14). Although the sample size was small, the results demonstrated that a stimulation programme can have a positive impact on oculomotor control and reading ability and that a relationship can be drawn between some of the components (92).

A relationship between eye movements and reading ability was demonstrated for Group A. According to the Clinical Observation, eye movements improved following the intervention and this was maintained after the period when intervention was removed. Horizontal time scores improved following the intervention and over the consolidation period. The scores for reading ability improved slightly following the intervention period but improved further after the consolidation period with overall positive change recorded for comprehension. However, effect sizes were small.

Clinical Observation scores for Group B improved following the intervention. All areas in the DEM, except vertical time scores, improved before and after the intervention and overall statistical improvement was shown. Reading ability scores

were varied with some scores improving and others worsening. Accuracy and comprehension standard scores improved following the intervention.

The between-group analysis showed that clinical observation scores for Group A improved and were maintained. However, Group B showed the greatest change in this area following the intervention. Group A showed improvements in reading ability following the consolidation period but overall, the margins were small. Group B showed positive change following the intervention but the overall change in accuracy and comprehension was small.

6.3 Effects of a sensory stimulation programme on oculomotor function and reading skills

The results of this study contribute to the understating of the potential benefits of a stimulation programme to improve performance in academic tasks. The need for this study and further research in this area is incredibly important as a large amount of stress is placed on the visual system for over 70% of the typical school day, proficient readers are reported to perform better than non-proficient readers when completing academic tasks and 30-60% of the school day consists of sustained reading, writing and near point tasks (14).

Although the research regarding the effectiveness of sensory integration therapy compared to alternative forms of intervention is controversial (93) and the main referral base for intervention is visual training with an optometrist (11), the results of this study suggest that learners who are identified as having reading difficulties may benefit from a sensory stimulation programme that promotes oculomotor function. This supports a bottom-up, sensory stimulation approach to learning that is both specific and unique to the practice of occupational therapy.

6.4 Limitations of the Study

A limiting factor of the study was the small sample size. A large sample size in quantitative research ensures more confidence when interpreting results and a more in-depth statistical analysis to be made. If this is done, clearer patterns and relationships between the various factors may be seen.

The justification of the study was to determine the effectiveness of the programme and in order to do so, it is important to determine the effectiveness of the contents of the programme.

Additional activities can be added to each session. Introducing a HART chart after the main activity could ensure further consolidation of the eye movement patterns (94). Hart charts can be used for accommodation, eye movements (saccades), and visual attention. There are two charts of rows of letters, one small and one large. The client is instructed to alternate reading a line from the distance and near charts during the activity. The activity can be made more challenging by alternating charts every half of a line. For saccadic work, only the distance chart is used. The client is instructed to read the outside two columns, one letter at a time, alternating between the two columns. As proficiency improves, the columns can be read in the same manner moving inward, eventually reading the two inner columns (94).

Clearer guidelines should also be included where descriptions of exact positioning of the participant and materials/ equipment in the environment, the postural alignment and control and the postural assumptions that should be avoided could be provided.

Further recommendations could be made drawn from the study conducted by Solan et al. (2001). Introducing stimulation of comprehension skills through reading programmes could further improve the scores. This can be introduced either before or following the stimulation programme as positive results were observed regardless of the order of the therapy that was received (92).

Visual problems can lead to a diagnosis of a learning disability or deficits within attention (95). The DEM exceeds what is assessed in a visual screening, which has been shown to be inadequate as mild and moderate visual functional difficulties may be overlooked (14) (95). It appears therefore that the DEM with specific time scores is an appropriate measure to determine the outcome of for visual function and the effectiveness of the sensory stimulation oculomotor-vestibular-proprioceptive intervention which targets oculomotor function and visual inattention. Ayton et al (2009) however suggests that other assessments are used in conjunction with the DEM as Ayton et al (2009) have shown that DEM scores

have little relationship with eye movements (50). The Clinical Observation of eye movements used in conjunction with the DEM may have affected the reliability of the assessments due to the nature of the scoring, which is not exact and open to subjective interpretation of the assessor. A visagraph could be introduced to measure eye movements more precisely as it provides a baseline score for the participant's reading eye movements (96).

The study consisted of learners from a remedial school. In order to generalize the results of the intervention, it would be beneficial to replicate the study with pupils in mainstream schools.

Although the researcher observed the research assistant completing a full assessment, a pilot study could be introduced where the researcher oversees the assistant during the assessment period to ensure consistency. The proficiency of the assistant would improve as more assessments are completed and as a result, the scoring and stringency could increase in the last assessment period, which could negatively impact on the scores. The pilot study would further aim to improve the level of skill of the assessor and gain an idea of the assessor's interest in the task as these factors can influence proficiency.

In order to address specific visual skills, it would be important to provide very clear and specific working definitions. Definitions that are more specific can be given for the areas that were assessed i.e. convergence (24).

Improvement was observed for Group A following the period when intervention was withdrawn. A limitation was that Group B did not have that same consolidation period and results could have been further increased if they had been tested following a consolidation period.

6.5 Clinical Recommendations

The number of sessions should be increased. It would be recommended that due to the short sessions, two sessions per week be conducted and that the intervention be increased to a minimum of six continuous weeks (12 sessions) instead of three. This was based on a study that explored the role of eye movement therapy and comprehension therapy on participants identified with

reading difficulties. Participants were seen weekly for 60 minutes; 12 weeks for eye movement therapy and 12 weeks of comprehension therapy (92). Positions of each of the originally proposed sessions could be repeated with the targets and symbols requiring matching being changed.

From a clinical perspective, the programme and the activities were not difficult to set up and administration to the participants was clear and simple. The main challenge and area that could improve is that the therapist conducting the session has to be sure of their clinical observations and very clear as to how to isolate the ocular component in each activity and to reduce any strain and tension in the body, especially the neck, shoulders and lower back area. The literature has shown that oculomotor control is a diverse topic and it is an area that is dependent on and influenced by many factors i.e. head and neck control, primitive reflexes, postural control and endurance. It would be important for the clinician to think about the topic, break down the activities and know what to look out for.

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Appendices

Appendix A : Demographic questionnaire

Appendix B : Neale Analysis of Reading Ability (NARA)

Appendix C : Clinical observation of oculomotor function

Appendix D : Developmental test of eye movements (DEM)

Appendix E : Snellen Chart

Appendix F : Permission letter principal

Appendix G : Guidelines to identify ‘poor’ readers

Appendix H : Information sheet for Parents/Legal guardians

Appendix I : Informed consent from Parents/Legal guardians

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Appendix K : Guidelines for the intervention

Appendix L : Activities

Appendix M : Precautions

Appendix N : Ethical Clearance

Appendix A

Demographic questionnaire

To be kept Separate

Code _____

Please fill in the below details:

General Information

Name of main caregiver	
Contact number of main caregiver	
Name of the child	
Home Language	
Name of Teacher	

Code _____

The below questionnaire is necessary to obtain basic demographics and medical and developmental information about each participant.

Age of learner: _____ yrs _____mnths Gender of learner: M F

Educational Information

Grade of learner	4	5	6	7
Has a grade been failed in the past?	Yes		No	
If yes, please specify.				
How would you rate your child's reading abilities on a scale from 1 to 4?	1 Excellent	2 Average	3 Difficult	4 Poor
How would you rate your child's comprehension abilities on a scale from 1 to 4?	1 Excellent	2 Average	3 Difficult	4 Poor

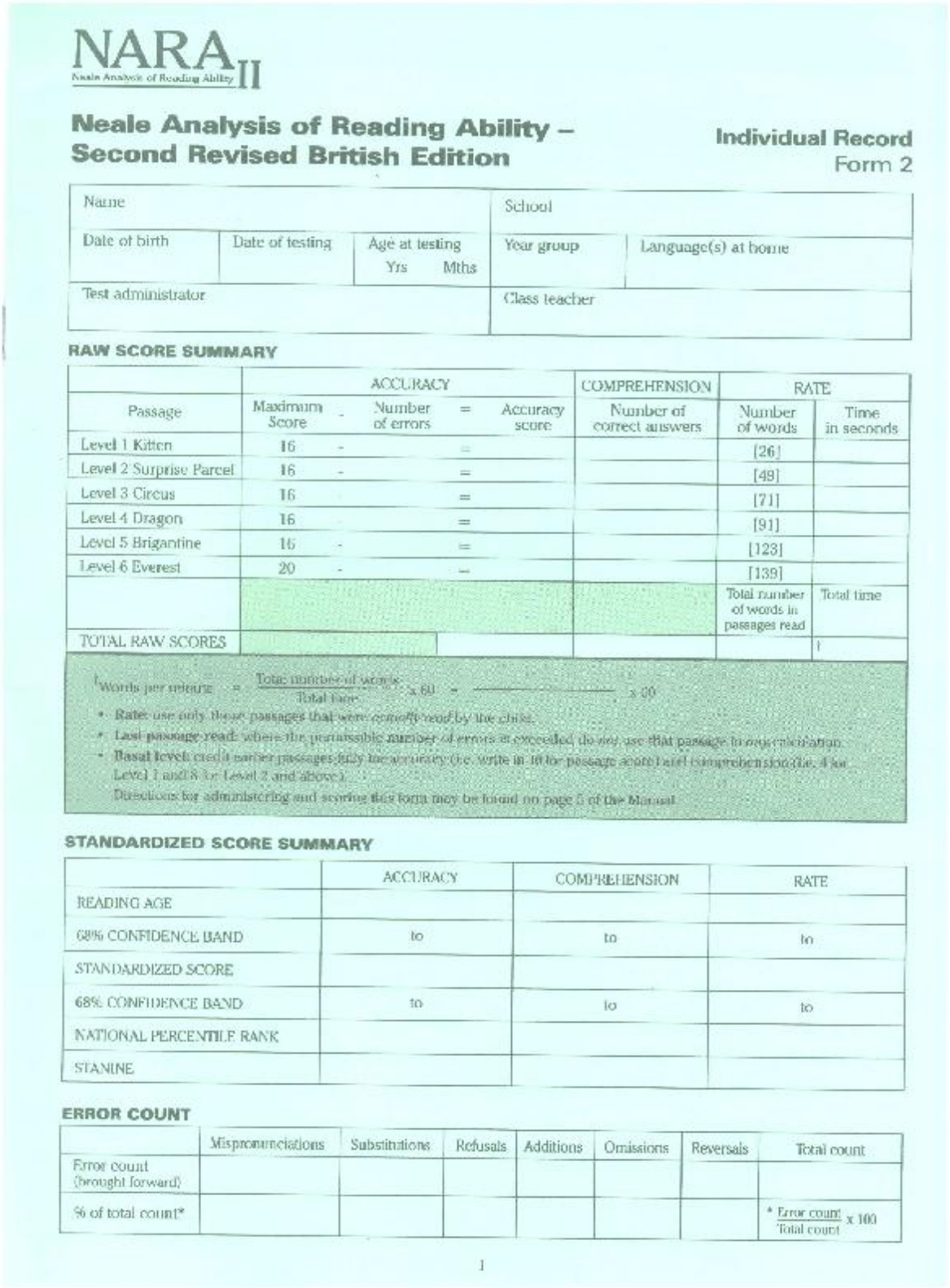
Developmental and Medical Information

Does he/she feel nauseous when travelling in a car/taxi/bus for a long period of time i.e. more than 30 minutes?	Yes	No
If yes, please specify.		
Does he/she not enjoy/ avoid movement i.e. swinging, spinning, rolling?	Yes	No
If yes, please specify.		
Does he/she have a history of ear problems i.e. middle ear infections, earache, grommets inserted?	Yes	No
If yes, please specify.		

Does he/she show dislike to anything at school or home i.e. does not like loud noises, bright lights, being thrown into the air, certain clothes, and certain foods?	Yes	No
If yes, please specify.		
Is there any history of learning difficulties i.e. attention deficit disorder, clumsiness or movement and co-ordination problems (dyspraxia) in the family?	Yes	No
If yes, please specify.		
Does he/she have a history of medical problems needing medical attention on a regular basis such as epilepsy, chronic ear infections etc	Yes	No
If yes, please specify.		
Is there a history of visual difficulties i.e. short or near sighted, blurred vision, wears contact lenses or glasses?	Yes	No
If yes, please specify.		
Has he/she had a visual examination?	Yes	No
If yes, by whom, where was it done and what were the results?		

Appendix B

Neale Analysis of Reading Ability



NARA II
Neale Analysis of Reading Ability

Neale Analysis of Reading Ability – Second Revised British Edition

Individual Record
Form 2

Name			School	
Date of birth	Date of testing	Age at testing Yrs Mths	Year group	Language(s) at home
Test administrator			Class teacher	

RAW SCORE SUMMARY

	ACCURACY				COMPREHENSION	RATE	
Passage	Maximum Score	-	Number of errors	= Accuracy score	Number of correct answers	Number of words	Time in seconds
Level 1 Kitten	16	-		=		[26]	
Level 2 Surprise Parcel	16	-		=		[49]	
Level 3 Circus	16			=		[71]	
Level 4 Dragon	16			=		[91]	
Level 5 Brigantine	16	-		=		[123]	
Level 6 Everest	20	-		=		[139]	
						Total number of words in passages read	Total time
TOTAL RAW SCORES							†

† Words per minute = $\frac{\text{Total number of words}}{\text{Total time}} \times 60 = \frac{\qquad}{\qquad} \times 60$

- Rate: use only those passages that were correctly read by the child.
- Last passage read: where the permissible number of errors is exceeded, do not use that passage to work out rate.
- Basal level: credit earlier passages fully for accuracy (i.e. write in 16 for passage accuracy and comprehension for Level 1 and 8 for Level 2 and above).

Directions for administering and scoring this form may be found on page 5 of the Manual

STANDARDIZED SCORE SUMMARY

	ACCURACY	COMPREHENSION	RATE
READING AGE			
68% CONFIDENCE BAND	to	to	to
STANDARDIZED SCORE			
68% CONFIDENCE BAND	to	to	to
NATIONAL PERCENTILE RANK			
STANINE			

ERROR COUNT

	Mispronunciations	Substitutions	Refusals	Additions	Omissions	Reversals	Total count
Error count (brought forward)							
% of total count*							* $\frac{\text{Error count}}{\text{Total count}} \times 100$

1

Appendix C

Clinical observation of oculomotor function

Eye Movements:

General

Dissociation & ability to maintain	3
X dissociation/inability to maintain	2
X dissociation & inability to maintain	1

Across midline

Maintain target	3
Fatigue maintaining target	2
Loses target	1

Convergence

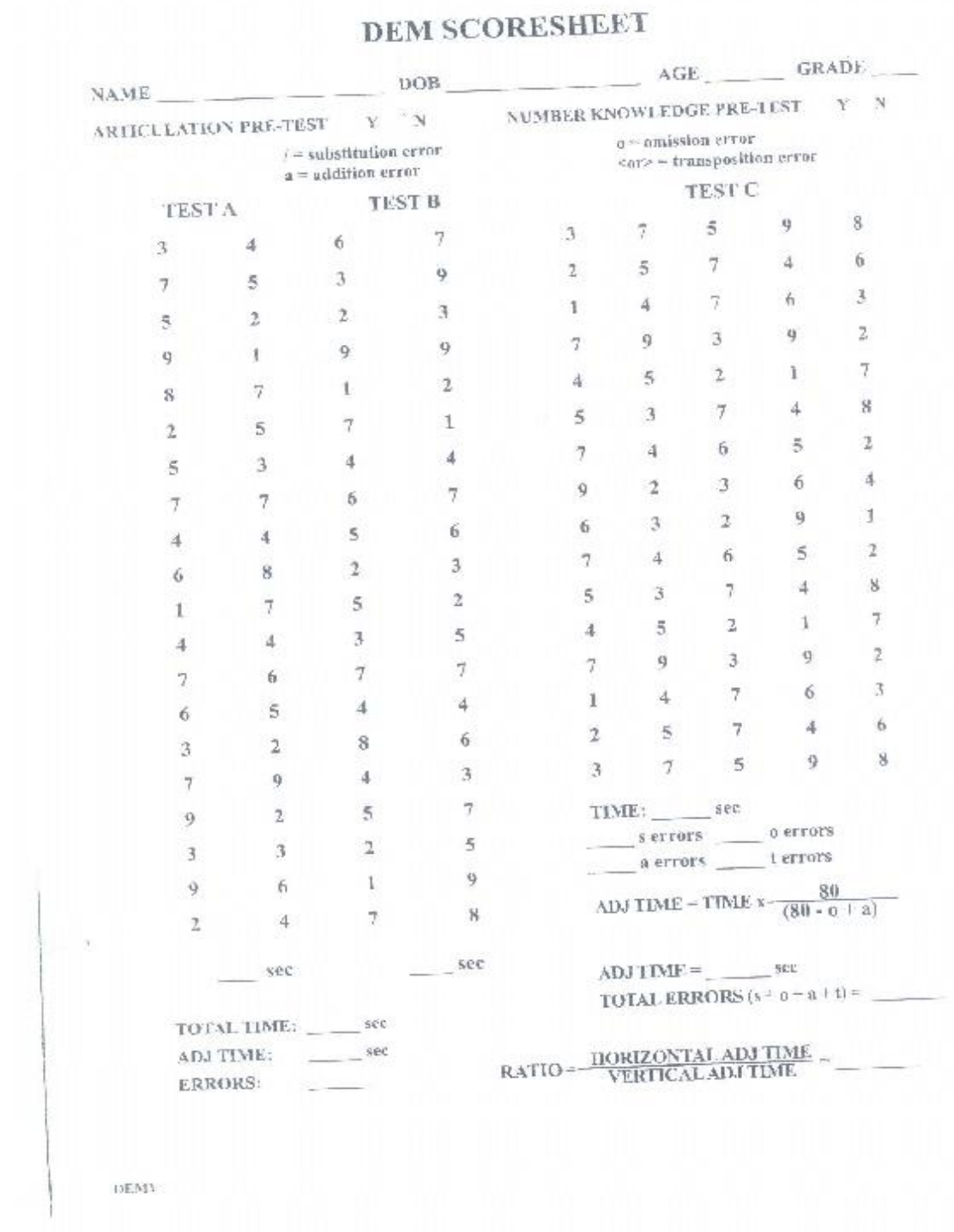
Full convergence	3
Partially converges	2
Cannot converge	1

Quick localization

Easily able	3
Delay in locating	2
Unable to locate	1

Appendix D

Developmental test of eye movements



DEM SCORESHEET

NAME _____ DOB _____ AGE _____ GRADE _____

ARTICULATION PRE-TEST Y N

/ = substitution error
a = addition error

TEST A

3	4	6	7
7	5	3	9
5	2	2	3
9	1	9	9
8	7	1	2
2	5	7	1
5	3	4	4
7	7	6	7
4	4	5	6
6	8	2	3
1	7	5	2
4	4	3	5
7	6	7	7
6	5	4	4
3	2	8	6
7	9	4	3
9	2	5	7
3	3	2	5
9	6	1	9
2	4	7	8

____ sec

TEST B

____ sec

TOTAL TIME: ____ sec
ADJ TIME: ____ sec
ERRORS: ____

NUMBER KNOWLEDGE PRE-TEST Y N

o = omission error
<or> = transposition error

TEST C

3	7	5	9	8
2	5	7	4	6
1	4	7	6	3
7	9	3	9	2
4	5	2	1	7
5	3	7	4	8
7	4	6	5	2
9	2	3	6	4
6	3	2	9	1
7	4	6	5	2
5	3	7	4	8
4	5	2	1	7
7	9	3	9	2
1	4	7	6	3
2	5	7	4	6
3	7	5	9	8

TIME: ____ sec
____ s errors ____ o errors
____ a errors ____ t errors

ADJ TIME = TIME x $\frac{80}{(80 - o + a)}$

ADJ TIME = ____ sec
TOTAL ERRORS (s + o + a + t) = ____

RATIO = $\frac{\text{HORIZONTAL ADJ TIME}}{\text{VERTICAL ADJ TIME}}$ = ____

DEMV

Appendix E

Snellen Chart

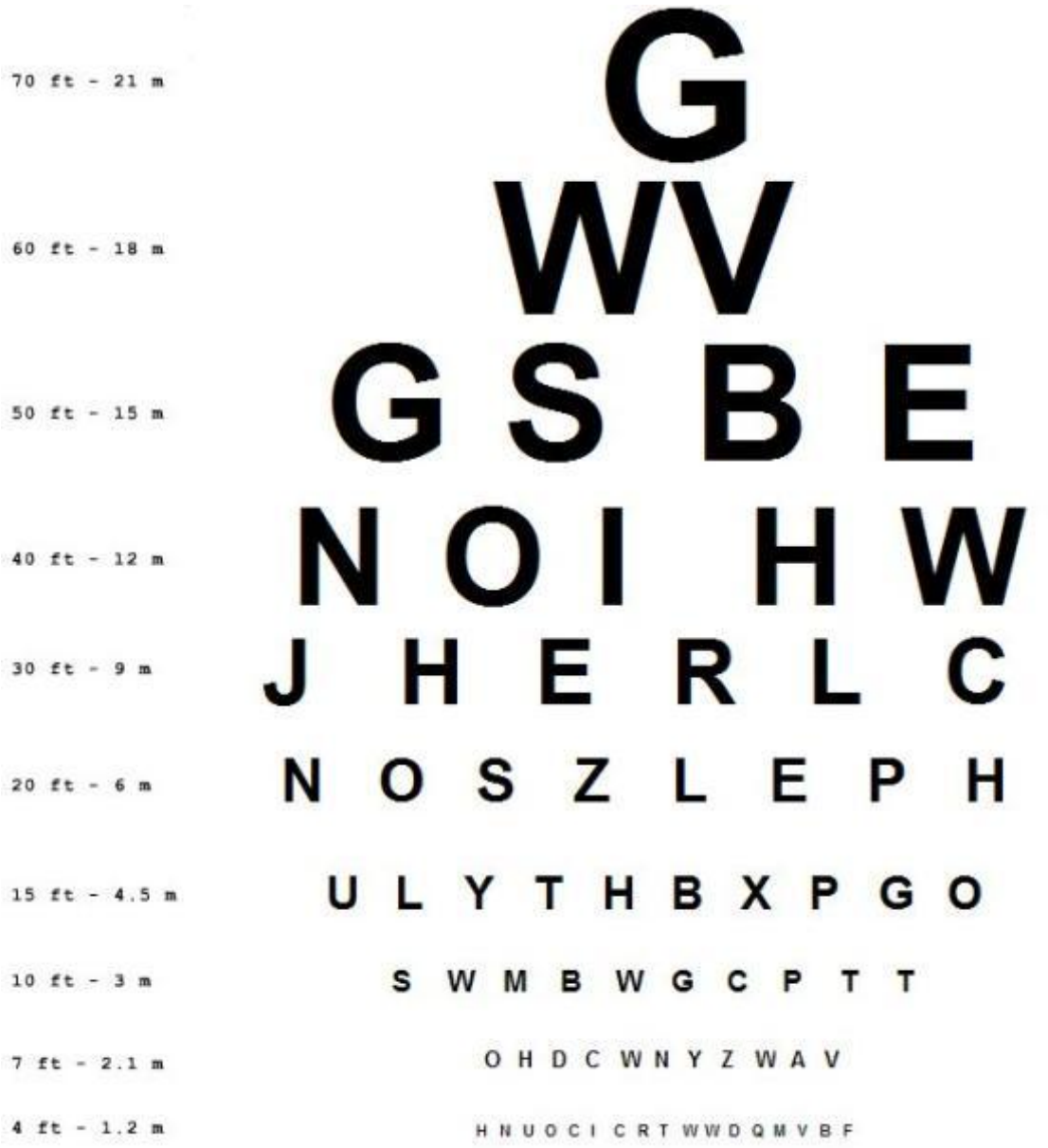
A Snellen Eye Chart is an eye chart used by eye care professionals and others to measure how well a person can see at various distances.

The Snellen chart is printed with eleven lines of block letters. The first line consists of one very large letter, an E. Subsequent rows have increasing numbers of letters that decrease in size. A patient taking the Snellen Eye Chart test covers one eye, and reads aloud the letters of each row of the Snellen Eye Chart, beginning at the top. The smallest row that can be read accurately indicates the person's visual acuity in that eye.

Scoring for the Snellen Eye Chart is based on a distance of 20 feet and is represented as a fraction. The numerator is 20 (for the distance) and the denominator is the number listed to the right of each row on the eye chart. They must read the whole line in order to receive that score. The number listed to the right of each line on the Snellen Eye Chart is the normal distance at which people with "normal" vision can read a letter of that row's size.

For instance, if they can read row 5 of the eye chart but not row 6, their vision would be scored as 20/30, meaning they can read letters at a distance of 20 feet that most people can read at a distance of 30 feet. The Snellen Eye Chart test can also be administered with one eye covered to see if the patient has better vision in one eye over the other.

It is considered normal for most human beings but it is possible to have vision better than 20/20. If you can read line 8 of the Snellen Eye Chart from a distance of twenty feet, your vision would be scored as 20/10.


70 ft - 21 m
G
60 ft - 18 m
W V
50 ft - 15 m
G S B E
40 ft - 12 m
N O I H W
30 ft - 9 m
J H E R L C
20 ft - 6 m
N O S Z L E P H
15 ft - 4.5 m
U L Y T H B X P G O
10 ft - 3 m
S W M B W G C P T T
7 ft - 2.1 m
O H D C W N Y Z W A V
4 ft - 1.2 m
H N U O C I C R T W W D Q M V B F

Appendix F

Occupational Therapy
School of Therapeutic Sciences • Faculty of Health Sciences • 7 York Road, Parktown 2192, South Africa
Tel: +27 11 717-3701 • Fax: +27 11 717-3709 • E-mail: denise.franzsen@wits.ac.za

Permission letter principal

The Principal,
Flamboyant School
P.O. Box 837
White River,
1240
Mpumalanga

Dear Madam

Title of the study: **The effect of an oculomotor-vestibular-proprioceptive sensory stimulation programme on reading skills in children aged 8 to 12 years 11 months**

My name is Megan Sylvia Bense, I am an occupational therapist in private practice and am carrying out the following study as part of my M Sc OT degree at the University of the Witwatersrand. I am doing research on a therapy programme that aims to improve reading skills. Research is just the action to learn the answer to a question. In this study I want to learn if stimulation of the senses can improve how fast a person can read, how correctly the person can read and how well the person can understand the information that has been read. The ability to read and understand information is very important in getting good marks and moving onto the next grade. Very few Occupational Therapists have looked at programmes to improve reading skills and this is why the study was decided to be done.

Permission: I am asking for your permission to work with the pupils of your school.

Details: The participant will be involved in three assessment sessions and six one on one therapy sessions with the therapist. The group of 30 participants will be expected to be available for 12 weeks in total.

The assessments will include the Neale Analysis of Reading, the Developmental Eye Movement test, a basic sight test and an informal test that looks at how the participant's eyes move.

These assessments will be carried out by a research assistant. They will however be under supervision of the researcher.

The programme includes specific rotational input and an activity that involves the whole body. This programme is designed to improve the control of the eyes and this will then be measured through the assessment of the reading skills. Therapy will take place at the therapy rooms on the school premises. Participants will be with the therapist at all times. When the participant is involved in the programme, they must be available for 15 minutes twice a week. This will be done for three weeks. When the assessments are being done, the participant must be available for 45 minutes once a week. This will be done for three weeks over the 12 week study.

A basic questionnaire must be filled in by the parents/legal guardians. This asks for basic information about the contact details, the participant's details and basic medical and developmental information. It should not take more than 15 minutes to complete. Details given in the questionnaire will decide whether the participant can or cannot continue in the programme.

The teachers and/or remedial team at the schools will also be approached for the identification of the learners whom are observed to be 'poor' readers according to set guidelines.

Children who fall within the age range will be screened used the Developmental Eye Movement test (DEM) and the Snellen chart. The children who obtain below the 16th percentile in the DEM and do not show any visual acuity deficits in scores obtained from the Snellen chart, will then be screened with the reading diagnostic in the Neale Analysis of Reading (NARA). The final participants will be indicated based on the scores obtained from the NARA.

Risks: Because the programme is looking at the stimulation of the senses, the participants may feel nauseous. The therapist is very aware of the signs showing that the participant has reached levels of overload and is aware of how to handle these situations. If the participant does feel nauseous, it should not last for longer than 20 minutes after the therapy session.

Benefits: The benefit of the study is clear. If the participant finds reading and understanding of what they have read to be difficult, this programme aims to make reading easier for the participant.

This can help to make class work and homework easier for them.

Alternative therapy: If the participant does find reading difficult, they may also benefit from visual therapy that they can receive from a behavioural optometrist.

Feedback: The participant will be given the most important information on the study while involved in the project and after the results are available.

Participation: It is important to understand that participation is voluntary. If the participant does not want to continue, there will be no penalty. The participant may stop at any time. It is important to realise that if the participant does not complete the programme, they may not receive the benefit of the programme.

Confidentiality: Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law. Organizations that may inspect and/or copy the research records for quality assurance and data analysis include groups such as the Research Ethics Committee and the Medicines Control Council (where appropriate). If results are published, it may result in individual / cohort identification.

Contact details: For further information please contact Megan at 0833041937 or megansb@live.com
To report negative reactions to the study please contact Megan at 0833041937 or megansb@live.com.
Should there be any ethical queries about the research please feel free to contact the Human Research Ethics Committee (HREC) Chairman Prof P Cleaton-Jones at 011 7171234 or anisa.keshav@wits.ac.za for reporting of complaints / problems

Thank you.

I look forward to working with you.

Please be so kind as to complete the slip below.

Kind Regards

Megan Bense

I, (print full name) _____ the (position at school)_____, fully understand the requirements of the study: **The effect of an oculomotor-vestibular-proprioceptive sensory stimulation programme on reading skills in children aged 8 to 12 years 11 months** and consent to Megan Sylvia Bense, an occupational therapist, to work with the teachers and pupils in the school and to contact, where appropriate, the participant's teacher and other therapists that may be involved in the management of the participant.

I understand that the therapist is indemnified against any claim made against her or her agents, arising out of the presence of the person on or about the premises, or any other cause arising from activities carried out during therapy.

It has been explained that the participant's confidentiality will be ensured as names will not be included in the reporting of the results and no information from the assessments will be divulged before contacting the parents/legal guardians.

Date: _____

Signature: _____

Occupational Therapy

School of Therapeutic Sciences • Faculty of Health Sciences • 7 York Road, Parktown 2192, South Africa
Tel: +27 11 717-3701 • Fax: +27 11 717-3709 • E-mail: denise.franzsen@wits.ac.za

I, (print full name) Ms Gail Allison van der Riet the (position at school) Headmistress, fully understand the requirements of the study: **The effect of an oculomotor-vestibular-proprioceptive sensory stimulation programme on reading skills in children aged 8 to 12 years 11 months** and consent to Megan Sylvia Bense, an occupational therapist, to work with the teachers and pupils in the school and to contact, where appropriate, the participant's teacher and other therapists that may be involved in the management of the participant.

I understand that the therapist is indemnified against any claim made against her or her agents, arising out of the presence of the person on or about the premises, or any other cause arising from activities carried out during therapy.

It has been explained that the participant's confidentiality will be ensured as names will not be included in the reporting of the results and no information from the assessments will be divulged before contacting the parents/legal guardians.

Date: 1st April 2016

Signature: _____

Appendix G

Guidelines to identify ‘poor’ readers

The following provides some guideline for identifying the poor readers in the classroom.

	Frequently misses words in the sentence
	Misreads words
	Has to use a finger/ points when reading
	Assumes words/ sentences
	Scans and does not read every word
	Is unable to verbally explain what has been read
	Is unable to answer questions about paragraphs that have been read in written form
	Unable to understand the main idea of the text/ what has been read
	Reads very slowly
	Unable to finish exams/ test
	Has to use a finger/ points when reading

Appendix H

Information Sheet for Parents/Legal guardians

Title of the study: The effect of an oculomotor-vestibular-proprioceptive sensory stimulation programme on reading skills in children aged 8 to 12 years 11 months

Hello,

My name is Megan Bense, I am an occupational therapist in private practice and am carrying out the following study as part of my M Sc OT degree at the University of the Witwatersrand. I am doing research on a therapy programme that may improve reading skills. In this study I want to learn how stimulation of the senses can improve how fast a person can read, how correctly the person can read and how well the person can understand the information that has been read. The ability to read and understand information is very important in getting good marks and moving onto the next grade.

I an investigating a programme to improve eye movements. This has been shown to be one of the problems areas associated with poor reading skills. The programme includes specific spinning and an activity that involves the whole body. This programme is designed to improve the control of the eyes and this will then be measured through the assessment of the reading skills.

I am inviting you and your child to take part in the study.

What does this mean

I will ask you to fill out a short questionnaire on your child and in which you will be asked brief questions about their reading and their medical and developmental information. It should not take more than 15 minutes to complete. Since the treatment includes spinning I will need you to indicate if your child has a problem with this and/or other types of movement. It is important to identify whether the child would be able to tolerate the type of movement used in the programme. A screening of all the children's ability to tolerate spinning movements will be done before treatment is started as a precaution as well.

therapist research assistant will be assessing your child using the Neale Analysis of Reading, the Developmental Eye Movement test, a basic sight test and an informal test that looks at how the participant's eyes move.

Following the assessment, the learners will be divided into two groups. The whole programme will take 12 weeks in total to complete. Each learner will be expected to complete six therapy sessions with the therapist. These sessions are 15 minutes each and they will be carried out twice weekly. Each learner will also be expected to complete three assessment sessions with the research assistant.

When the assessments are being done, the participant must be available for 45 minutes once a week. All assessment and treatment will be carried out on the school premises in the occupational therapy practice situated there. Time for the assessments and treatment will either be in the therapy time allocated at school or after school as arranged with you at your convenience.

Participation in this study is voluntary and your child will also asked to give assent to take part. Refusal to take part will have no consequences and if you and your child do not want to continue, there will be no penalty. You may stop and withdraw at any time.

There may be no direct benefit of the study but experience has shown this may assist with your child's ability to read faster and better understand what they have read. You will be informed if any eyesight problems in your child are noted and the names of services in White River and/or Nelspruit area will be provided if you wish to follow up with further assessment and treatment.

Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed but, only codes and not names will be used on all data sheets. Personal information will be kept separate in a secure location by myself but may be disclosed if required by law. Organizations that may inspect and/or copy the research records for quality assurance and data analysis include groups such as the Research Ethics Committee and the Medicines Control Council (where appropriate). If results are published, it may lead to individual / cohort identification.

For further information please contact Megan at 0833041937 or megansb@live.com
To report negative reactions to the study please contact Megan at 0833041937 or megansb@live.com.
Should there be any ethical queries about the research please feel free to contact the Human Research Ethics Committee (HREC) Chairman Prof P Cleaton-Jones at 011 7171234 or anisa.keshav@wits.ac.za for reporting of complaints / problems

You will be given feedback on your child's progress. If they still need therapy for reading and/ or eye movements the names of occupational therapists and optometrists, who do vision therapy, will be provided to you should you wish to follow up with further assessment and treatment for your child.

Thank you

I look forward to working with you.

Please be so kind as to complete the slip below.

Kind Regards

Megan Bense

Appendix I

Informed Consent from Parents/Legal guardians

I, (print full name) _____ the main caregiver of the participant in the study, fully understand the requirements of the study: **The effect of an oculomotor-vestibular-proprioceptive sensory stimulation programme on reading skills in children aged 8 to 12 years 11 months** and consent to Megan Sylvia Bense, an occupational therapist to supervise the assessments and deliver the intervention programme and to contact, where appropriate, the participant's teacher and other therapists that may be involved in the management of the participant.

I understand that the therapist is indemnified against any claim made against her or any other cause arising from activities carried out during therapy.

It has been explained that the participant's confidentiality will be ensured as names will not be included in the reporting of the results and no information from the assessments will be divulged before contacting the main care giver.

Date: _____

Signature: _____

Appendix J

Informed Assent Group A

My name is Megan and I am an occupational therapist. I am doing some research on reading ability. I would like to invite you to take part in the research. This means I will assess your reading and your eye movements. The tests will take just over half an hour.

I will also be asking you to take part in some treatment. That means that you will be moved around, spun around and looking at objects while playing throwing games. You will need to come and do this for 15 minutes twice a week for three weeks.

I will be testing your reading and your eye movements again after the treatment as well a few weeks later to see if there is any change.

Informed Assent Group B

My name is Megan and I am an occupational therapist. I am doing some research on reading ability. I would like to invite you to take part in the research. This means I will assess your reading and your eye movements. The tests will take just over half an hour.

I will also be asking you to take part in some treatment. That means that you will be moved around, spun around and looking at objects while playing throwing games. You will need to come and do this for 15 minutes twice a week for three weeks.

I will be testing your reading and your eye movements again after the treatment as well a few weeks later to see if there is any change.

Signed informed assent

I, (print full name) _____ a participant in the study, fully understand the requirements of the study and agree to take part in the assessments and treatment programme.

I understand the participation in the study is voluntary and I can withdraw at any time.

Date: _____

Signature: _____

Witness: _____

Appendix K

Guidelines for the intervention

Rotation is sitting

- This position activates the horizontal semicircular canals.
- The learner must sit crossed leg in the centre of the astronaut board.
- Proper head alignment and body position has to be maintained. The head must be held in a way that the learner's nose is orientated at 45 degrees off the midline toward the support surface.
- The learner must be instructed to keep their eyes closed even when the revolutions are completed.
- The number of rotations will be determined by the learner's tolerance; this can be increased or decreased between the sessions (See precautions).
- Complete one revolution every two seconds.
- Rotate clock wise and then counterclockwise. A break must be given between each set of revolutions, when the PRN stops, wait ten seconds and then move on to the next set of revolutions.

Rotation in side lying

- This position activates the superior and posterior semicircular canals.
- The learner will lie in the astronaut board on the left side in flexion with their arm under their head to maintain spinal alignment. The next set of revolutions will have the learner lying on the right side in flexion.
- Proper head alignment and body position has to be maintained. The head must be held in a way that the learner's nose is orientated at 45 degrees off the midline toward the support surface.
- The learner must be instructed to keep their eyes closed even when the revolutions are completed.
- The number of rotations will be determined by the learner's tolerance; this can be increased or decreased between the sessions (See Precautions).
- Complete one revolution every two seconds in a counterclockwise direction.
- Rotate with the learner lying in flexion on the left side, then with the learner lying in flexion on the right allowing ten seconds following the end of the PRN before the next set of revolutions.
- The learner will then engage in volitional visual tracking exercises. The learner will be required to look at each target alternatively. The position of the targets will be changed so that the eyes move in specific directions. The positions must be completed as follows:

1. Horizontally at eye level
2. Diagonally up to the right and down to the left
3. Diagonally up to the left and down to the right
4. Vertically

The guidelines for all four positions are the same. They are as follows:

- Have the learner sit crossed leg in front of the therapist.
- Hold two lasers approximately 30.5cm apart and roughly 41cm away from the learner's face.
- Light up each laser alternatively, making sure that the learner fixates on the laser before moving the eyes to the next target.
- The learner should be hold the head steady while moving the eyes.

Appendix L

Activities

Intervention

The intervention will take place at the therapy rooms on the school premises. The intervention will take 15 minutes to complete with each learner. Depending on the schedule of the learners, they will either be seen for 15 minutes once a week or for 15 minutes twice a week. They would be expected to complete six intervention sessions with the therapist.

Each session will begin with the rotation in sitting and side lying, clockwise and anti-clockwise. The number of rotations will be determined by the learner's tolerance; this can be increased or decreased between the sessions. The learner will be instructed to close their eyes. The metronome will be set at 32 beats per minute to regulate the speed of the rotations.

The learner will then engage in volitional visual tracking exercises. The lasers will be held 16 inches away from the eyes and 6 inches apart. The learner will be required to look at each target alternatively. The position of the targets will be changed so that the eyes move in specific directions.

The positions must be completed as follows:

1. Horizontally at eye level
2. Diagonally up to the right and down to the left
3. Diagonally up to the left and down to the right
4. Vertically

Learners will then be required to follow a moving target in an infinity pattern that is approximately 24 inches wide, 18 inches high and centered at eye level.

Learners will be required to complete figure eight smooth pursuits.

- Hold one laser 41cm from the learner's face at midline.
- Move the laser in horizontal figure eight pattern (25cm x 35.5cm)
- Move the laser in vertical figure eight pattern.
- The learner must follow the light through two figure of eight patterns in each direction.
- The learner must follow with their eyes and not move their head.

After completing the localization and tracking exercises, learners will then engage in a whole body activity that include a strong oculomotor component. Activities 1, 2 and 3 include linear movements which are appropriate to work on near-far visual targets that require divergence and convergence of the eyes for depth perception.

Activity 4 and 5 requires monitoring of the periphery while maintaining central vision on a target. Activity 6 requires wide range head movements in co-ordination with visual fixation and quick localization of a visual target.

The activities will be as follows:

1. Prone in a hammock. The learner will be required to select a sticky ball and stick it onto the respective target while swinging forwards i.e. the sticky ball indicating the number 50 must be stuck onto the number 50.
2. Prone on a scooter board. The learner will be required to look at the board placed 3meters ahead of them and select the appropriate picture card in front of them, push off from the wall using their feet and place the card on the matching picture card i.e. toothbrush and toothpaste.
3. Prone in hammock. The learner will be required to pull hand over hand up on an inclined rope, remove a peg at a certain point along the rope, release the rope and toss the peg into a container while swinging backwards and forwards.
4. Blow toy. The learner will be required to keep blowing the ball and keep it in the basket while completing an obstacle course where they have to move between, around and over cushions and blocks.
5. Around the world. The learner will be required to lie prone on the mat. They will be expected to read 3 rows of numbers from a chart. The instruction is for them to read the first number, roll once (get to your tummy again), read the next number and so on. Once they get to the end of the mat, closest to the chart, they have to carry on rolling and reading but go in a backwards direction (roll away from the mat). Once all the rows are completed, they have to repeat the activity but read the numbers in columns.
6. Infinity walk. The learner will be required to walk in a large infinity pattern around two objects while maintaining visual fixation on a target that is aligned with the centre of the infinity pattern.

Appendix M

Precautions

Precautions

When vestibular stimulation is used, it is important to monitor for signs of overload. The following guidelines need to be followed.

Sensory overload

- Overload signals activation of the sympathetic nervous system.
- Rotary activation is more likely to result in vestibular overload than linear activation.
- When overload occurs, it is important to use strategies to counteract this reaction.
- Vomiting is a natural response of the autonomic nervous system to bring the system back into balance.

Signs of sensory overload

- Yawning.
- Changes in skin color i.e. face turns pale in color, ears turn red.
- Headache.
- Changes in heart rate and respiration.
- Pupil dilation.
- Prolonged dizziness.
- Nausea.
- Changes in behavior i.e. an active, talkative child may become quiet.

Avoiding sensory overload

- There will be a wide variation in the tolerance of vestibular inputs by the learners.
- There may be variation from one session to another in how much input the learner will be able to handle.
- Always start with less input and build on that.
- Increase the amount of input gradually, as the learner's tolerance improves.
- Observe the client's motor, behavioral and arousal response to determine the appropriate amount of input the learner can handle.
- Stimulation is cumulative i.e. consider stimulation before the therapy session, too much input before the session can result in overstimulation during the session.

- Do not rely on the learner's feedback alone, their response to the input can be delayed.

Counteracting sensory overload

- Counteract sensory overload by engaging in immediate, vigorous, intensive, self regulated proprioceptive input.
- Place hands on head and press down while jumping in place and sucking vigorously with sealed lips.
- Have the learner lie supine, therapists stands over the learner with a ball and they are instructed to first push it away with their upper limbs and then with their lower limbs.
- Place ice cubes into the learners hands and at the back of their neck.
- Give the learners a chewing gum, which has been slightly frozen, to increase resistance and so intensify the proprioceptive input when chewing.
- Provide the learner with coldwater in a glass and a straw. They should be instructed to suck vigorously.

Appendix N

Ethical Clearance

R14/49 Ms Megan Sylvia Bense

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130862

NAME: (Principal Investigator)	Ms Megan Sylvia Bense
DEPARTMENT:	Occupational Therapy Flamboyant School White River
PROJECT TITLE:	The Effect of an Oculomotor-Vestibular-Proprioceptive Sensory Stimulation Programme on Reading Skills
DATE CONSIDERED:	30/08/2013
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr Denise Franszen
APPROVED BY:	Professor PE Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	18/10/2013

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**.

Principal Investigator Signature _____ Date _____

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Megan Bense (734648)

The effect of an oculomotor-vestibular-proprioceptive sensory stimulation programme on reading skills in children aged 8 to 12 years 11 months

Amendments

Page Number	Paragraph Number	Line Number	Description
iv	1	3 4	Added type of school Added number of learners and age group
	2	2	Added conclusion on the relevance of findings for clinical practice
viii	A-O		Added the names of the Appendices in the table of contents
3 4 19 20 21 65 74	1 2 3 5 6 2 4 4 2 4 1 Heading 3 3	2 2 2 2 2 2 1 4 6 3 3 7 9	Changed reading speed to *reading rate* to keep terms consistent
10	3	11	Added *information* after afferent
14	3	2	Changed verdical to *vertical*
	4	4	Removed *students* after 567 Changed students to *learners*
15	2	6	Added *assessment* after function
16	2	5-7	Rephrased the end of the paragraph
20	4	2	Changed understating to *understanding*
22	3	1-3	Clarified the role of the Astronaut training programme in the intervention programme

Page Number	Paragraph Number	Line Number	Description
23	3	1-10	Added details on the intervention programme
24	2	4-12	Identified the gap in evidence that this study aims to rectify
26	2	2-3	Clarified the intervention
34	Heading 2		Removed *Research* from the heading
36	3	3	Added that participants were seen individually
36	4	1-2	Clarified how the intervention programme was developed
38	4	1-4	Acknowledged source for statistical test
39-40	1-7	1-	Added a summary for the Chapter 3
40	2-3	1-	Discussed validity and reliability
39	1	5-6	Clarified the use of the results from the Snellen chart
	4	3-5	Clarified why other information in the demographic questionnaire was not included in the discussion.
42	1	3	Changed students to *learners*
42	Table 4.1		Not corrected as error not found
49	4	1	Added information regarding vertical time scores
51	1	2	Added accuracy after reading
55	Heading		Changed 4.5.1 to 4.5.2 Changed 4.5.1.1 to 4.5.2.1
	Heading 2		Deleted repeated word based on
55 58 60	Figure 4.7 Figure 4.8 Figure 4.9		Changed intevention to intervention

Page Number	Paragraph Number	Line Number	Description
57	Heading		Changed 4.5.1.2 to 4.5.2.2
60	Heading		Changed 4.5.2 to 4.5.3 Changed 4.5.2.1 to 4.5.3.1
64	2	1	Added reading in front of accuracy and comprehension
67	3	1	Corrected author's name
67	3	1	Changed students to learners
76			Moved Limitations of the study to page 78
77-81			Added headings 6.1 - 6.5
79	1	1-3	Justified why the content of the programme had to be evaluated
80	1	6	Added reference for visagraph
82-91	References		Revised for consistency
92	Appendices		Added List