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THE EFFECT OF ASSISTIVE DEVICES ON WRITING SPEED AND LEGIBILITY IN GRADE TWO LEARNING DISABLED CHILDREN.

Taryn Ann Levin

A Research Report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science in Occupational Therapy

May 2010
Ethical Clearance: M080540

DECLARATION

I, Taryn Ann Levin, declare that this research report is my own work. It is being submitted for the degree of Master of Science in Occupational Therapy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

_____Taryn Ann Levin

_____ day of _____ 2010

DEDICATION

To my parents for always believing in me and for their unconditional love and support.

ABSTRACT

The effect of assistive devices on the speed and legibility of a child's writing is not fully understood in the literature. This study therefore investigated the effects of Stetro pencil grips, soft splints and inclined surfaces on handwriting speed and legibility in order to better guide occupational therapists with regard to handwriting intervention. A writing legibility score sheet was developed to measure the factors of handwriting requiring assessment in this study namely: letter formation, spacing between words, letter spacing between lines, accuracy and general appearance. The study also compared the handwriting speed and legibility of grade two learning disabled learners with grade two mainstream learners. In analysing the results, letter formation and general appearance were the two areas where the learning disabled sample scored significantly worse than the mainstream sample. The various assistive devices were shown to have different impacts on writing speed and the five areas of legibility.

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My Supervisors:

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OPERATIONAL DEFINITIONS

Learning disabilities: A general term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities [1]. In schools and clinics the ratio of males to females with learning disabilities is 4:1 [1]. According to studies by Phipps and Clarizio gender differences were found in terms of learning difficulties, with far more boys than girls being referred for special education placement [2,3]. Zelnick and Goez documented that left handedness is more prevalent in individuals with learning disabilities, dyslexia, autism and developmental coordination disorder than in the general population [4].

Writing Speed: Measured by counting the number of letters or words an individual copies in an allocated time frame [5].

Writing Legibility: Measured by both the ease with which the readers can decipher the written text (overall legibility) and by the components of handwriting legibility e.g., letter formation, spacing and letter size [5].

Dysgraphia: A written-language disorder that concerns the mechanical writing skill. It manifests itself in poor writing performance in children of at least average intelligence who do not have a distinct neurological disability and/or an overt perceptual-motor handicap [6].

Splint: Supports the fingers, thumb and wrist in a functional and/or resting position [7].

Inclined Surface: This is also referred to as a 'slant board'. It encourages proper wrist position and promotes better functional postural position and stability [8].

Elementary School: Refers to grade R to grade five.

Middle School: Used interchangeably with 'intermediate school' and 'junior high school'. It includes grades six, seven and eight.

Secondary School: Used interchangeably with 'high school'. It includes grades nine to twelve.

Prosthetic Pencil Grip: The prosthetic device that is placed on the pencil in order to enhance an individual's pencil grasp [9]. Examples include:

- Stetro Pencil grip: A plastic moulded pencil grip with finger indentations. The star indicates thumb placement and the forefinger and middle finger fit comfortably into the other two indentations. This grip can be used with both the right and left hands [10].
- The Crossover Pencil grip: This grip has a thick body with 'wings' that keeps the index finger and thumb securely positioned in the correct place. The 'wings' help to facilitate the feeling of control [11].
- The Triangle Pencil grip: The triangle shape helps to facilitate the tripod grasp. It is suitable for both left and right handed children [11].

Pencil Grasp: The finger and wrist position adopted by the child when holding the pencil [9].

Somatosensory Discrimination: Referred to as kinaesthetic in this study. Somatosensory discrimination impacts on the individual's ability to know the boundaries of their fingers or the position of their joints, thus impacting on their motor planning and motor memory [12] and consequently affecting many aspects of their handwriting [12].

ABBREVIATIONS

ADHD	Attention Deficit Hyperactivity Disorder
BHK	The Concise Evaluation Scale for Children's Handwriting
CHES	The Children's Handwriting Evaluation Scale
CHES-M	The Children's Handwriting Evaluation Scale - Manuscript
DCD	Developmental Co-ordination Disorder
ETCH	The Evaluation Tool of Children's Handwriting
ETCH-C	The Evaluation Tool of Children's Handwriting – Cursive
ETCH-M	The Evaluation Tool of Children's Handwriting – Manuscript
LD	Learning Disabled
MS	Mainstream
MHA	Minnesota Handwriting Assessment
WRIT	Writing Rate Information Test
THS	Test of Handwriting Skills
VMI	Visual Motor Integration
SD	Standard Deviation
p	Significance Value

CHAPTER 1

Introduction

The development of functional handwriting skills is an essential factor for school success [13]. Children spend approximately 31-60% of their school day involved in the performance of handwriting and other fine motor tasks [14]. Handwriting is used in all aspects of a child's school career, particularly with regard to taking notes, test-taking, as well as when completing homework and composing stories [5]. Despite the introduction of modern technology such as computers, during their school years children are still required to complete the majority of their assignments in writing [13,15]. Competence in writing is not only important for academic success during a child's school years but is also a vital skill that is required throughout adulthood [16].

Approximately 10-30% of children have been found to experience handwriting difficulties [17-19]. These difficulties include cognitive, kinaesthetic or perceptual-motor components [20-23]. Handwriting problems can be interpreted as a reflection of an individual's capabilities or intelligence level and often overshadow a child's abilities in other areas [16]. Handwriting difficulties also impact negatively on a child's academic performance [16,24,25] such as difficulty keeping up with their peers when completing written class assignments [9] and affecting their ability to express their thoughts in the written form [26], hampering their progress at school which may result in lowered self esteem [27,28], low motivation for studying and problems with regard to their social interaction [25,29]. These problems tend to continue into middle and secondary school as the written work requirements increase [5]. As a result, children with handwriting difficulties tend to be susceptible to a variety of frustrations and disappointments [30].

When analysing handwriting difficulties, the two most important elements are legibility and speed [16,31-33]. Problems in these areas result from the children's difficulty in learning to form their letters using the correct formation, struggling to place their letters accurately on the line and experiencing difficulty with the production of letters; which negatively affects their writing speed [31]. This impacts on the neatness and legibility of the writing on a page

and their ability to keep up with the written work demanded of them during their school years [16].

In grade one the focus is on the mechanics of writing and the motoric patterns needed to produce written text [25], such as forming all the lower case letters correctly. In grade two children are required to use handwriting functionally to complete school tasks [25] and their handwriting generally becomes smaller and neater. Children at this stage are beginning to focus on the cognitive aspects of writing tasks [25].

Both writing speed and legibility ultimately create a barrier to the accomplishment of higher order skills including story composition and spelling [34,9]. For example, when a child's letter formations are not completely automatic, extra demands are placed on other processes, particularly memory and attention, which in turn affects the higher order cognition required for written composition [9,35-37]. Not developing adequate skill in handwriting prevents the child from creating a readable product in which their thoughts and ideas can be communicated adequately as well as preventing them from getting their thoughts across in a reasonable amount of time [38].

Handwriting difficulties tend to occur predominantly among children with learning disabilities [39] and it is one of the most common reasons for referral to occupational therapy [40-43]. After assessing the handwriting problem, occupational therapists may recommend appropriate adaptive equipment to facilitate a child's pencil grasp or posture. Common modifications or assistive devices recommended include prosthetic pencil grips, which assist the child in positioning their fingers correctly in order to encourage better manipulation of the writing tool [9], hand strengthening programs to develop hand arches and fine motor skills [44], small splints which encourage a functional pencil grasp by providing a balance of stability and mobility[9] or writing on an inclined surface [45] which facilitates correct positioning of the wrist for fine-motor and handwriting skills [46].

Currently there is a lack of conclusive evidence on the functional importance of these modifications on writing speed and legibility in occupational therapy intervention.

1.1 Statement of the problem

Handwriting difficulties, in terms of writing speed and legibility are a significant concern particularly among learning disabled children [39]. Although certain norms are available regarding the number of letters written in two minutes by South African grade two learners there is presently no writing legibility score sheet that has been developed in South Africa that is inclusive of all aspects of handwriting that require consideration in occupational therapy. These aspects include letter formation, spacing between words, letter spacing between lines, accuracy and general appearance. Therefore a suitable measure needed to be developed.

This assessment is needed to confirm the differences in speed and legibility in the handwriting of learning disabled children as compared to children in mainstream schooling. [47]

Currently little conclusive evidence exists on the contribution of prosthetic pencil grips i.e. Stetro pencil grips as well as inclined surfaces and splints to the enhancement of handwriting speed and legibility in learning disabled children. Therefore although a few modifications and assistive devices are presently being used in the schools, their impact is not fully understood. Research regarding the effectiveness of assistive devices is not readily available to support their recommendation by occupational therapists and other educational specialists.

1.2 Purpose of the study

This study intended to develop a measure of handwriting speed and legibility that would include all the areas of handwriting requiring assessment. This measure was based on pre-existing analytic evaluations and incorporated the difficulties that grade two children most commonly experience with regard to their writing legibility including letter formation, spacing between words, letter spacing between lines, accuracy and general appearance. The writing samples were carried out on grade two children, as at the grade two level children have mastered certain basic reading and writing skills required when copying a written passage. Once a normative sample had been established, the effectiveness of Stetro pencil grips, inclined surfaces and soft splints on the speed and legibility of the

learning disabled participants' handwriting was established, through the use of writing samples. The purpose of this was to confirm which of the assistive devices is the most effective in enhancing the speed and legibility of handwriting in order that occupational therapists can recommend the appropriate intervention.

1.3 Aims of the study

The aims of the study were to develop and pilot suitable instruments to measure the speed and legibility of handwriting in South African children. The study also investigated the difference in writing speed and legibility between children in mainstream grade two classes and children in grade two classes at remedial schools. The research also aimed to identify whether Stetro pencil grips, inclined surfaces and splints were effective in enhancing writing speed and legibility in grade two learning disabled children.

1.4 Objectives of the study

a) To establish a measurement scale for handwriting speed and legibility for the mainstream sample.
b) To establish normative data for handwriting speed and legibility for the mainstream sample.
c) To compare the speed and legibility of handwriting of a sample of grade two learning disabled learners with the normative data of a sample of grade two mainstream learners in order to determine the sensitivity of the measure in determining handwriting problems in the absence of an assistive device.
d) To assess the speed and legibility on these writing samples for grade two learning disabled children with:
    - no assistive device,
    - Stetro pencil grip,
    - inclined surface,
    - splint.

1.5 Justification for the study

Children with handwriting difficulties are often referred to occupational therapy and an assessment that can help the therapist identify specific legibility and speed problems will be useful in determining the intervention necessary.

Assistive devices are recommended by occupational therapists and other educational specialists as a means of enhancing a child's writing speed and legibility. Their impact is however not fully understood as to whether they are in fact aiding or rather hampering a child's writing in specific areas. Evidence on whether Stetro pencil grips, inclined surfaces and splints are in fact beneficial in enhancing the speed and legibility of a child's writing needs to be ascertained as well as to determine which specific assistive device is the most beneficial in improving an individual's writing speed and specific aspects of their writing legibility including: letter formation, spacing between words, letter spacing between lines, accuracy and general appearance. This will be important in guiding occupational therapists with regard to handwriting intervention. It is important that occupational therapists are cautioned about indicating an assistive device for an individual, unless they have a particular difficulty in terms of their handwriting speed and legibility, which will be enhanced through using a specific assistive device.

CHAPTER 2

Literature Review

This literature review will cover the importance of handwriting and the internal performance components needed to write. Factors related to competence in handwriting and problems with handwriting at primary school level will be discussed. The role of the occupational therapist in evaluating and treating handwriting difficulties including the function of various modifications or assistive devices will also be considered. Different types of literature were reviewed, particularly that from the field of psychology literature and educational occupational therapy literature as these are the key frames of reference drawn on when working with school children.

2.1 Hierarchy of handwriting

A child begins to experiment with pre-writing skills at approximately 18 months of age and continues to refine these skills up to the age of six years [48]. Before a child can master the use of a pencil, pre-writing skills need to develop [44].

In kindergarten children are generally able to copy a cross, right oblique line, square, left diagonal line, some letters and numbers, and they are attempting to write their name [9]. As children enter grade 0, they are beginning to print their own names as well as copy many lower and uppercase letters [9]. In grade one the focus is on the mechanics of writing and the motoric patterns needed to produce written text [25], such as forming all the lower case letters correctly. In grade two children are required to use handwriting functionally to complete school tasks [25] and their handwriting generally becomes smaller and neater. Children at this stage are beginning to focus on the cognitive aspects of writing tasks [25]. The more children are required to compose as they go higher up in the grades, the more their handwriting becomes automatic [49]. Once they have mastered basic writing legibility skills, children are able to progress to tasks such as composing stories without focusing too much on the writing mechanics [50]. Manuscript writing is the general approach in

grades one and two and cursive writing is generally introduced at the end of grade two or the beginning of grade three [51].

According to a study by McHale and Cermak, children spend approximately 31-60% of their school day involved in the performance of fine motor tasks, predominantly handwriting activities [14]. Writing is a vital skill used in all aspects of a child's schooling, particularly with regard to taking notes, writing tests, completing homework and composing stories [5,9]. Even though computers exist, which may possibly provide some solutions to an individual's handwriting difficulties such as improved legibility [1], handwriting still remains a vital skill for children to develop and master [13,15] .

Many skills impact on a child's ability to write including cognitive, linguistic, kinaesthetic and perceptual-motor skills [9,20-23]. Bilateral integration, motor planning, fine-motor control (including in-hand manipulation), visual motor integration and visual perception are some of the factors that may affect a child's handwriting performance [16].

In order to execute a written task it requires multiple motor and cognitive components including ideation, planning, the production of text, spelling, punctuation, grammar, self-monitoring, evaluation and the integration of orthographic and motor skills [35,52,53]. Pupils with handwriting problems often have difficulty learning to form their letters correctly and struggle to place their letters accurately on the line [31] . These children also experience problems with written class assignments and may tend to avoid writing tasks due to their difficulties [54,9,55].

2.2 Assessment of handwriting

Many assessments have been developed over the years in order to evaluate handwriting problems [24]. Both informal and standardised tests are vital in the assessment of children with handwriting difficulties [24]. The basis for research regarding the developmental sequence of writing and the clinical manifestations of handwriting difficulties was derived from these evaluations [24] .

The main aim of the researchers who devised the handwriting evaluations was to develop a standardised handwriting assessment that produced scores assessing the quality of

handwriting that were quantitative [18,56,57]. The handwriting evaluations that have been developed over the years can be classified into two main categories: global-holistic evaluations and analytic evaluations [24].

2.2.1 Types of handwriting evaluations

2.2.1.1 Global-holistic evaluations

These assess the readability of the individual's handwriting in comparison to a group of standard handwriting samples previously graded from readable to unreadable [24]. They are referred to as global as the written product is evaluated based on its overall merit rather than specific criteria [24].

The Test of Legible Handwriting (TOLH) is an example of a global holistic evaluation [58]. It aims to determine the readability of second to twelfth grade children's manuscript and cursive handwriting [58]. It consists of a series of writing samples which are graded from one to nine with one being the least and nine the most readable [58]. Writing samples are written stories that are based upon pictures or passages and written by the children during school [58]. The aim of the evaluator is to match the child's writing sample as accurately as possible to one of the test samples [58].

The Evaluation Tool of Children's Handwriting (ETCH) which was developed by Amundson is another global holistic assessment [59]. This test was developed in order to assess the children's handwriting readability and speed generated on written tasks, that are similar to what is expected of them in a classroom situation [59]. The test has two parts, which assess both manuscript (ETCH-M) and cursive (ETCH-C) handwriting [59]. The writing tasks include writing uppercase letters, lowercase letters and numbers from memory, near-point and far-point copying of text and composing a sentence [59]. Scoring focuses on the overall readability, writing speed and the biomechanics of handwriting [59].

2.2.1.2 Analytic evaluations

These assess the readability of an individual's written product relative to a number of predetermined criteria. These scales are based on the assumption that a relationship exists between the overall look (i.e., readability) and certain criteria such as the formation of letters and spaces between words. The handwriting sample is evaluated by scoring each aspect of the written passage and then obtaining an overall score [24]. Examples of analytic handwriting evaluations include the Writing Rate Information Test (WRIT), The Test of Handwriting Skills (THS) and The Minnesota Handwriting Assessment (MHA).

On examination of early literature regarding the development of handwriting evaluations, it is evident that the earliest handwriting scales were global and these led to the development of the analytic approach [24]. One of the earliest analytic scales was developed by Freeman in 1959. He developed a scale in order to evaluate handwriting samples that included the following five criteria: tilt, height, shaping of letters, line quality and general merit [60].

There are multiple analytical tests that are documented in the literature which are used to evaluate handwriting speed and legibility. These include:

The Children's Handwriting Evaluation Scale (CHES). This test was developed by Phelps et al. [61] It is used to assess the fluency of cursive handwriting in third to eighth graders [61]. Children are asked to read a story and then copy it onto blank paper [61]. It is also used to measure writing speed and the examiner marks the point after two minutes of copying [61]. This test was therefore not acceptable for use in this study as cursive writing is assessed.

The Children's Handwriting Evaluation Scale-Manuscript (CHES-M) was developed to evaluate print writing for children in first and second grades [62]. According to Graham, the 5-point scale on the CHES is not sensitive enough to pick up slight changes in the child that may result from maturation, age or treatment [62]. This test is carried out using blank paper and was therefore not acceptable for use in this study.

The Concise Evaluation Scale for Children's Handwriting (BHK) was developed by Hamstra-Bletz et al. [63]. It aims to assess both the readability and speed of dysgraphic children's handwriting in second and third grade [63]. A written task is used that resembles

school assignments [63]. Children are asked to copy a written passage for five minutes [63]. The text is graded [63]. The first five sentences consist of one syllable words at a first grade level [63]. As the sentences progress they become more complex [63]. The children's writing is graded according to thirteen criteria of legibility and the writing speed of the children is calculated according to the number of letters written in five minutes [63]. The writing samples were considered to be too long for use in this study.

Aspects of a number of analytic handwriting evaluations were used in this study including the WRIT, THS and MHA. These will be discussed.

2.2.2 Tests utilised in this study

2.2.2.1 Writing Rate Information Test (WRIT)

The Writing Rate Information Test (WRIT) is a test measuring writing speed [47]. This test was originally conducted on 742 learners (from grades one to seven) in five schools in the Durban area [47]. The norms of this test are therefore reflective of the South African population [47]. The test provides grade norms rather than age norms, as according to the creators of the test, it is important for a learner to be able to write at the speed required by his grade, irrespective of his age [47].

The learner is required to copy a passage for two minutes [47]. This is dependant on the individual's grade level. There are two possible writing passages [47].

- A grade one copy passage which uses handwritten familiar three to four letter words. It has wide lines and a margin in order to assist the young learner with spacing [47].
- A grade two and up copy passage (APPENDIX A) which utilises every letter of the alphabet, and does not have lines in order to observe the learner's use of unstructured space [47].

The instructions are very specific [47]. The individuals are required to use an HB pencil when completing the writing sample [47]. No erasers are allowed. The child is required to cross out the word with one line if he/she makes a mistake [47]. The evaluator says the

following: 'When I say **go** I want you to copy this piece until I say **stop.** It is not a race, don't do your best writing; but don't scribble. Just write as you usually do in class' [47].

The number of letters that the individual is able to copy in two minutes is then calculated to establish the individual's writing speed [47]. This assessment also includes a learner's speed deviations from the norm for example, severely below, slightly below [47]. The test includes an observation form, which enables the examiner to observe the individual's posture, paper position, behaviour and concentration, type of pencil grip used and their reading of the passage [47]. The following aspects of legibility are also observed during the performance of the writing task: general appearance, accuracy, size, spacing, slant, rhythm, letter formation, reversals and perseveration [47].

Validity

The large sample size (742 learners) is of value in establishing the validity of this test.

2.2.2.2 The Test of Handwriting Skills (THS)

This test was developed to measure how a child writes letters, words, sentences and numbers, either spontaneously, from dictation, or through copying [64]. It is comprised of two types of writing, manuscript and cursive [64]. It is designed to measure ten areas of handwriting skills of children from 5 to 11 years of age [64]. For each type of writing (manuscript and cursive), there is a test booklet, statistical data, scoring criteria and a set of norms [64]. In terms of the normative data, the test provides standard scores, scaled scores, percentile ranks and stanines in three month increments for children 5 to 11 years of age [64]. In the Manuscript version (for children 5 years to 8 years 11 months) each individual number or letter which the child is required to copy is scored from 0 to 3, with 0 being the poorest and 3 being the best possible performance [64].

The test assesses aspects of legibility including letter formation, reversals of letters and letters touching one another [64]. The THS can be administered and scored by various professionals including occupational therapists, teachers, psychologists and learning specialists and can be administered to individuals or groups [64].

Reliability

The median reliability coefficients for the manuscript version of the THS ranged from .51-.74 and the reliability for the total sample ranged from .51-.78 [64].

Validity

Content validity of the THS was established [64]. The THS was compared to a number of tests in order to establish its concurrent validity [64]. Moderate to low correlations were found [64].

2.2.2.3 The Minnesota Handwriting Assessment (MHA)

This test was developed in order to assist school-based occupational therapists in identifying children with handwriting difficulties in grades one and two, and to evaluate the effectiveness of treatment [21,57,65] .

It is a near-point copying test that requires students to copy words from a printed stimulus sheet onto a series of lines beneath it [65]. The words are from the sentence 'the quick brown fox jumped over the lazy dogs' [65]. The jumbled word order forces the child to have to look back at the stimulus paragraph and decrease the speed and memory advantages that better readers could have [65]. The examiner presents the child with a writing test sheet that is either in manuscript or D' Nealian printing, which are two different printing styles taught in North America [65].

Instructions in this test are very specific [65]. The children are instructed to try and make the letters the same size as the stimulus letters and '*to write as you usually do when you are trying to use good handwriting'* [65]. Small triangles are printed on the left side of each baseline to assist the children in finding the starting point for each line on the paper [65]. The child is required to use a pencil and erasing is allowed [65]. After writing for 2.5 minutes the children are asked to circle the last letter written and put their pencils down [65]. They are then given the time to complete the sample, so that the whole sample is available for scoring [65]. Writing speed is calculated according to how many letters are written in 2.5 minutes [65]. The majority of second graders completed at least 31 out of 34 sample letters

in 2.5 minutes (67 percent), which supports the use of this amount of time [65]. The selection of lined paper was also justified following research in this area [65].

Besides writing speed, the MHA also assesses five quality categories: legibility, form, alignment, size, and spacing [65]. The first category is legibility [65]. This assesses if the letter that the child has written is recognisable out of context (including reversals) [65]. If the letter does not meet the criteria for legibility, the letter loses all five potential points and scoring is discontinued [65]. If the legibility criteria are met, scoring is continued in the other four categories: Form assesses the letter quality including the absence of gaps or letter overlaps [65]. In order to score a point for Alignment, the letters must rest within 1/16th inch of the baseline [65]. Size assesses the relationship of each letter with reference to the solid top line, dotted line or lower dotted line [65]. Spacing assesses both correct letter and word spacing [65]. Spaces are measured using a ruler, and those that are too narrow or too wide score an error point [65].

Each category is noted on the record form as: like peers, somewhat below peers or well below peers [65]. Additional observations are also checked which includes factors such as: uncoordinated finger movements, inappropriate grasp of the pencil, too light/too heavy pencil pressure, changes hands during writing task, poor trunk stability and rests head when writing [65].

The MHA is meant to be administered to students in first and second grade who have some knowledge of English [65]. It provides normative information at grade level that is based on the handwriting performance of 2000 first and second grade students [65].

Reliability

Interrater reliability of the MHA was studied by the author and other researchers and was found to be high for both evaluators with and without experience (.77-.88 for inexperienced and .90-.99 for experienced scorers) [65]. A number of interrater reliability studies were completed during the development of the MHA [65].

Intrarater reliability studies were undertaken to determine the variability among individual raters [65]. The intrarater reliability ranged from .96 for form to 1.00 for rate [65].

With regard to the test-retest reliability, a correlation of .62 was obtained for rate and the other categories ranged from .60-.89 [65].

Validity

In order to assess the concurrent validity of the MHA, it was compared to the Test of Visual-Motor Skills with moderate to high correlations [65]. A study was performed using the MHA in order to compare the handwriting samples of children with and without autism spectrum disorders [66]. It was found that children with autism spectrum disorders performed worse than their matched controls on handwriting tasks [66].

A variety of global and analytic handwriting assessments have been developed with the aim of finding the most practical and reliable means of assessing an individual's handwriting [24]. Many of the handwriting measures that presently exist have a number of limitations which will be discussed.

2.2.3 Limitations of existing handwriting evaluations.

2.2.3.1 The examiner

According to Daniel and Froude in 1998, many of the assessments fail to identify who is certified to administer them i.e., a teacher or therapist and whether the individual requires preparation before carrying out the assessment [67]. Specific instructions regarding the exact method of administration are also not always present, which may impact on the results according to Stott et al. (1984) [68].

2.2.3.2 Assessment criteria

Debates regarding which factors most contribute to the legibility or readability of a child's handwriting are still ongoing as well as the most reliable means of measuring these factors [20,21,67]. Most researchers are in agreement that the most significant criteria contributing to the readability of a child's writing are: size (height, width), slant, spacing (spaces between letters/words), the degree of line straightness, shape (letter form and

shape) and the general appearance of the writing [69]. The measurement scales for many handwriting evaluations also differ. Grading criteria that is ambiguous may impact on the reliability of the scale [24].

2.2.3.3 Complexity of the writing task

According to Ziviani and Watson-Will in 1998, many of the assessments also do not take into account the complexity of the tasks on the child's handwriting performance [70]. Certain scales require the child to copy shapes, letters and words [71]. Others require the child to copy a paragraph [61,72] or write letters and/or numbers from memory such as the ETCH [72]. Evaluation measures also exist that require the child to write a 20 minute essay about a specified topic [73]. This is very important regarding the impact that type of task has on handwriting performance, which has been documented in the research [38,50]. The literature has demonstrated that individuals write differently when undertaking a copying task than when they are required to compose creatively [36,37].

2.2.3.4 Instructions in undertaking the written task

A variety of instructions are evident in the existing handwriting evaluations; which explain how written tasks should be carried out [24]. The nature of the instructions given may impact on a child's handwriting performance [24]. A child may perform very differently when asked to write as quickly as possible without stopping for corrections [70,74] versus a child who is instructed 'write as you usually do when you try to write well' such as in the MHA [21].

2.2.3.5 Lined or unlined paper

In certain assessments such as the MHA, lined paper [73,65,72] is utilised and in others unlined paper, such as the CHES-M [18,61]. There is conflicting research regarding whether children write more legibly on lined or unlined paper [24]. A pilot study by Weill and Amundson showed that the use of unlined paper led to improved writing legibility in kindergarten children [75]. Pasternicki; however suggested that lined paper improves the legibility of a child's handwriting during writing activities when compared to using unlined paper [76]. This was confirmed in a study involving 56, 7 year old pupils. Of the essays written, 75 percent were regarded as more legible when written on lined paper as

compared to unlined paper, by the same children [77]. Lined paper assists the child in organising their writing [77]. Age must be considered as a factor when utilising lined versus unlined paper.

There is often no regard for the type of paper that the child is using for writing at his/her specific school [24]. The effect that writing on lined versus unlined paper has on a child's handwriting was documented in a study by Trap-Porter et al. [78]. The study showed that both the presence and absence of lines as well as the width of the line impacts on a child's handwriting [78]. The study was done on cursive writing and therefore not applicable to this specific research study.

2.2.3.6 Writing tool used

In many evaluations the writing tool is not specified i.e., pen or pencil and no consideration is given to the specific writing utensil that the child is presently using at his/her school [24]. Many of the assessments fail to specify whether the individual is allowed to use an eraser or if they should rather cross out their work [24]. Erez et al. emphasised that children should not have an eraser when completing the evaluation [72]. An eraser may impact on the time taken to complete a specific task as well as possibly on the general appearance of the written product [24].

2.2.3.7 Observation of behaviours

Very few handwriting evaluation scales make examiners aware of specific behaviours to take note of when observing poor handwriters such as fatigue, which can impact greatly on their handwriting performance [24]. Often the measurement is more on the quality of the end product rather than the task process.

2.2.3.8 Writing speed measurement

Existing handwriting tools vary greatly in terms of how writing speed is measured [24]. Certain measures test speed according to the number of letters written in one minute [18], others in two minutes such as the CHES [61,71] and others in five minutes such as the BHK

[63]. Differences in writing speed are impacted by the factors previously mentioned including: duration and requirements of the writing task, time needed to carry-out the task, writing tools used and the instructions given to the child [24].

2.3 Factors related to competent handwriting

Competence in handwriting is usually demonstrated by the speed and legibility with which the child writes [16,31-33]. The speed and legibility of handwriting, whether impacted by a specific learning difficulty or not, are both found to be key factors impacting on a student's potential to succeed academically [23,79].

2.3.1 Writing speed

Writing speed is vital if a child is able to cope with the demands of the classroom [16]. Children's writing speed can impact on their ability to complete written assignments, keep up with class note-taking and influence how frequently they write on their own accord [38,49]. Additionally if a child's handwriting is particularly slow, they may forget the plans and ideas that they have held in their working memory, before they are able to transfer these thoughts and ideas onto paper [38]. Handwriting speed is very dependent on the context of the written task, instruction given by the teacher and whether the child is copying, taking down dictation or simply writing freely [20].

Handwriting speed becomes an issue of greater concern as children approach their higher school years when they begin written school examinations [80]. Handwriting speed is often indicated as the problem, leading to the initial referral for extra time allowances for examinations [81]. Psychologists and occupational therapists are often required to support the students plea to gain extra writing time and indicate whether their writing speed is in fact hampering their academic performance [23].

The speed of writing has also been found to deteriorate when the complexity or volume of the writing task increases [38,82]. Lyth documented that the speed of the writing varied significantly when the child was required to write one versus thirteen lines [83]. With longer writing tasks, various factors may come into play including inattention and boredom; which

may impact on an individual's writing speed [23]. In a study by Sawyer et al., the students were required to complete a two minute test of copying and a two minute test requiring the individual to generate their own writing. Even though the students were given time to prepare, they produced 2.5 percent less letters in two minutes on the self-generated task [84].

Writing speed is often referred to in the literature as fluency [81] and measured by counting the number of letters written per minute [5,85]. The most common means of assessing handwriting speed is to use a short duration handwriting speed test, requiring the individual to copy either a simple sentence [86] or a written passage [84]. A measure of handwriting speed is then obtained through counting the number of letters correctly copied in a specified time-frame [36]. This means of measuring writing speed is evident in many pre-existing studies on children, young adolescents and adults [18,61,63,71,81].

Despite the numerous research studies investigating children's writing speed, congruent information has not been elicited. The writing speed norms among typical children vary in research studies due to differing methodologies, subjects and the means of data collection [9]. For example, literature which looks at the average writing speed of grade two children has elicited very different results:

- **The Children's Handwriting Evaluation Scale-Manuscript (CHES-M)** requires children to copy a written passage on unlined paper at their usual pace for two minutes. According to this test the average writing speed for grade two children is 35 letters per minute [62].
- **The Concise Evaluation Scale of Children's Handwriting (BHK)** was developed as a screening tool in order to assess the readability and writing speed of dysgraphic children. Children were asked to copy a standard text that is presented to them on a card for five minutes. Handwriting Speed is calculated according to the number of letters written in five minutes. The average writing speed per minute was found to be 24, 25 and 25 in the three groups evaluated [63].
- In a study by Sasson et al., children were given two sets of instructions. Firstly to write at their usual pace (U) and secondly to write as fast as they could (R). The average writing speeds for the grade two children were 46(U) and 55(R) characters in one minute [29].
- The average writing speed given on the **WRIT** are 49- 58 letters per two minutes [47] (2.5.2.1 pg. 23).

Handwriting skills are said to improve with both age and schooling [87]. During their first three years of school, most children are required to be proficient enough in handwriting in order that they are able to carry out their schoolwork [88].

The speed of writing tends to develop linearly throughout a child's primary school years [16] and stabilises during a child's middle school years [36]. The more children are required to compose as they go higher up in the grades, the more their handwriting becomes automatic, therefore resulting in a gradual increase in the child's writing speed [49]. According to Graham et al. in 1998, the development of writing speed tends to occur in a steady fashion during the earlier grades, there is a slight slowing down in the intermediate grades and a plateau is reached in grade nine when the children tend to reach speeds similar to those obtained by adults [36]. A study by Killeen et al. [89] to establish norms for the Handwriting Speed Test for 8-18 year olds in the Irish education system, also found that the speed of writing tended to increase linearly over the ten school years evaluated; although the rate decreased considerably in the final four years of secondary school [89]. The children's writing speed varied from 44 letters per minute in the third year of primary school to 24 letters per minute in the last year of secondary school [89]. The progress of handwriting speed was most noticeable in the last year of primary school and the first year of secondary school [23].

According to Graham and Weintraub in 1996; however, it was suggested that handwriting speed and its relationship to the grade of the child may not be linear, but may in fact be influenced by the developmental 'spurts and plateaus' that the child is experiencing [38]. This was also suggested in a research study by Phelps, Stempel and Speck in 1985 [61]. They documented that children's handwriting speed typically increased from one grade to the next however this relationship did not occur in a linear fashion [61]. Graham et al. documented that there appeared to be no significant differences between the seventh, eighth and ninth graders, with writing speed changing predominantly from the first to sixth grades [36,90]. Research has also documented considerable variations in handwriting speeds at the same grade level [36]. In a study by Graham et al., writing speed in grade five children ranged from 43 to 125 letters per minute [36]. This variability was also indicated in the grade two studies discussed previously. This could possibly be related to a number of intrinsic and extrinsic factors such as fine motor difficulties, visual perceptual components and ergonomic factors.

2.3.2 Writing legibility

Writing legibility is often referred to as readability or quality of writing [9,85]. In order to achieve efficient and effective written communication, a balance of both speed and legibility is necessary [81,24]. The legibility of handwriting may deteriorate when the child is required to write at a greater speed than what he/she is used to or when the complexity of the written task increases [18].

Handwriting legibility is often determined by the ease with which the reader can make sense of the writing [9] as well as by the specific components of writing legibility: letter formation (including inversions, reversals, confusion of letter forms), spacing between letters and words, and letter size [91,92,93,20,73]. According to Amundson and Weill, reduced letter formation and size are the two most significant factors impacting on the readability of a child's handwriting [9].

By the age of 6 or 7 years, typical children are reasonably competent in terms of writing legibly when they have been taught a specific handwriting curriculum. Through mastery of the above mentioned basic writing legibility skills, children are able to progress to tasks such as composing stories without focusing too much on the writing mechanics [50].

Children with learning disabilities, neurological impairments and developmental disabilities; however, exhibit difficulties with regard to writing legibility [9]. When handwriting is illegible it has the potential of creating a barrier for the child in terms of accomplishing additional higher order skills such as spelling and composing stories [34], as these children need to focus considerably on the aspects of writing legibility [9]. The literature also suggests that lower marks are more often assigned to individuals with poor, illegible handwriting and higher marks given to those individuals with legible handwriting despite similar content [94,95].

The legibility of writing has also been found to deteriorate when the volume of the writing task increases [96]. In a study on fourth grade students, Dennis and Swinth found that writing legibility was better on a short writing task of approximately two to four sentences than on a longer writing task of eight sentences [96].

Graham et al. carried out a study on individuals in grades four to six that included 61 students with learning difficulties [91]. In this study, six aspects that impact on the overall legibility of the child's written work were documented. These included: letter formation, spacing, neatness, size, slant and alignment. The results concluded that letter formation, spacing and neatness contributed mostly to the overall legibility, with letter formation being the most significant variable [91]. In a study in which written stories of learning disabled and typical children were compared, it was found that one of the most significant differences between the two groups was in letter formation with the learning disabled children scoring significantly worse in this aspect [97].

Contradicting views on the development of handwriting legibility in the various grades have been documented in the literature. Several of the studies failed to find a correlation between a child's handwriting legibility and their grade level [36]. For example in 1991, Maeland and Karlisdottir [92] and Sovik and Amtzen [98] documented no significant difference in the handwriting legibility of students whether they were in grade three or six [92,99]. Tarnopol and de Feldman showed that the handwriting legibility of students in both grade two and five was in fact very similar [100].

Studies of handwriting in typically developing children in grades one to five have shown that the quality of handwriting develops rapidly in grade one and tends to plateau in grade two [16]. Further development in legibility is seen in grade three [16]. At this stage the children's handwriting tends to become more automatic, organised and becomes a way of enabling the child to express their thoughts and ideas [17,90].

Ziviani and Elkins showed that children's handwriting legibility improved steadily from grades two to six [74]. Hamstra-Bletz and Blote; however, showed that writing legibility improved primarily during formal handwriting instruction until grade three [101]. Mojet documented that handwriting legibility began to plateau in grade four, but the children demonstrated subtle improvements in grades five and six [102].

In a study by Graham et al. on 900 children in grades one to nine, incorporating three tasks: copying a paragraph, writing a narrative and composing an essay, it was found that writing legibility in both males and females improved from grades one to six and then remained constant from grade seven to nine [36]. An exception to this was the copying task where the legibility was reduced in grades seven to nine [36]. His results for copying tasks

concluded that little change was evident with regard to the legibility of students copying in the primary grades. In the intermediate grades copying legibility improved greatly, most significantly in grades five and six and in junior high school copying legibility was at the same level as the primary grade children [36]. The findings indicate that the handwriting of students in grades one to six was more legible during the copying task, than when they were required to create a narrative or write an essay, therefore confirming that the processes utilised by the child when composing stories, including aspects such as generating ideas, interferes with the processes that are involved in writing neatly [36,103] .

2.3.3 Correlation between handwriting speed and legibility

Studies that have documented the correlation between handwriting speed and legibility have elicited contradictory results [36]. A low correlation between the speed and legibility of writing was reported by Karlsdottir and Steffanson [17], Volman et al. [104] and Graham et al. [36] who demonstrated that most of the sample of primary school children that were found to have decreased writing quality were also very slow writers [36,104].

In the study by Graham et al., it was documented that a linear relationship was evident between handwriting speed and the three measures used to assess handwriting legibility in the study i.e., copying a paragraph, writing a narrative and composing an essay [36].

Although handwriting speed has been demonstrated to be of little importance when predicting a child's writing legibility, it has been shown that these variables are related. Ziviani concluded that a positive correlation exists between the speed and legibility of handwriting ($r = 0.41$) [74]. It has been demonstrated that one of these variables does suffer as a result of the other [36]. This occurs when children make a conscious attempt to speed up their writing or write more neatly [36]. Weintraub and Graham demonstrated that when children were asked to write quickly, their writing legibility decreased. Alternatively when children were requested to write neatly, their handwriting speed consequently declined [105].

2.4 Demographic factors related to handwriting

Writing speed and legibility have been shown in a number of studies to increase with age; girls have generally been found to write faster than boys and right-handers have shown to be faster writers than left-handers. Other factors affecting writing speed and legibility include writing style, endurance and ergonomic factors such as type of pencil grasp used [81], sitting posture [23] and pain and fatigue in the writing arm [81].

2.4.1 Gender

Previous research has documented that girls often perform better than boys with regard to both their writing speed and legibility [5,71,90,100]. According to Graham et al., these gender differences may be due to both biological and environmental factors [38]. For example girls have a more advanced progression of fine motor skills than boys, which may have an impact on their writing speed [106].

Many studies have demonstrated a difference in writing speed among the sexes, with females being faster writers than males [74,107,108]. However, other studies have confirmed that boys write faster [108,109],with girls performing significantly better than boys only in grades one, six and seven [36]. Further studies which compared the writing speed of males and females indicated that males tended to write slower than females when writing in both Hebrew [110] and English [36,70,108].

The writing speed and legibility of 372 typically developing children between the ages of 7 to 14 years residing in Australia was assessed through the use of Ziviani and Watson-Will's scale. This scale assesses the global readability of a child's handwriting through the use of a 7-point scale. In this scale no significant differences were found between males and females in terms of their average writing speed [70].

Studies have demonstrated that in terms of writing legibility gender differences do exist, with girls' handwriting being more legible than boys' [38] both in elementary school [110,111] and middle school [5,87,112]. In a study by Graham et al., it was documented that the girls' handwriting was more legible than the boys' in all three writing tasks [36]. This was

confirmed in a study by Ziviani and Watson-Will where the readability of the girls' handwriting was found to be significantly better than the boys' [70]. In a study by Weintraub et al. on 134 middle school students, it was found that girls performed better than boys particularly in the areas of letter formation and spatial organisation [5].

2.4.2 Handedness

There have been conflicting results in the research in terms of handwriting speed and the handedness of the child [23]. Two studies showed that right-handed students demonstrated a tendency to write at a faster speed than left-handed students [36,61]. This was contradicted by Bonoti et al. who showed no apparent difference in the writing speed between right- and left-handed individuals [113]. Ziviani and Elkins also concluded that the handwriting speeds of right- and left-handed students did not differ [71]. These findings were confirmed by Wallen et al. who showed that there was no difference between left- and right-handed students in terms of writing speed when they were required to write for a three minute time period [82]. This could be related to the length of the writing sample.

Further research is required to investigate whether there is a difference in writing speed among right- and left-handed individuals and if so, what the underlying causes of these differences are [36]. One possible reason is the positioning of the paper that left-handed individuals use [36]. Enstrom identified that left-handed individuals used 15 different paper positions whilst writing [114]. He also showed that students who tended to use four of these particular adjustments to the positioning of their paper generally seemed to write above grade level in terms of both the speed and legibility of their writing [114]. In a study by Athenes and Guiard (1991), it was documented that the more effective adjustments were not generally used by the left-handed students [115]. However, the quality of handwriting instruction given to left-handed students may also be a contributing factor. Teachers may be aiming their instructions at the right-handed students when teaching handwriting. For example all students may be instructed to place the paper that they are writing on directly in front of them and turn in 30-40 degrees anti-clockwise [33]. Although this is the preferred paper position for right-handed students, it is not the case for left-handed students [33,114].

2.5 Dysfunction in handwriting

Children with reduced handwriting performance are often referred to in the literature as either being 'poor handwriters' or alternatively as dysgraphic [24,93]. These individuals struggle to produce handwriting that is regarded as acceptable despite the fact that they may have had a fair amount of instruction and practice in writing [93]. Hamstra-Bletz and Blote [93] defined dysgraphia as 'a written-language disorder that concerns mechanical writing skill. It manifests itself in poor writing performance in children of at least average intelligence who do not have a distinct neurological disability and/or an overt perceptual-motor handicap' [93] (p.690). Sovik and Arntzen described it as a learning disorder that is not related to other forms of learning such as spelling, math and reading [98]. According to De Ajuriaguerra et al., dysgraphia tends to occur in children who are at least of average intelligence [93]. It has been documented that dysgraphia is most commonly reflected in reduced writing speed and impaired legibility [116].

2.5.1 The role of the occupational therapist in assessing handwriting dysfunction

Approximately 10-34% of school-aged children are said to experience handwriting difficulties [17-19] and this is the main reason that school-aged children are referred to occupational therapy [40-43]. The occupational therapist's role in assessing handwriting dysfunction is to determine which aspects of handwriting are difficult for the child [9], to evaluate which environmental aspects may be affecting the child's handwriting performance [9] and to identify if an underlying sensory, motor, cognitive, perceptual or psychosocial factor may be impacting on their handwriting [9]. These factors are assessed in order that the appropriate intervention strategies can be provided.

Handwriting difficulties ultimately impact on the child's academic performance [16,24,25] and may lead to poor self esteem and possible behaviour problems [27], impacting on the child's emotional and social functioning [25]. Handwriting problems can often overshadow a child's abilities in other areas as this is often seen as a reflection of an individual's capabilities and level of intelligence [16]. Handwriting difficulties are especially prevalent among children diagnosed with learning disabilities [39] and those diagnosed with developmental co-

ordination disorder [117]. There is also literature which links Attention-Deficit Hyperactivity disorder (ADHD) to handwriting difficulties [55,118-120]. Approximately 50 percent of children with ADHD are said to demonstrate fine motor difficulties thus impacting on their handwriting performance [119]. Difficulties with handwriting during a child's earlier school years may in fact be a predictor of later learning problems [121].

There are a number of intrinsic factors – those that relate to a child's actual performance capabilities [16], that can impact on an individual's writing speed and legibility. These include: age/grade level, gender, postural control, fine motor difficulties including poor pencil grasp, bilateral integration and motor planning, kinaesthetic difficulties and visual perceptual skills.

2.5.2 Postural control difficulties

'Postural control is the base of stability from which any purposeful movement may occur' [122] (pg.65). Often children who demonstrate reduced postural control, exhibit poor handwriting [51]. They struggle to maintain an upright position, especially while seated at their desks and experience difficulty in making the necessary postural adjustments during the performance of fine motor (e.g. handwriting) activities [51].

Lack of stability of the shoulder, elbow and wrist impact on the child's ability to manipulate the pencil, as the speed and dexterity of the intrinsic movements of the hand are greatly affected [51]. According to Amundson, difficulties with postural control and upper extremity stability commonly impact on writing legibility [51].

2.5.3 Somatosensory/kinaesthetic difficulties

Kinaesthesia is 'the awareness of the extent, weight and direction of movement' [51] (p. 65). Kinaesthesia influences the degree of pressure exerted on the pencil, the ability to write within the lines as well as the directionality of the writing tool [51]. Children who demonstrate kinaesthetic dysfunction may either press too hard or too softly with their pencil [51]. They may also struggle in terms of forming their letters properly and spacing their letters accurately in the lines, due to difficulties with regard to directing their pencils adequately

[51]. In a study by Schneck of grade one children, between the ages of 6 to 7 years with handwriting problems, a less mature pencil grasp was shown to be linked to kinaesthetic difficulties [123].

Children who present with poor somatosensory discrimination often rely on visual feedback in order to monitor what they are doing with their hands [124]. These children often present with motor planning or motor memory difficulties which may affect the automaticity of their writing as well as impacting on their ability to retrieve the motor patterns of letters [12]. Copying of letters may also be affected [12].

A study documented a significant correlation between reduced tactile awareness and handwriting execution in children with a mild motor impairment [41]. Another study on grade one children who were born preterm showed that reduced sensory awareness of their individual fingers, resulted in impaired writing legibility as compared to their peers [125].

2.5.4 Fine motor difficulties

Berninger and Rutberg in 1992 suggested that finger function is a significant predictor of handwriting dysfunction [126]. According to Alston and Taylor (1987), fine motor skills are vital, as letters can only be formed accurately if the proper force, timing and control of arm, hand and finger movements exists [127]. Exner referred to three main areas of fine motor control that impact on a child's handwriting ability. These include isolation, grading and timing of movements [128]. Difficulty with regard to the isolation and grading of finger movements may result in children having inadequate pencil grasps [128]. Children with these difficulties tend to use compensatory methods including locking their fingers into extension or fisting their fingers into flexion in order to gain stability when using their pencils [128]. Difficulty with timing of movements may impact on the rhythm and flow of handwriting and result in handwriting that is slow and jerky or alternatively rapid, disorganised handwriting [128]. Incorrect size and placement of letters and other common writing errors can also be attributed to a child's difficulties with fine motor control. This is documented in a study of grade one children [129].

2.5.4.1 In-hand manipulation

In-hand manipulation is an aspect of fine motor control that has also been shown to impact on handwriting performance [25]. It involves adjusting objects within the hand after they have been grasped [128]. After a child has grasped their pencil, they are required to shift it in order to adjust it for writing [128]. This is defined as the linear movement [128]. Translation is an aspect of in-hand manipulation which is the ability to move an object from the palm to the finger pads or visa versa [128]. An example of this would be pushing the fingers towards or away from the pencil point during a handwriting task [130]. Rotation is another aspect of in-hand manipulation which involves moving the pencil around an axis [128]. It is essential for tasks such as turning the pencil from its grasp position to a position for writing or erasing [128].

2.5.4.2 Pencil grasp

The efficient use of the pencil is a significant factor with regard to the handwriting process [43]. Pencil grasps and their relationship to functional writing (i.e., speed and legibility) remains an area of uncertainty for occupational therapists and educators.

The few studies are contradictory in terms of their views on the relationship between pencil grasp and handwriting performance (speed and legibility). Ziviani and Elkins and Sassoon et al. found no relationship between a child's handwriting speed and their pencil grasp [29,131]. This was further confirmed in a study by Rubin and Henderson [18]. Schneck et al. however, found a statistically significant difference in the handwriting performance of children with mature pencil grasps versus those with immature grasps [123].

A child's pencil grasp has been shown to contribute to the efficient use of their pencil because it impacts on the degree of movement that is available in the interphalangeal joints of the index finger and thumb of the writing hand [43].
Occupational therapists and educators have in the past stressed the importance of children using a dynamic tripod grasp when writing [9]. This grasp involves resting the pencil on the distal phalanx of the radial side of the middle finger while controlling it between the pads of the thumb and index finger, with the thumb somewhat opposed [43,132].

Prior to 1980, studies that documented the development of the dynamic tripod grasp indicated that the grasp had generally developed in young children by the age of 6 years [132]. The assumption of these studies was that all children had developed this grasp [43]. Studies that have been undertaken since 1980 have demonstrated that not all children are inclined to use the dynamic tripod grasp [43].

Benbow demonstrated in a study on 68 children between the ages of 6 to 8 years that only 49% used a dynamic tripod grasp [133]. Schneck and Henderson performed a study on 320 functional children between the ages of 3 to 6 years in order to examine their grasp position for pencil and crayon control [134]. They found that the use of the dynamic tripod grasp increased with age. It was used by 72.5 percent of these children who were aged between 6 years to 6 years 11 months [43,134]. Approximately one quarter of the children age 5 years 0 months to 6 years 11 months preferred to rather use the lateral tripod grasp [134]; which was also considered as a mature grasp in this study. This study indicates that a variability of grasps exists among typical children [51]. Blote and van der Heijden found that in a study of 55 Dutch children between the ages of 5 to 6 years that 60% were using a dynamic tripod grasp [135].

Studies by Schneck and Henderson and Ziviani have demonstrated that both adults and children with adequate handwriting skills use a number of different pencil grasps [136,137]. Although atypical grasp patterns are demonstrated more in poor writers than legible writers; an atypical pencil grasp does not necessarily affect the speed or legibility of a child's handwriting [137].

Different classifications of pencil grasps are evident in the literature. In the study by Schneck and Henderson, pencil grasps were classified into primitive, transitional and mature grasps [136]. The primitive grasps were the radial cross palmer grasp, palmer supinate grasp, digital pronate grasp, brush grasp and grasp with extended fingers [136]. The transitional grasps were the cross thumb grasp, static tripod grasp and four finger/quadrupod grasp [136]. The mature grasps in the Schneck and Henderson scale included the lateral tripod grasp and the dynamic tripod grasp [136]. Benbow classified pencil grasps into six inefficient and three efficient grasps [138]. The inefficient grasps included the thumb wrap, thumb tuck, transpalmer grasp (palmer supinate grasp), transpalmer interdigital brace, supinate grasp and the index grasp [138]. The efficient grasps according to Benbow are the tripod grasp, quadrupod (four finger) grasp and the adapted

tripod grasp [138]. The WRIT also classifies pencil grasps according to inefficient and efficient grasps. Inefficient grasps include the thumb wrap, thumb tuck, hooked wrist, interdigital brace, closed web space and unstable thumb grasps [47]. Efficient grasps include the tripod, quadrupod and adapted tripod as in Benbow's classification [47].

Although the dynamic tripod grasp is the pencil grasp recommended by educational authorities [51] children with and without handwriting difficulties demonstrate a variety of pencil grasps with certain grasps resulting in handwriting that is more difficult and less functional [139] .

According to Schneck and Henderson, the majority of typical children use either a static tripod, quadrupod or dynamic tripod grasp [136]. A much smaller percentage of children use the lateral tripod grasp [136]. The lateral tripod grasp does not include the open web space of the other grasps [46].

2.5.5 Bilateral integration and motor planning difficulties

Bilateral integration and motor planning are important elements with regard to handwriting performance. Bilateral integration is "the brain function that enables coordination of functions of the two sides of the body" [140] (p. 353). It is involved in tasks such as when the child is required to stabilise the paper with the non-preferred hand while he/she is holding the pencil with the preferred hand [51]. Motor planning is 'the process of organising a plan for action. This aspect of praxis is a cognitive process that precedes the performance of a new action' [140] (p.353). It impacts on handwriting when the child is required to plan, sequence and execute letter forms and sequence letters in words [51]. It is particularly significant when children are first learning to write as it impacts on their ability to perform new and unfamiliar movements [16]. Tseng and Murray documented in their study that motor planning was another significant predictor of legibility in individuals with poor handwriting [141].

2.5.6 Visual perceptual components

According to Amundson, visual motor integration (VMI) is defined as "the ability to co-ordinate visual information with a motor response" [51] (p.66). VMI is an important factor with regard to handwriting performance and strong correlations have been documented in the research between visual motor integration and handwriting legibility [75,141,142]. Weil et al. documented a significant relationship between kindergarten children's handwriting and their VMI skills [75]. This was confirmed by Weintraub and Graham [111]. Visual motor-integration and eye-hand co-ordination were also found to be the most significant variables contributing to handwriting legibility in 143 Chinese schoolchildren in grades three to five [141]. Visual motor integration is particularly important when copying from the text to either cursive or manuscript writing [25].

Visual perception is "the ability to organise and interpret what is seen" [51] (p.65). Although certain studies have found a correlation between visual perception and handwriting performance, the connection between these two variables is not fully clear [143]. Certain aspects of visual perception may impact on a child's handwriting performance. Visual closure enables a child to identify letters that have not been formed completely [16]. Position in space impacts on a child's spacing between letters and words and between the writing lines (horizontal alignment) [51]. In a study by Graham et al., poor handwriters were shown to exhibit differences to competent handwriters particularly with regard to the visual-spatial aspects of writing in terms of situating letters accurately on a page [37]. Form constancy impacts on the child's ability to discriminate between similar letters, numerals or words such as b/d, was/saw and 2/5, which can impact significantly on a child's handwriting [51]. Poor visual memory for sequences of letters has been demonstrated in children experiencing difficulties particularly with handwriting tasks involving copying [144]. These children may experience problems with regard to recalling the formations of letters and numbers i.e., in revisualising the letters and numbers without the aid of visual cues [145]. According to Hagin, the upright orientation of the inclined surface may decrease directional confusion, as on the inclined surface, up means up and down means down, whereas on a horizontal surface up means away from the body and down means toward the body [146]. Tseng and Cermak concluded that additional research is required to ascertain the exact role that visual perception has to play in handwriting [139]. According to Tseng and Cermak, tactile-kinaesthetic, visual motor integration and motor planning are

factors that have a greater association to handwriting performance than visual perception [139].

2.5.7 External components

Other factors that may impact on a child's handwriting performance are extrinsic [16]. These are environmental or biomechanical factors [16] which include sitting position, chair and desk height, writing instrument used, the type of paper that is used and its placement on the desk, environmental lighting and noise, the distance from the blackboard when copying and the amount and type of handwriting that the child is required to complete [16].

2.5.7.1 Ergonomics

When writing, the child should be seated with their feet flat on the floor, hips and lower back supported against the back of the chair, knees flexed to approximately 90 degrees, and elbows flexed slightly with forearms resting on the desk [16].

Extrinsic factors may compromise the child's written output. If for example the child's chair and desk height are too low it will encourage the child to slouch forwards [16]. When the chair and desk height are too high, the feet are unsupported [16]. These factors can both impact on the child's handwriting performance [16]. It is therefore vital to identify the biomechanical factors that are involved when treating both learning disabled and typically developing children with handwriting difficulties [16].

2.5.7.2 Pain and fatigue

The effect of pain and fatigue on the writing speed of third grade students was carried out in a study by Parush et al. The children's handwriting speed was assessed before and following a ten minute period of sustained writing which was the fatiguing aspect. Surprisingly, a significant difference was evident before and after, with the students writing at a faster speed following the writing exercise that was considered to be fatiguing [147]. In a study by Summers et al. on university students in examinations, it was reported that

fatigue caused their handwriting to become less legible and slow down [81]. An incorrect pencil grasp has also been shown to impact on pain and fatigue in the writing hand [13].

2.5.7.3 Demands of the writing task

Previous research by Graham and Weintraub and Martlew has shown that handwriting performance is strongly influenced by the demands of the writing task [38,50]. Composing tasks such as writing a story or describing an event are more demanding than copying tasks [37]. In a study by Graham et al., it was found that the handwriting of children in grades one to six was more legible during tasks when the children were allowed to copy in comparison to tasks where they were required to create a narrative or expository text [36]. This suggests that the processes that are involved in composing, particularly during the elementary school years, do impact on the speed and legibility of the written product [36,148]. Younger students often require focusing and increased attention to be paid to aspects such as generating ideas and planning, particularly when composing [35-37]. This impacts on their ability to write neatly as they are often focusing considerably on these other areas [36]. Copying tasks can therefore be seen as a reflection of the speed with which an individual is able to carry out the physical aspects of writing [47].

In order to ascertain the effects of the above-mentioned factors on a child's handwriting performance, their handwriting needs to be thoroughly assessed and the specific areas where the child is experiencing difficulties need to be identified.

2.6 Assistive devices used to improve handwriting

2.6.1 Stetro pencil grip

A variety of prosthetic pencil grips are available to assist the child in positioning his or her fingers for better use of the pencil [9]. A lack of empirical research exists regarding the benefits of these assistive devices in aiding a child's handwriting performance [149]. Tripod grasps may be achieved through the use of Stetro grips, triangular grips and mouldable grips [130] among others. The Stetro pencil grip is a plastic moulded pencil grip with finger indentations [10]. The star indicates thumb placement and the forefinger and middle finger fit

into the other two indentations [10]. The grip can be used with both right- and left-handed individuals [10]. For children who have a closed web space or flexed fingers, the Stetro grip may aid in preventing some of the muscle fatigue and tension that these children experience when writing [150]. There is a lack of literature supporting the use of Stetro pencil grips during the performance of handwriting tasks. In one such study no differences in writing performance related to pencil grips or a change in the pencil diameter were reported [151]. Ziviani suggested the risk of young children developing immature pencil grasps as a result of using a pencil grip [74].



Figure 2.1 Prosthetic pencil grips

2.6.2 Soft splint

The soft splint is a means used to encourage the balance of stability and mobility needed for a functional pencil grasp [130].

When children are learning to write they may demonstrate laxity in one or more of their joints [43]. The need for stability is why children often do not use the dynamic tripod pencil grasp; which may be impacted by joint laxity [43]. Joint laxity is said to decrease with age, and children are found to have a larger amount of flexibility in their joints than can be seen in adults [152]. When a child's joint stability in their hands is not optimal for controlled mobility, then he/she will tend to use a grasp such as the lateral tripod grasp, which aids their pencil control, by providing stability [130,153]. In the lateral tripod grasp, the thumb is adducted [43], which restricts the child's finger movement [43]. If the child has instability in the metacarpophalangeal joint of the thumb or a collapsed web space, the child will tend to use grasps such as a thumb wrap or a thumb tuck [130].

Other external supports have also been demonstrated to enhance this stability-mobility balance, including micro foam surgical tape supports, ring splints and neoprene splints [130]. There are no available studies that support stabilising the thumb with a splint to facilitate improved pencil grasp and handwriting performance.

2.6.3 Inclined surface

Studies have demonstrated that when using horizontal work surfaces, children often adopt bad postures. Horizontal work surfaces may also cause physical discomfort and problems with the head, neck and shoulders such as pain and reduced stability. Inclined work surfaces have been demonstrated to lessen musculoskeletal complaints and improve work performance [154]. They provide the appropriate hand and wrist position required for the performance of fine motor and handwriting skills [46].

The importance of working at an inclined surface has been emphasised [155]. In this posture the wrist is correctly positioned in order to develop stability [46]. In this position, thumb abduction and opposition are also facilitated for developing dexterity [46]. Stable wrist extension and thumb opposition encourage total arching of the hand which is required for the skilled manipulation of objects [46].

When children work at a horizontal surface, the intrinsic muscles are not used optimally, as they often place their wrists in neutral or in flexion [46]. The wrist extension which is facilitated by an inclined surface encourages the balanced use of the hand's intrinsic muscles [156]. The inclined surface also promotes the development of the arm and shoulder muscles, as both the arms and hands are required to move against gravity [46].

2.7 Conclusion

In conclusion, much research exists regarding the development of writing, the assessment of writing at different ages, the importance of writing speed and legibility and the factors that affect handwriting. Occupational therapists are involved in assessing and remediating poor handwriting which is related to a number of postural control, somatosensory/kinaesthetic, bilateral integration, visual perceptual and fine motor internal

components. These have an effect on the child's pencil grasp and although there is evidence to support the use of assistive devices to assist with providing facilitation of positioning of the hand and posture to improve handwriting, little research exists regarding the impact of these assistive devices on writing speed and legibility (particularly among the learning disabled population) and whether in fact these devices are beneficial in enhancing writing speed and legibility. Therefore it is apparent that there is a great need for research into this area in order to ascertain conclusive evidence regarding this.

CHAPTER 3

Methodology and Results - Phase One

3.1 Phase One: Confirmation of handwriting speed and legibility in mainstream South African urban sample

Phase one consists of two parts. The first part (Part A) is the development of a speed and legibility measuring scale and the second part (Part B) is the norming of the scale on a South African mainstream urban sample.

Part A meets objective a.
Part B meets objective b.

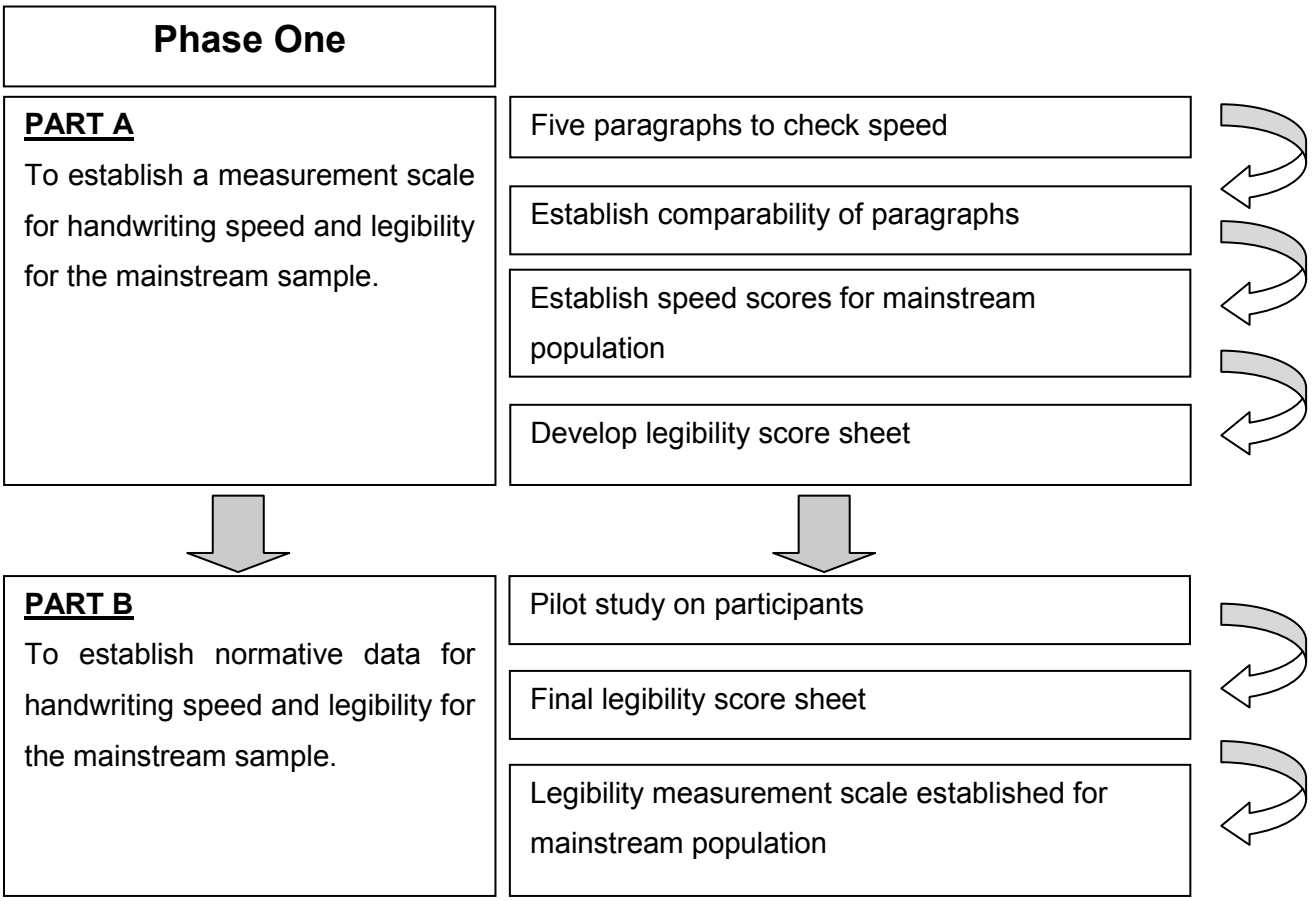


Figure 3.1 The components and method flow of the first phase of the study which is the development of a speed and legibility outcome measure

Phase one of the study was implemented in order to:

PART A - establish a measurement scale for handwriting speed and legibility for the mainstream sample.

PART B - establish normative data for handwriting speed and legibility for the mainstream sample.

3.1.1 PART A: Development of a speed and legibility measuring scale

Part A of the study was implemented in order to establish a measurement scale for handwriting speed and legibility for the mainstream South African urban sample.

3.1.1.1 Research design

The research design implemented for this phase of the study was a quantitative cross-sectional design. Cross-sectional designs are utilised when one is required to compare different types of people in terms of a dependent variable that can be measured immediately [157]. The data for this phase of the study was collected by observing all of the participants on one specific day. This ensured that there would be no dropout of participants when carrying out the writing samples. Descriptive research was utilised to describe specific characteristics of the research sample [157] such as gender, handedness and pencil grasps , which are all factors impacting on handwriting.

3.1.1.2 Population

The population for phase one of the study consisted of mainstream grade two learners in Johannesburg.

3.1.1.3 Selection of participants

Convenience sampling was used to obtain the sample for this phase of the study. Convenience sampling is the most readily used method in research in terms of obtaining participants [158]. The study involved the use of easily available participants at a

conveniently located school [158]. As participants agreed to take part in the study, they were enrolled until the required sample number was reached.

The gender and ethnicity of the participants and their first language were not regarded as a selection criterion. The total mainstream sample consisted of 24 participants, comprising of a number of participants from each of the grade two classes.

A sample size calculation set this sample number with at least 23 participants per group having 80% power to detect a difference between the groups of at least one category, on letter formation in the legibility scoring when testing at the 0.05 level of significance. This follows from the fact that the difference in the score should be one point with a standard deviation of 0.94.

Inclusion criteria

- Age: All participants were in grade two and between the ages of 7 to 9 years
- Gender: Both males and females were included
- Handedness: Both right- and left-handed individuals were included.

Exclusion criteria

Those individuals whose parents did not give consent and who themselves did not give assent were excluded from the study.

3.1.1.4 Research location

The research was carried out at Fairways Primary School in Johannesburg. This particular school was chosen due to its easy access (convenience sampling). Permission to undertake the research there was granted by the principal of the school (APPENDIX B). These schools admit children from a variety of socio-economic groups, races and cultures.

3.1.1.5 Measurement tool

In order to establish inter-paragraph reliability, grade-appropriate standardised reading samples obtained from the Ekwall Reading Inventory (APPENDICES C1-C4) were used [159]. The four grade two reading samples from the Ekwall Reading Inventory- Second Edition, a set of reading passages that range in difficulty from pre-primary to ninth grade level were chosen [159] because they could be read by the participants of this study. In addition to these paragraphs, a grade-appropriate sample from the Writing Rate Information Test (WRIT) discussed in chapter 2, section 2.2.2.1 was used (APPENDIX A). This paragraph was included so that the other paragraphs could be compared to the scoring for speed and legibility on a test standardised in South Africa, the WRIT.

The paragraphs from the Ekwall Reading Inventory were therefore compared to each other and the WRIT in terms of the speed and legibility with which they could be copied in order to establish speed and legibility norms.

3.1.1.6 Control of variables

Ergonomic factors were considered where possible such as desk height, chair height and background noise. The desks were all 60cm in height.

3.1.1.7 Ethical considerations

This study obtained ethical approval from the University of Witwatersrand Ethics Committee for Research on Human Subjects prior to the start of the research (APPENDIX D). Admission to the study was voluntary and participants (both parents and children) were given the opportunity to withdraw from the study at any time without any consequences. A parent information sheet (APPENDIX E) and a letter of informed consent (APPENDIX F) was sent to the parents of all the grade two learners at Fairways Primary School and verbal/ written assent was obtained from the participants themselves (APPENDIX G). Both the parents and children indicated their consent by signing the relevant forms. A standard introduction was read out loud to each participant at the start of the assessment (APPENDIX H) in order that the participants were aware of the procedure

of the assessment and exactly what was required of them during this phase of the research.

The assessment forms were individually coded e.g. 01, 02 in order to ensure confidentiality. Participants were free to withdraw from the study voluntarily with no consequences and to request feedback on the outcomes of the study.

3.1.1.8 Data collection

In this study the mainstream participants were required to copy five written passages each for two minutes, which is the same time frame utilised in the WRIT. The order of the paragraphs was consistent for each child, and was as follows: Sample A (APPENDIX C1), Sample B (APPENDIX C2), Sample C (APPENDIX C3), Sample D (APPENDIX C4) and Sample E from the WRIT (APPENDIX A). Each participant was provided with a sharp HB pencil and five sheets of Irish-lined paper to complete the writing samples. No erasers were provided. Very specific instructions were given to the participants by the researcher, which were based on those in the WRIT. They were as follows:

'*When I say **go** I want you to copy this piece until I say **stop.** It is not a race, don't scribble. Just write as you usually do in class.'* They were also instructed to cross out the word with one line if they made a mistake (APPENDIX I).

The participants were timed for two minutes using a stopwatch. Once each sample was completed, the next sample was read out aloud to the participants. After the paragraph had been read, the participants were given time to write a spacing cue in the margin i.e. head, tummy, tail if they felt this was necessary. The participants were allocated time to do this before beginning each writing sample in order that once the timing of the paragraphs began, they were able to focus solely on their writing.

The participants were assessed in a quiet classroom provided by the school. The writing samples were carried out during school hours at a time deemed appropriate by the teacher. The participants were assessed as a single group of 24 children.
A teacher whom the participants were familiar with was present in the room throughout the duration of the writing samples. The administration of the test was carried out by the researcher. Ergonomic factors were maintained as much as possible such as correct desk

and chair height. While observing the writing samples note was taken of factors such as the child's handedness and their pencil grasp.

Each subject involved in the study received a reference number/code in order to maintain their anonymity i.e., 01, 02, 03. After all the samples had been completed, they were placed in an envelope by the teacher and given to the researcher to be scored.

3.1.1.9 Data analysis

The number of letters written in two minutes for each sample was scored utilising the scoring criteria in the WRIT. The number of letters written for each paragraph were compared with one another on an excel spreadsheet in order to identify whether the paragraphs were comparable with one another or not. The speed of writing on the four samples was compared to that on the WRIT, which already has a confirmed writing speed in order to confirm that the four writing samples could be written within a similar time. In order to compare the speed of handwriting between all the samples, t-tests were used. The average number of letters that could be written in two minutes by the mainstream sample over the four samples from the Ekwall Reading Inventory was compared to those written in the WRIT sample. This was used for comparison with the speed of the learning disabled sample.

3.1.2 PART B : Norming of the measurement scale

Using the same writing samples, a writing legibility score sheet for grade two children was created.

3.1.2.1 Writing legibility score sheet

In order to assess the writing legibility of the learning disabled participants, a writing legibility score sheet was created. This score sheet used aspects of the THS, MHA and the WRIT which were discussed in Chapter two.

3.1.2.2 Pilot study

In order to establish if the criteria on the writing legibility score sheet were adequate, five participants of the mainstream sample from Part A were randomly selected. After plotting these scores on an excel spread sheet, it was found that a number of areas on the score sheet were not sensitive enough and required to be changed (APPENDIX J). After analysing this sample it was decided to alter the letter formation, letter spacing between lines, accuracy and general appearance categories, which are discussed below. (APPENDIX J and K) show the changes that were made between the first and last writing legibility score sheets.

Table: 3.1. The scores for each area of legibility utilising the first writing legibility score sheet in five mainstream children

	LETTER FORMATION				SPACING BETWEEN WORDS				LETTER SPACING BETWEEN LINES				ACCURACY				GENERAL APPEARANCE			
CHILD NUMBER	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	3	3	3	3	5	5	5	5	3	3	3	2	5	4	5	3	4	4	4	4
2	3	2	3	1	5	5	5	5	4	3	4	4	5	4	4	4	4	4	4	1
3	2	2	3	2	3	4	2	3	4	2	3	3	5	4	4	2	4	4	4	3
4	1	1	2	3	4	5	4	4	4	4	3	4	4	5	4	4	4	4	4	4
5	3	3	3	3	5	5	5	5	4	4	4	4	5	4	5	3	5	3	5	3
Mean	2.45				4.45				3.45				4.15				3.80			
SD	0.76				0.89				0.69				0.81				0.83			

The writing legibility score sheet consists of five areas. Each area is based on a 6-point scale (APPENDIX K).

3.1.2.3 Changes made to the writing legibility score sheet

Following the first analysis of the selected writing sample, it was decided to make the following changes to the score sheet:

- The letter formation section was altered from a 4-point scale from the Test of Handwriting Skills (THS) to a 6-point scale using aspects from both the THS and the MHA. This was done in order that it was consistent with all the other categories which were all comprised of a 6-point scale. The scoring criteria were made to be more specific and include aspects such as reversals. The child was also required to make errors on 10 or more letters to obtain a score of 1, whereas on the initial score sheet, the child could only make a single error to obtain a score of 1. This made the scoring more sensitive.
- The letter spacing between lines section was altered. A transparency was used, whereas previously the words that didn't touch the top line and the baseline were merely counted. This was altered in order to make the scoring more reliable and consistent.
- The accuracy section was altered to make it more specific i.e., to include an error score for adding or omitting capital letters.
- The general appearance section was altered in order to make it more specific incorporating aspects from the other four legibility criteria. This included particularly cross-outs, spacing in the lines and spacing between words.

3.1.2.4 Final writing legibility score sheet

The final legibility score sheet was therefore created. An explanation of the five areas of writing legibility that were assessed and the scoring criteria follows (APPENDIX K).

Letter formation

This category looks at the way each individual letter was formed including reversals, added or missing parts, spaces between letter parts and the direction of movements used to form the letters.

Scoring: Each letter in the handwriting sample was scored for formation on a sheet that was based on the Minnesota Handwriting Assessment (MHA). All letters from the paragraph were listed and a space provided for the marker to indicate if there was an error on a particular letter or not. The number of errors was then calculated (APPENDIX K and L1-L4).

Spacing between words

This refers to the space that exists between words.

Scoring: No spaces between words were counted and deducted from spaces between words in order to obtain an overall score. Points were not deducted for too large a space. If the participant did not leave any spaces between his/her words they obtained a score of 0. All words accurately spaced obtained a score of 5. Therefore the more words accurately spaced, the higher the score (APPENDIX K)

Letter spacing between lines

Each letter in the sample was measured for size.

Scoring: A transparency was placed over the writing sample. The blue line was marked in blue and a 1mm line on either side of the line marked in black. A letter scored an error point if it went beyond the outer 1mm line or did not reach the inner 1mm line. The number of letters that were too large or too small was calculated. This was then used as the criteria in establishing the six-point scale (APPENDIX K and M).

Accuracy

This measures the accuracy with which the child copies the written passage. It incorporates capital letters, omissions and cross-outs.

Scoring: A letter or word that was not an exact copy of the paragraph, earned an error point for accuracy. The errors were compared against the criteria of the score sheet (APPENDIX K).

General appearance:

This aspect looks at the overall impression of the child's writing.

Scoring: Aspects such as untidiness, omissions, spacing and cross-outs were all scored against the criteria listed on the score sheet (APPENDIX K).

3.1.2.5 Data analysis

Once the score sheet was finalised, all 24 mainstream participants' writing samples were evaluated using the new writing legibility score sheet to establish norms for legibility of handwriting of this sample. This was necessary so that a comparison could be drawn between the mainstream participants and the learning disabled participants in terms of the five legibility areas. All these scores were plotted on an excel spreadsheet and statistically analysed. Descriptive statistics were used to determine the means and standard deviations. Two-tailed t-tests were also used to obtain significance values when comparing the legibility of each sample with the others.

3.2 Results - Phase One

The results of phase one includes the demographics of the mainstream sample as well as the measurement of their writing speed and legibility scores on five paragraphs which they copied.

3.2.1 Sample demographic information

The demographic information of the 24 mainstream children is presented below:

3.2.1.1 Age

All 24 children in the sample were grade two learners and between the ages of 8 to 9 years.

3.2.1.2 Gender

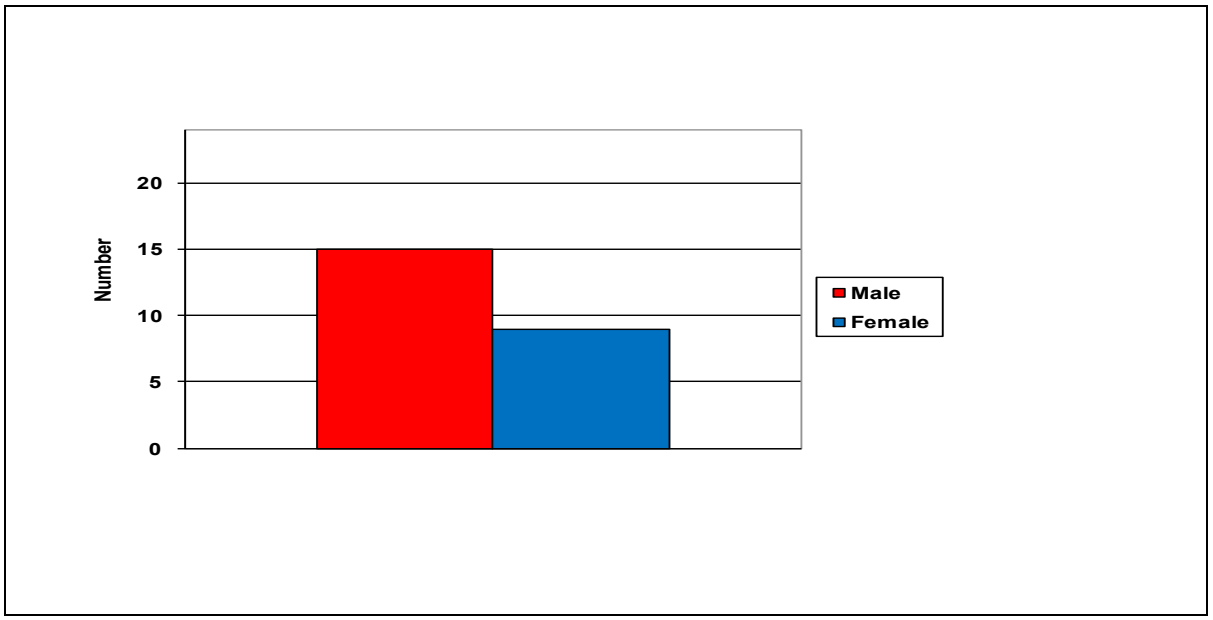


Figure 3.2 The gender distribution among the mainstream sample

Figure 3.2 above illustrates the gender distribution of the 24 mainstream children that were assessed. Of the 24 children, 15 were male and nine were female.

Table 3.2 Means, standard deviations and t-tests for writing speed in terms of gender

	Mean	Standard Deviation
Male n= 15	49.68	11.62
Female n=9	45.33	15.88
		p value Gender
		p≤ 0.49

Table 3.2 indicates that there was no significant difference between males and females in terms of their writing speed although males wrote faster in a two minute writing test.

3.2.1.3 Handedness

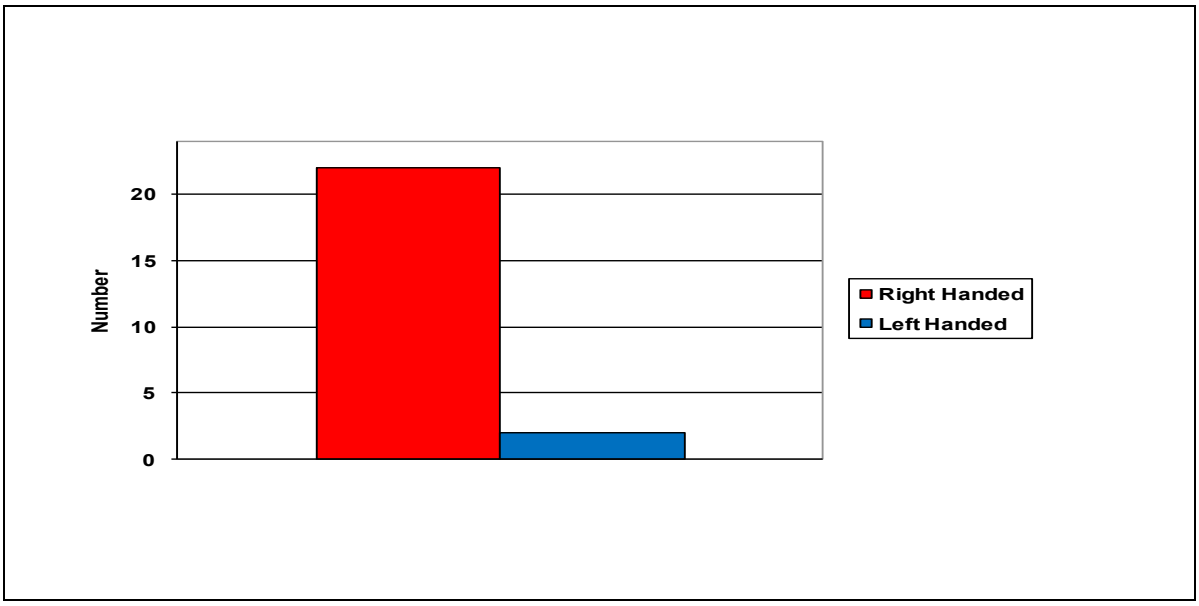


Figure 3.3 Handedness distribution among the mainstream sample

The handedness of the mainstream children was collected as they were completing the writing samples. Figure 3.3 above illustrates the handedness distribution among the 24

mainstream children that were tested. It shows that 22 of the children were right handed and two were left handed.

Table 3.3 Means, standard deviations and t-test for writing speed in terms of handedness.

	Mean	**Standard Deviation**
Right-handed n=22	47.73	13.42
Left-handed n =2	51.63	14.32
		p value Handedness
		p≤ 0.77

Table 3.3 indicates that there was no significant difference between right-handers and left-handers in terms of their writing speed. Left-handers wrote faster. The left-handed group was comprised of only two children.

3.2.1.4 Pencil grasp

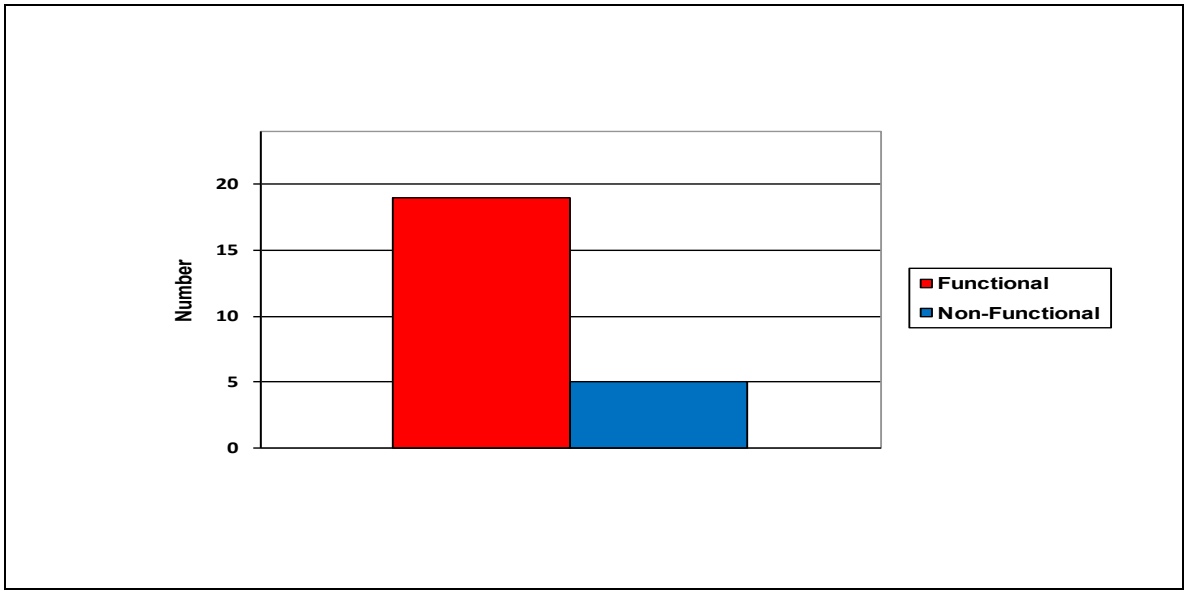


Figure 3.4 Pencil grasp distribution among the mainstream sample

The pencil grasps of the children were evaluated according to two categories: functional and non-functional (APPENDIX N). Pencil grasps with an open web-space, such as a dynamic tripod and quadrupod grasp, were considered as functional. Pencil grasps with a closed web-space, such as a thumb-wrap, were considered as non-functional. Figure 3.4 above illustrates the pencil grasps of the 24 mainstream children. Of the 24 children, 19 were observed to have a functional pencil grasp and 5 had a non-functional pencil grasp.

Table 3.4 Means, standard deviations and t-test for writing speed in terms of pencil grasp

	Mean	**Standard Deviation**
Functional n=19	50.32	11.53
Non Functional n=5	39.45	17.01
	t test	**p value Grasp**
		p≤ 0.24

Table 3.4 indicates that there was no significant difference between children with a functional and non-functional grasp in terms of their writing speed. Individuals with a functional grasp wrote faster.

3.2.2 Writing speed in the mainstream sample

Writing speed was assessed for the mainstream sample over four trials using paragraphs from the Ekwall Reading Inventory (APPENDICES C1-C4) and a fifth trial which used a standardised writing measure from the WRIT (Appendix A).

Table 3.5 Means and standard deviations for the mainstream sample for writing speed trials and comparison of the first and last trial scores

Trial 1 (Sample A) Mean (SD)	**Trial 2 (Sample B) Mean (SD)**	**Trial 3 (Sample C) Mean (SD)**	**Trial 4 (Sample D) Mean (SD)**	**Mean Total Mainstream Sample Mean (SD)**
42.08 (13.66)	46.66 (13.13)	49.95 (15.33)	53.50 (16.08)	48.93 (12.73)
	Difference Trial 1-2 p≤ 0.002	**Difference Trial 2-3** p≤ 0.13	**Difference Trial 3-4** p≤ 0.07	

Significant p≤ 0.05

It can be seen in Table 3.5 and 3.6 that the participants' handwriting speed increased over the four trails (Sample A-D) with more letters being written each time.

Trial 1-4 were the paragraphs (Sample A-D) to be compared. There was an initial significant increase in the speed of the mainstream participants' writing from the first trial to the second trial after which although the writing speed did increase with each trial, the increase was not significant. It can be seen that although the participants' speed

increased as they moved from trial to trial, multi-factorial analysis was not considered as the trend in terms of increased speed from the first to the last paragraph was clear.

Table 3.6 Means and standard deviations for the mainstream sample for WRIT paragraph speed trial and comparison to other trial scores

WRIT **Mean (SD)**	54.95 (13.61)
Difference WRIT and Trial 1	p≤ 0.000
Difference WRIT and Trial 2	p≤ 0.000
Difference WRIT and Trial 3	p≤ 0.06
Difference WRIT and Trial 4	p≤ 0.62

Significant p≤ 0.05

A 5th writing speed trial was done using the paragraph from the WRIT test. The trend of increased speed was evident in this last writing speed test as well and when compared to the initial paragraphs in the first two trials, the writing in the WRIT paragraph was significantly faster (p≤ 0.000), whereas this was not true for the last two trials. The average number of letters that should be written in two minutes on the WRIT test according to the authors is 49-58 letters per two minutes. This is slightly faster than the mean writing speed obtained for the mainstream sample.

3.2.3 Writing legibility in the mainstream sample

The writing legibility of the mainstream participants was assessed using the five factors on the writing legibility score sheet (APPENDIX K).

Table 3.7 Means and standard deviations for the mainstream sample for writing legibility trials and comparison of the first and last trial scores

Legibility	Trial 1 Mean (SD)	Trial 2 Mean (SD)	Trial 3 Mean (SD)	Trial 4 Mean (SD)	Mean Total Mainstream sample Mean (SD)	Difference first and last trial
Letter formation	3.75 (0.94)	3.71 (0.86)	3.75 (0.90)	3.58 (0.93)	3.70 (0.76)	0.17 NS
Spacing between words	4.37 (1.05)	4.29 (1.12)	4.25 (1.22)	4.29 (1.19)	4.30 (1.09)	0.08 NS
Letter Spacing between lines	3.58 (1.79)	3.17 (1.88)	3.33 (1.79)	2.96 (1.68)	3.26 (1.56)	0.63 NS
Accuracy	4.33 (0.92)	3.79 (1.22)	3.96 (0.91)	3.58 (0.93)	3.92 (0.58)	0.83 p≤ 0.01
General Appearance	4.00 (1.41)	3.67 (1.31)	3.67 (1.24)	3.29 (1.20)	3.66 (1.15)	0.71 p≤ 0.05

Significant p≤ 0.05

NS= not significant

Table 3.7 indicates a change in legibility scores from the first to the last trials in the mainstream sample with accuracy and general appearance both showing a significant decrease. Therefore the mainstream participants wrote more quickly over the four trials but the accuracy and general appearance of their handwriting showed a significantly decrease.

3.2.4 Summary

Four paragraphs from the Ekwall Reading Inventory (APPENDICES C1-C4) and a fifth from a standardised writing measure i.e. the WRIT (Appendix A) were used to assess the number of letters grade two children at a mainstream school could write in two minutes. There was a clear trend of increased speed in writing over the five paragraphs with a significant decrease in accuracy and general appearance of the writing in relation to the legibility scores. The mean legibility scores in the five aspects were also established for the mainstream sample.

The average writing speed and legibility scores of the mainstream sample were established. These scores were compared to those of the learning disabled sample in order to determine if there was a significant difference between the two groups of children in terms of their writing speed and five areas of writing legibility. The scores were then used to ascertain whether assistive devices do facilitate in enhancing learning disabled children's writing speed and legibility.

CHAPTER 4

Methodology and Results - Phase Two

4.1 Phase Two: Comparison of learning disabled and mainstream children in terms of handwriting speed and legibility and the effectiveness of various assistive devices on the handwriting speed and legibility of learning disabled children.

Phase two of the study aimed to compare learning disabled and mainstream children in terms of their handwriting speed and five areas of writing legibility established in phase one. It also assessed the effectiveness of various assistive devices on the learning disabled sample's handwriting speed and legibility. Since the learning disabled sample are known to have handwriting problems the researcher wanted to assess the immediate influence of assistive devices on writing. Phase two meets objectives c and d.

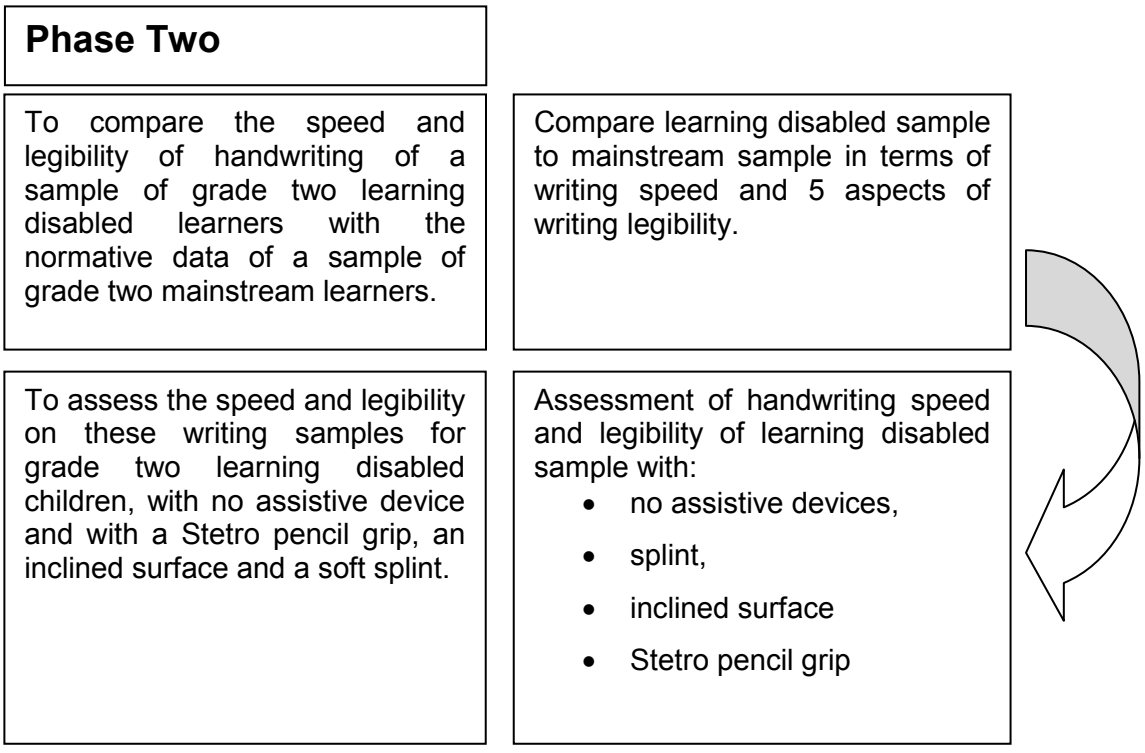


Figure 4.1 The components and method flow of the second phase of the study

Phase two of the study aimed to:

- compare the speed and legibility of handwriting of a sample of grade two learning disabled learners with the normative data of a sample of grade two mainstream learners in order to determine the sensitivity of the measure in determining handwriting problems in the absence of an assistive device.
- assess the speed and legibility on these writing samples for grade two learning disabled children, with no assistive device and with a Stetro pencil grip, an inclined surface and a soft splint in order to assess the effect of the immediate influence of assistive devices on writing speed and legibility.

4.1.1 Research design

The research was quantitative and the format followed a cross-sectional design with each child acting as his/her own control. The purpose of a cross-sectional design is to compare different groups of participants with regard to an immediately measureable dependent variable [157]. The data for this study was collected by observing each participant on one specific day so there would be no dropout of participants when carrying out the writing samples. Descriptive research was utilised to describe specific characteristics of the research participants including gender, handedness and pencil grasps[157], which are all factors that affect handwriting. Multivariate statistics were used which deal with more than one dependent variable simultaneously [157]. Two-tailed t-tests were used when comparing the speed and legibility of the handwriting using different assistive devices and when comparing the mainstream and learning disabled samples in terms of writing speed and legibility. Descriptive statistics were used to determine the means and standard deviations.

4.1.2 Population

The population included grade two learning disabled learners in Johannesburg.

4.1.3 Selection of participants

Convenience sampling was used to obtain the sample for this phase of the study. Convenience sampling is the most readily used method in research in terms of obtaining participants [158]. The study involved the use of easily available participants at two conveniently located remedial schools[158]. As participants agreed to take part in the study, they were enrolled until the required sample number was reached.

The children all receive therapeutic services (occupational therapy and/or speech therapy intervention). The gender and ethnicity of the participants, their co-existing diagnoses i.e. Aspergers, ADHD and their first language were not regarded as a selection criterion. The sample consisted of 22 children.

In order to see the sample size calculation refer to chapter 3, section 3.1.1.3. which indicates an optimal sample size of 23 .

4.1.3.1 Inclusion criteria

- Age: All children were in grade two and between the ages of 7 to 9 years.
- Gender: Both males and females were included
- Handedness: Both right- and left-handed individuals were included.

4.1.3.2 Exclusion criteria

Those individuals whose parents did not give consent and who themselves did not give assent were excluded from the study.

4.1.4 Research location

The research was carried out at two remedial schools. These schools were selected as they are two of the private remedial schools in Johannesburg. The schools were Crossroads School and Japari School. Permission to carry out the research was granted

by the principals of the schools (APPENDIX B). These schools admit children from a variety of socio-economic groups, races and cultures.

4.1.5 Measurement technique

The paragraphs that were used in phase one of the study that were deemed to be comparable in terms of their readability and length , as they were from the same source, were utilised . These included the four samples from the Ekwall Reading Inventory Second Edition (APPENDIX C1-C4). An analysis of the handwriting speed and legibility of the mainstream participants indicated significant differences over the samples; which appeared to be due to accommodation and fatigue. Therefore these four paragraphs were used; however three to four minute breaks were given between the writing samples in order to control for these problems. Mean values for speed and legibility from the four samples were used in order to compare the mainstream and learning disabled participants.

When assessing the writing legibility of the learning disabled participants, the finalised writing legibility score sheet was used (APPENDIX K).

4.1.6 Control of variables

- Ergonomic factors were controlled where possible such as desk height, chair height and background noise.
- It was ensured that the inclined surfaces were all placed at the same distance on the table, that the Stetro pencil grips were placed on the same point on the pencils, and that the splints were all applied adequately and in a uniform manner.

4.1.7 Ethical considerations

This study obtained ethical approval from the University of Witwatersrand Ethics Committee for Research on Human Subjects (APPENDIX D). A parent information sheet (APPENDIX O) and a letter of informed consent (APPENDIX P) was sent to the parents

of all the grade two learners at the two selected remedial schools. Verbal/ written assent was obtained from the participants themselves (APPENDIX Q). Both the parents and students indicated their consent by signing the relevant forms. A standard introduction was read out loud to each participant before beginning the assessments so they were aware of the procedure and exactly what was required of them during this phase of the research (APPENDIX R). Participants were free to withdraw from the study voluntarily at any time without consequences and request feedback on the outcomes of the study.

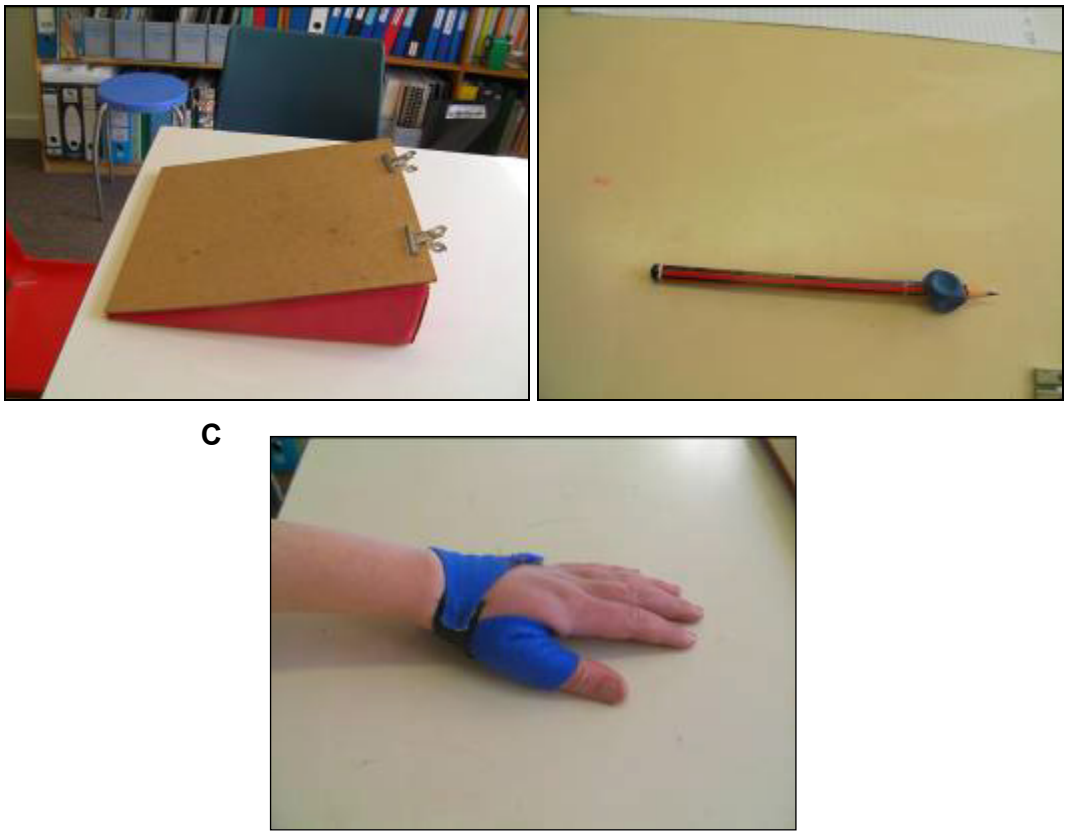
4.1.8 Data collection

The research was carried out during school hours, at a time deemed appropriate by the teacher, or during the participant's allocated therapy time. All the learning disabled participants were individually assessed in the occupational therapy departments of the remedial schools. All the participants receive therapy services and therefore the occupational therapy department was a familiar environment to them. The research assistants who carried out the writing evaluations were occupational therapists at the specific schools where the participants were assessed and therefore known to the participants. The researcher completed the observations during the administration of the writing samples and completed the scoring of each writing sample.

Each participant completed all four writing samples on one allocated day. The participants were given three to four minute breaks between samples to provide time for:

- the assistive devices to be correctly placed i.e. the inclined surface to be placed in the correct position on the desk (Figure 4.2:A), the Stetro grip to be placed at the correct point on the pencil (Figure 4.2:B) and the splint to be applied adequately (Figure 4.2:C).
- the paper on which the samples had to be written to be placed uniformly according to the handedness of the child.
- each paragraph to be read out loud to the participant by the research assistant to ensure that they were aware of what they were writing.
- the participant to have a short break i.e., three to four minutes.

A B



C

Figure 4.2 The assistive devices and their application

A: Inclined surface positioned on the desk.
B: Stetro pencil grip on HB pencil.
C: Splint on left-handed child.

The participants were provided with a sharp HB pencil, and Irish lined paper on which to write. They were not allowed to use an eraser. The paper had dot-dot bunny log indicated in the margin (APPENDIX S) which is the spacing method used by the schools and is therefore familiar to the participants. A margin cue was not given to the mainstream participants as they are felt to demonstrate less visual perceptual difficulties and are routinely able to space their work on the Irish lines. Learning disabled children; however frequently have spatial difficulties and this was thus controlled for by using this spacing method.

The standard and very specific instructions, used in phase one, were read to the learning disabled participants by the research assistants. These were as follows: 'When I say **go** I

want you to copy this piece until I say **stop.** It is not a race, don't scribble. Just write as you usually do in class.' They were also instructed to cross out the word with one line if they made a mistake (APPENDIX I).

The writing samples were done by research assistants who are practicing occupational therapists registered with the HPCSA. Two occupational therapists were responsible for carrying out the writing samples. These occupational therapists were chosen as they were practicing occupational therapists at the schools that were participating in the study. The occupational therapists are paediatric occupational therapists working at remedial schools and are therefore familiar with aspects of handwriting, handwriting difficulties and the carrying out of writing samples. They had previously carried out writing samples on grade two children on multiple occasions. The carrying out of these specific writing samples was explained to them prior to the evaluations and specific instructions typed up for them (APPENDIX I).

The samples were given to all the learning disabled participants in the same order: Sample **A**, **B**, **C** and lastly, **D**. The order of the assistive devices was however varied by the research assistants from child to child. These were varied according to a specific pattern.

Table 4.1 Sample of the order in which the assistive devices were presented.

CHILD NUMBER	ORDER OF ASSISTIVE DEVICES	Key
CHILD 1	N I P S	
CHILD 2	S N I P	**N=** No assistive device
CHILD 3	P S N I	**I** = Inclined surface
CHILD 4	I P S N	**P=** Stetro pencil grip
		S= Splint

The writing samples were analysed by the researcher. During the performance of the writing samples, the researcher was an observer and was therefore present throughout the assessments. The reading of the paragraphs, timing of the samples and giving of instructions was, however all done by the research assistants in order that the researcher could be an observer. The researcher ensured that the inclined surfaces were all placed at the same distance on the table (Figure 4.2: A), that the Stetro pencil grips were placed

on the same point on the pencils (Figure 4.2: B), and that the splints were all applied adequately and in a uniform manner (Figure 4.2: C). The researcher also ensured that the paper and written paragraphs were placed on the table in a uniform manner according to the handedness of the child. Even though the paper was placed directly in front of the participant, this is not the natural writing position for most children. The participant was therefore allowed to turn the paper as he/she felt necessary when performing the writing samples i.e., many of the right-handed students chose to slant their paper slightly to the left, so the right corner of the paper was up. While observing the writing samples note was taken of factors such as the participant's handedness and their pencil grasp without the aid of assistive devices. The following factors were also observed:

- Postural control: including the child's ability to maintain an upright posture whilst seated at their desk, postural adjustments.
- Fine-motor: including in-hand manipulation skills.
- Bilateral integration and motor planning: such as stabilising the paper with the non-preferred hand; planning, executing and sequencing letter forms.
- Kinaesthetic awareness: including pencil pressure.
- Visual perceptual components: including spacing their letters accurately in the lines; leaving spaces between their words (position in space); discrimination between similar letters (form constancy); copying letter by letter versus whole words or groups of words (visual memory).

Each participant involved in the study received a reference number/code in order to maintain their anonymity e.g., 01, 02. This ensured that the researcher could not be influenced when scoring the samples. The writing samples using the various assistive devices were collected by the research assistants and placed in separate envelopes. Each one was individually coded according to the specific assistive device i.e. inclined surface =I Stetro pencil grip=P, splint =S and no assistive device=N. This code was hidden from the researcher i.e., a flap was stuck over the number and code. Therefore the researcher was unable to identify which assistive device was utilised for a particular writing sample when initially analysing the data.

4.1.9 Data analysis

Once the data was collected it was analysed according to the type of assistive device under a number of headings. The legibility and speed for writing completed with each assistive device was compared to the norms established for the mainstream sample.

4.1.9.1 The following were analysed:

- Writing sample without the aid of assistive devices (Figure 4.3).
- Writing sample using a Stetro pencil grip (Figure 4.4).
- Writing sample using an inclined surface (Figure 4.5).
- Writing sample using a soft splint (Figure 4.6).

These categories were analysed according to writing speed, letter formation, spacing between words, letter spacing between lines, accuracy and general appearance. These categories were developed by the researcher. Descriptive statistics were used for the demographics of the sample. Multivariant analysis was used to compare all the different scores for handwriting obtained with the assistive devices and with no assistive devices, for speed and legibility. A p value of ≤ 0.05 was considered as significant.

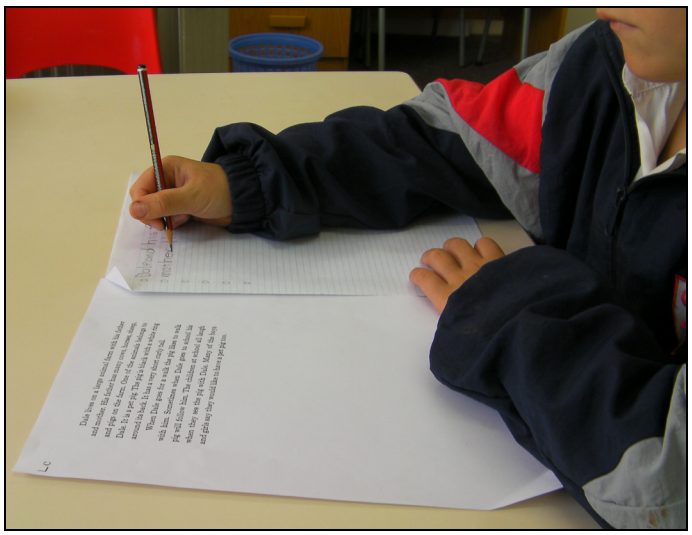


Figure 4.3 A child completing a writing sample the aid of assistive devices

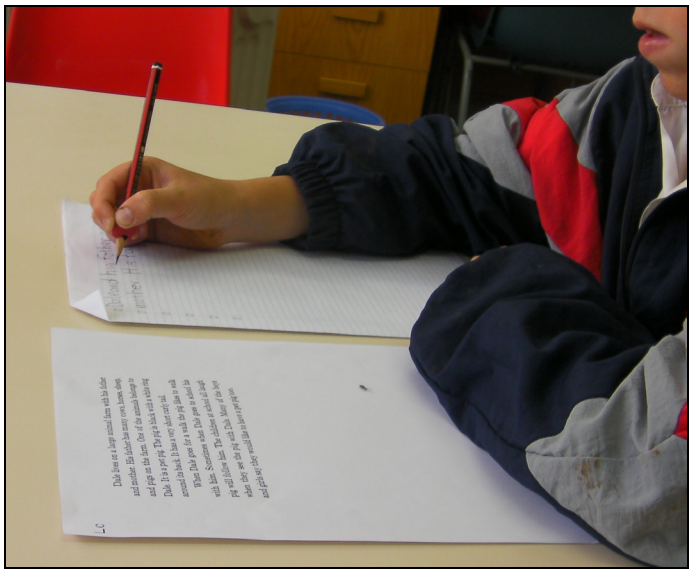


Figure 4.4 A child completing a writing sample with the aid of a Stetro pencil grip

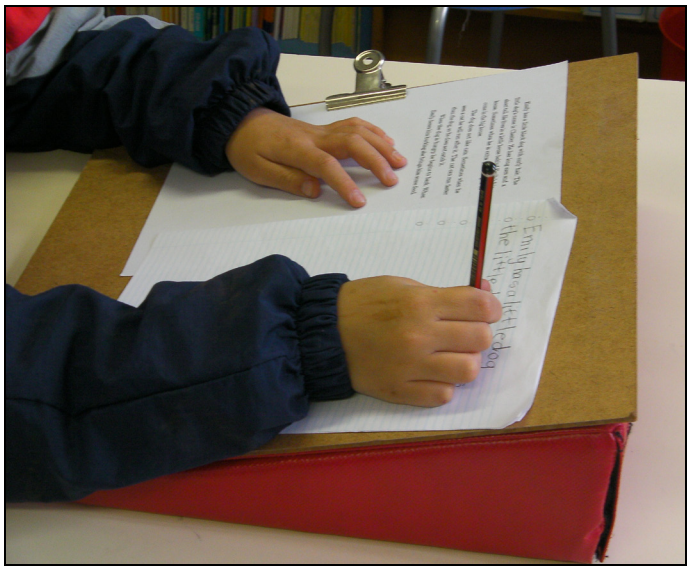


Figure 4.5 A child completing a writing sample with the aid of an inclined surface

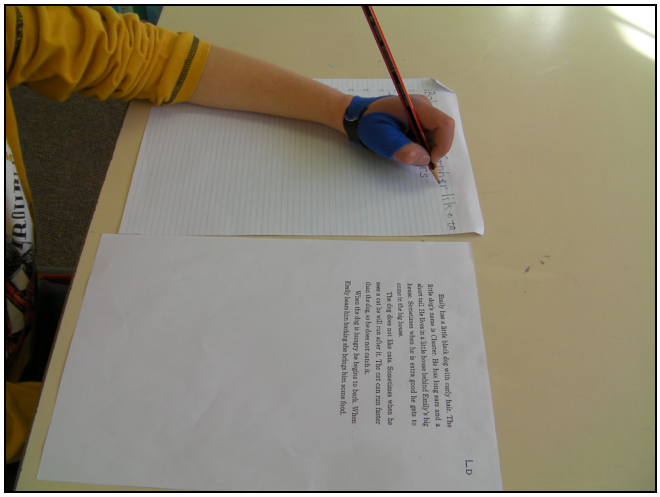


Figure 4.6 A child completing a writing sample with the aid of a soft splint

The learning disabled and mainstream participants' scores were all plotted on an excel spreadsheet and then compared according to writing speed and the five aspects of legibility specified in the writing legibility score sheet: letter formation, spacing between words, letter spacing in the lines, accuracy and general appearance. As the mainstream participants did not complete the writing samples using any assistive devices, their samples could only be compared to the learning disabled participants' scores where they were not using any assistive devices (Table 4.2). These scores were statistically analysed using two-tailed t-tests as well as descriptive statistics to determine the means and standard deviations.

The assessment forms were individually coded by the research assistant e.g. 01, 02 in order to ensure confidentiality. The different modalities of assessment were coded by the research assistants i.e. inclined surface (I), splint (S) Stetro pencil grip (P) and no assistive device (N).

4.2 Results

The results of phase one includes the demographics of the learning disabled sample as well as the measurement of their writing speed and legibility scores on four paragraphs. One with no assistive device which was compared to the mean scores found for the mainstream sample. The handwriting speed and legibility of the learning disabled sample with no assistive device was then compared to the same criteria when writing with three different assistive devices, namely: a Stetro pencil grip, inclined surface and a splint.

4.2.1 Sample demographic information

4.2.1.1 Age

The children tested ranged between 8 and 9 years.

4.2.1.2 Gender

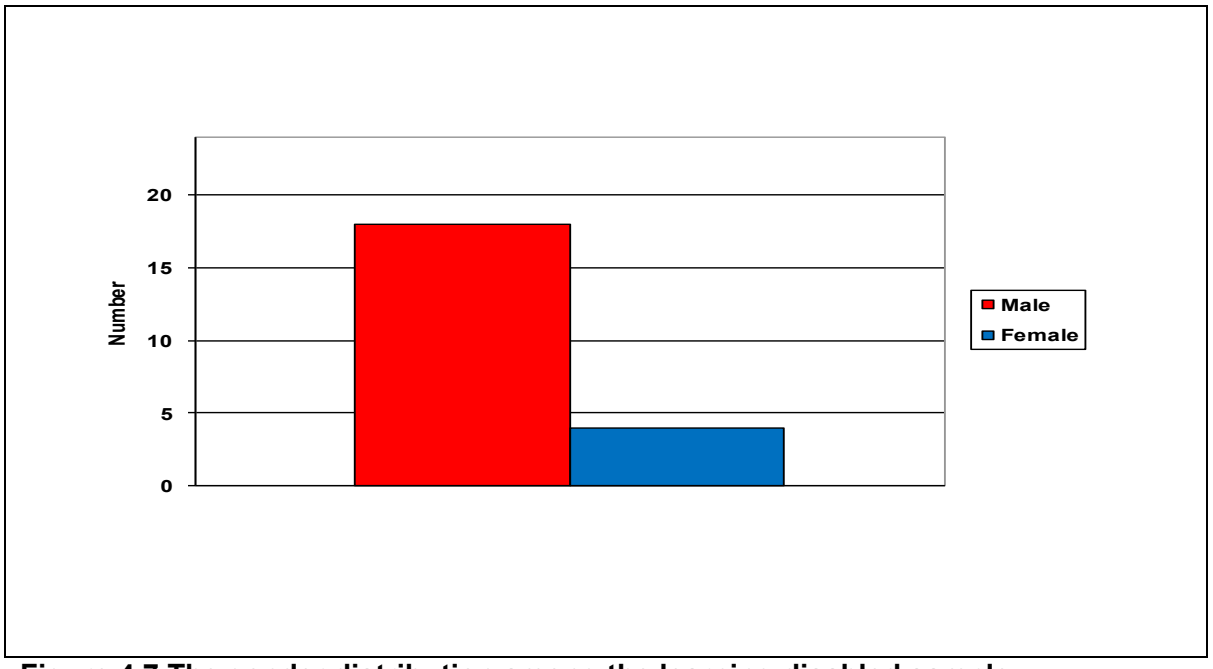


Figure 4.7 The gender distribution among the learning disabled sample

As can be seen in Figure 4.7, the sample of learning disabled participants consisted of 18 males and four females. In terms of gender there was no significant difference between the learning disabled and mainstream samples (p≤ 0.06).

4.2.1.3 Handedness

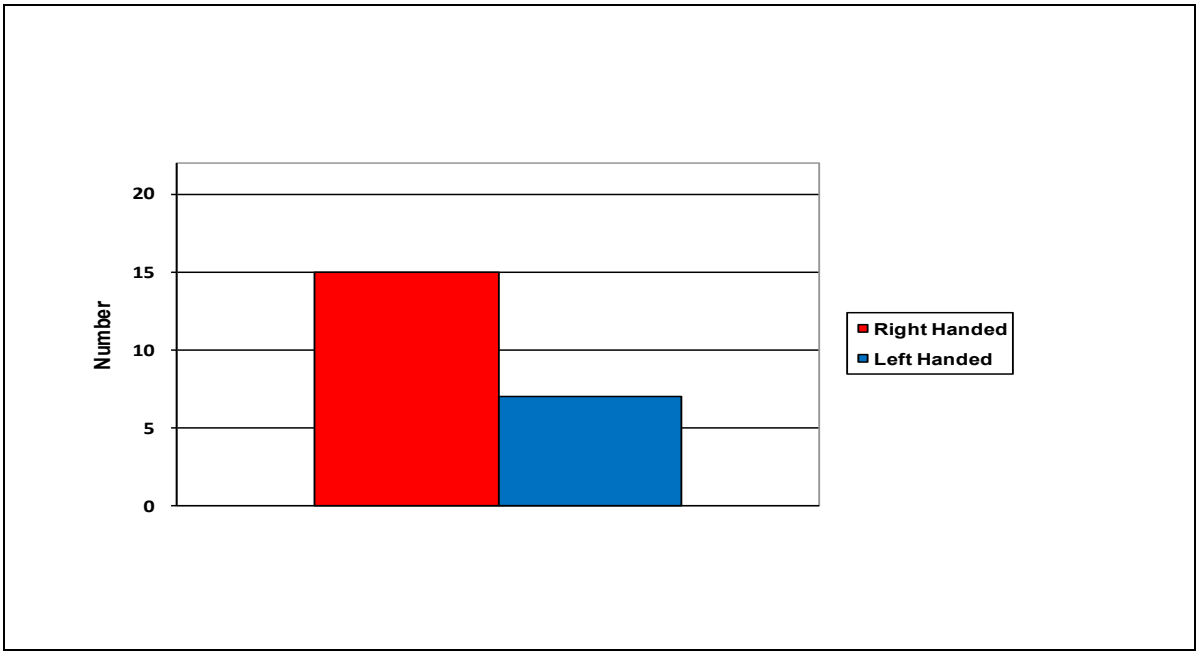


Figure 4.8 The handedness distribution among the learning disabled sample

Figure 4.8 illustrates that the learning disabled sample consisted of fifteen participants that were right-handed and seven that were left-handed. In terms of handedness there was a significant difference between the learning disabled and mainstream samples (p≤ 0.03).

4.2.1.4 Pencil grasps

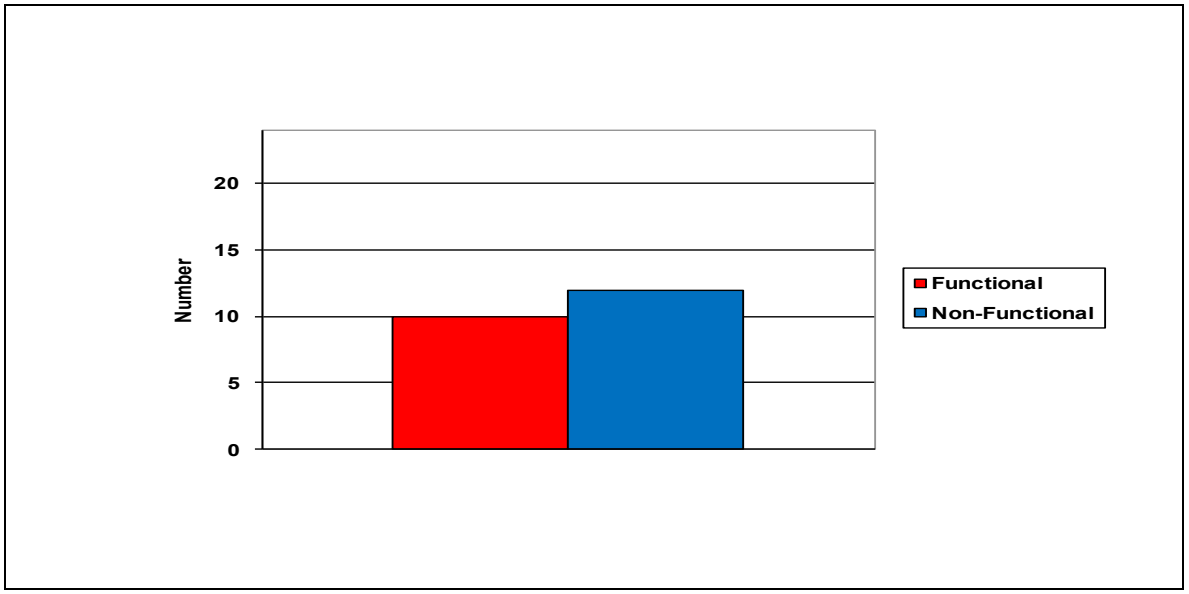


Figure 4.9 The pencil grasps among the learning disabled sample

While the participants were completing the writing samples without the aid of any assistive devices, their pencil grasps were recorded. The pencil grasps were evaluated according to two categories: functional and non-functional (APPENDIX N). Pencil grasps with an open web-space such as a dynamic tripod and quadrupod grasp were considered as functional. Pencil grasps with a closed web-space such as a thumb-wrap were considered as non-functional. As can be seen in Figure 4.9, of the 22 children in the sample, 10 were found to have a functional pencil grasp, and 12 were found to have a non-functional pencil grasp. In terms of pencil grasp there was a significant difference compared to the mainstream sample ($p \leq 0.04$).

Table 4.2 Comparison of mainstream sample and learning disabled sample without assistive devices for writing speed and legibility

	Speed	**Legibility**				
		Letter formation	Spacing between words	Letter Spacing between lines	Accuracy	General Appearance
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Mainstream Sample	48.05 (13.25)	3.70 (0.91)	4.30 (0.91)	3.26 (0.91)	3.92 (0.57)	3.66 (1.29)
Learning Disabled Sample None	48.09 (11.06)	2.73 (0.98)	4.14 (1.28)	2.73 (1.24)	3.95 (0.95)	2.86 (1.08)
p value	p≤ 0.99 NS	p≤ 0.001 p≤ 0.05	p≤ 0.42 NS	p≤ 0.17 NS	p≤ 0.73 NS	p≤ 0.002 p≤0.05

Significant p≤ 0.05

NS= not significant

Table 4.2 illustrates that there are significant differences between the mainstream and learning disabled sample for normal writing with regard to letter formation and general appearance only.

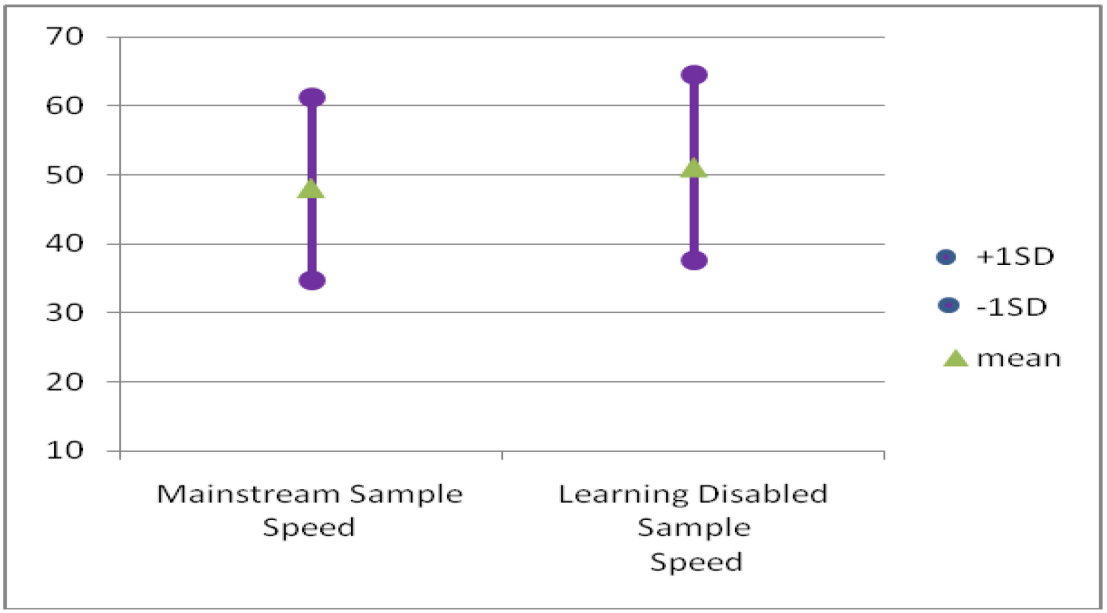


Figure 4.10 Comparison of writing speed between the mainstream sample and learning disabled sample with no assistive devices

Figure 4.10 illustrates that the speed of the learning disabled sample was slightly better than the mainstream sample when no assistive devices were utilised and the standard deviation was smaller. The writing speed of the mainstream sample was however affected by the performance over the five trials. The learning disabled participants' writing samples using no assistive devices were in a random sequence.

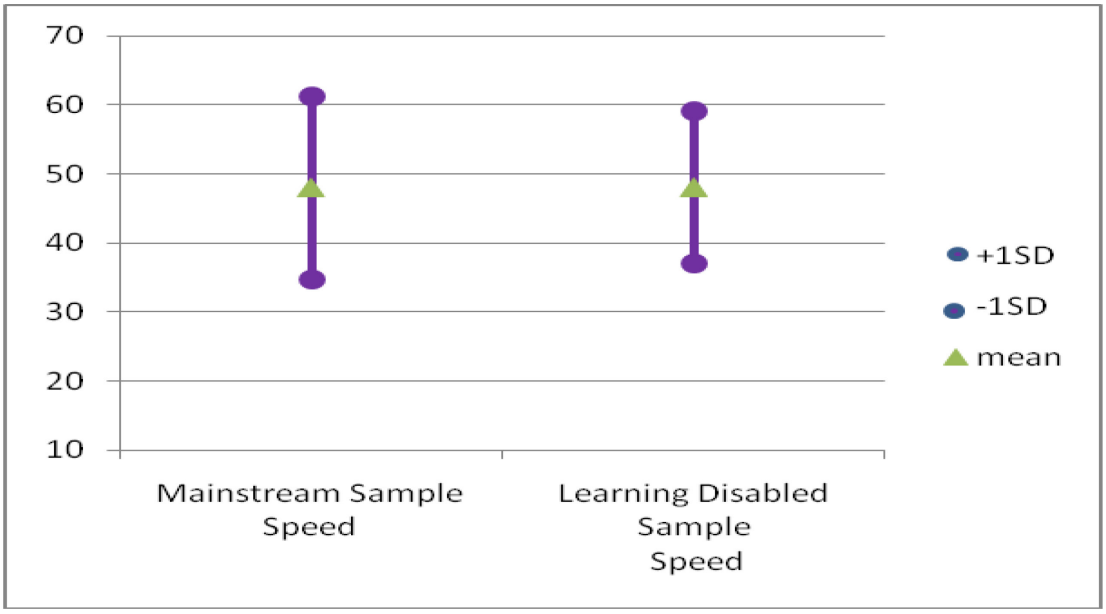


Figure 4.11 Comparison of the overall means for writing speed between the mainstream sample and learning disabled sample

There was no significant difference between the overall mean of the learning disabled participants (across all four writing samples) and the mainstream participants as illustrated in Figure 4.11 and Table 4.2 ($p \leq 0.99$).

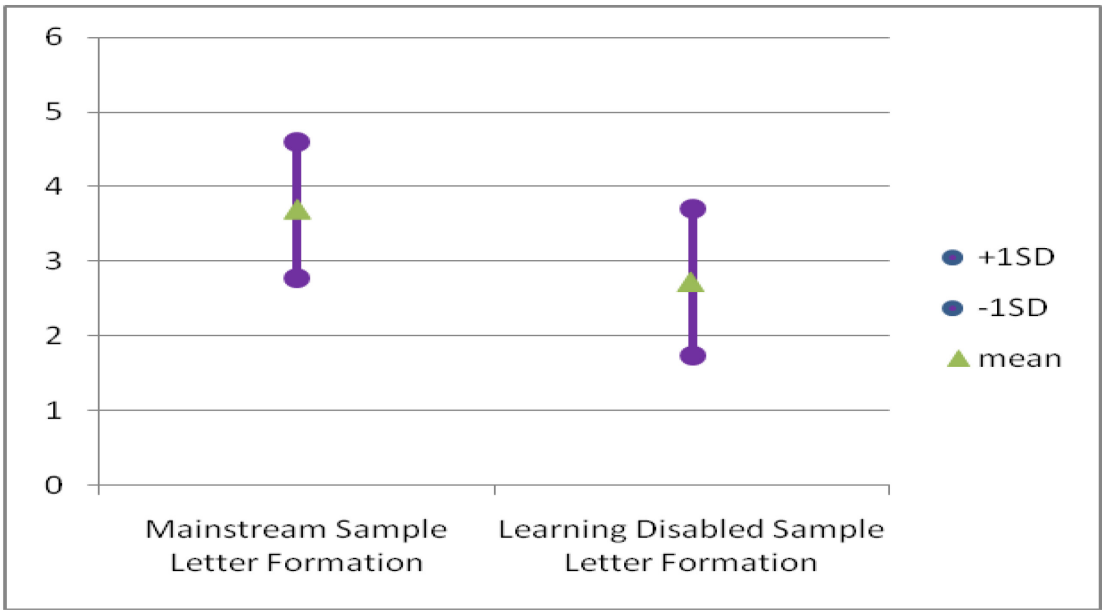


Figure 4.12 Comparison of letter formation between the mainstream sample and learning disabled sample with no assistive devices

As can be seen in Figure 4.12 and Table 4.2 when no assistive devices were utilised, the learning disabled sample scored significantly worse than the mainstream sample in terms of their letter formation (p≤ 0.001).

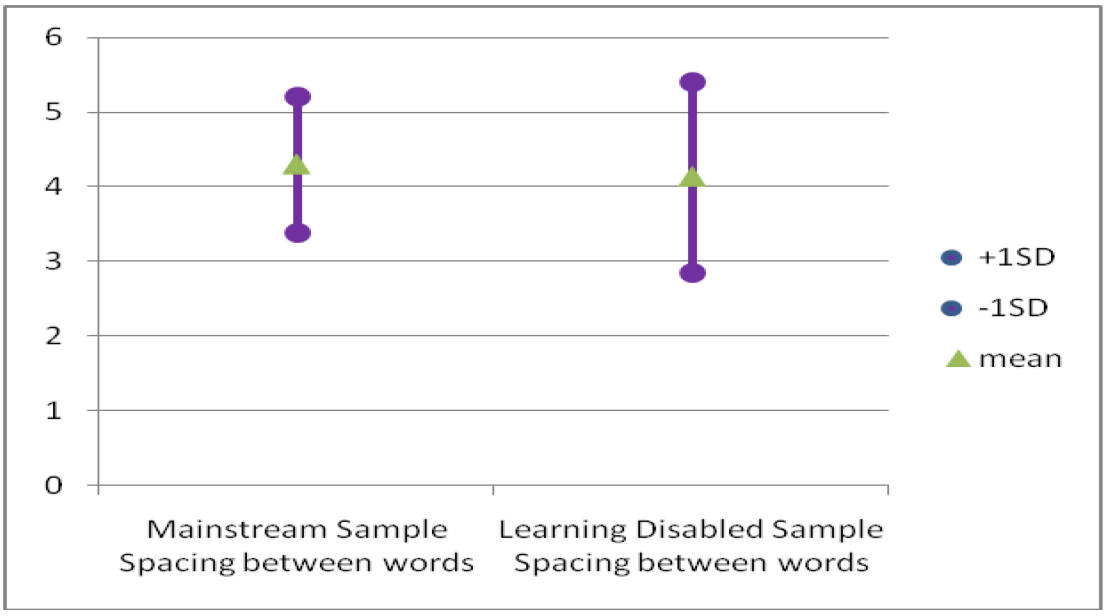


Figure 4.13 Comparison of spacing between words between the mainstream sample and learning disabled sample with no assistive devices

As illustrated in Figure 4.13 and Table 4.2, there was no significant difference (p≤ 0.42) between the learning disabled and mainstream samples in terms of their spacing between words. However the scores were more varied among the learning disabled sample.

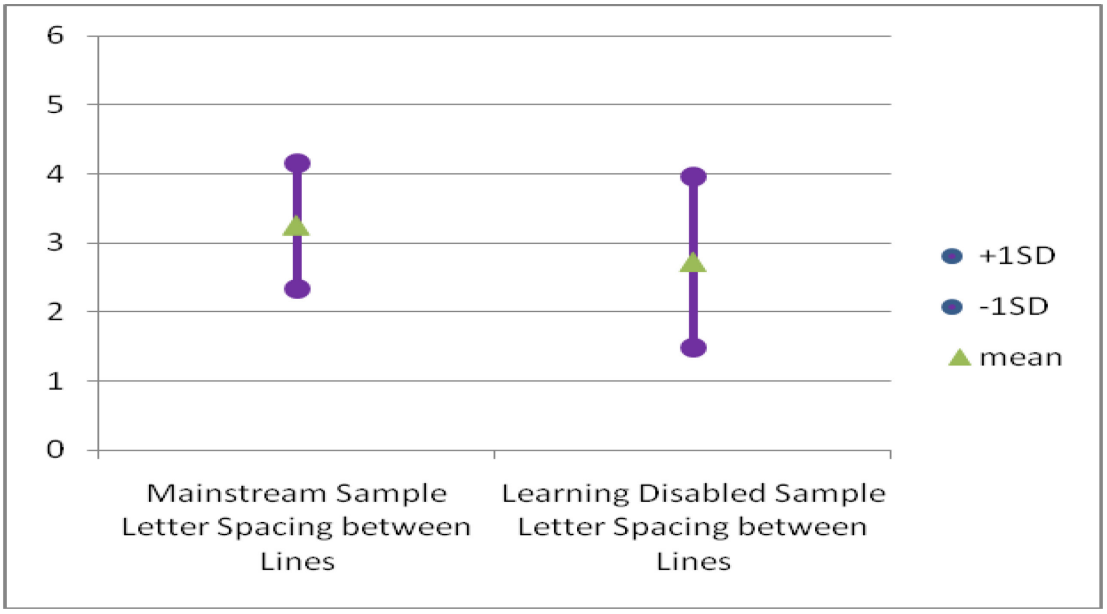


Figure 4.14 Comparison of letter spacing between lines between the mainstream sample and learning disabled sample with no assistive devices

As illustrated in Figure 4.14 and Table 4.2, there was no significant difference ($p \leq 0.17$) between the learning disabled and mainstream samples in terms of letter spacing between lines. However the scores varied more in the learning disabled sample.

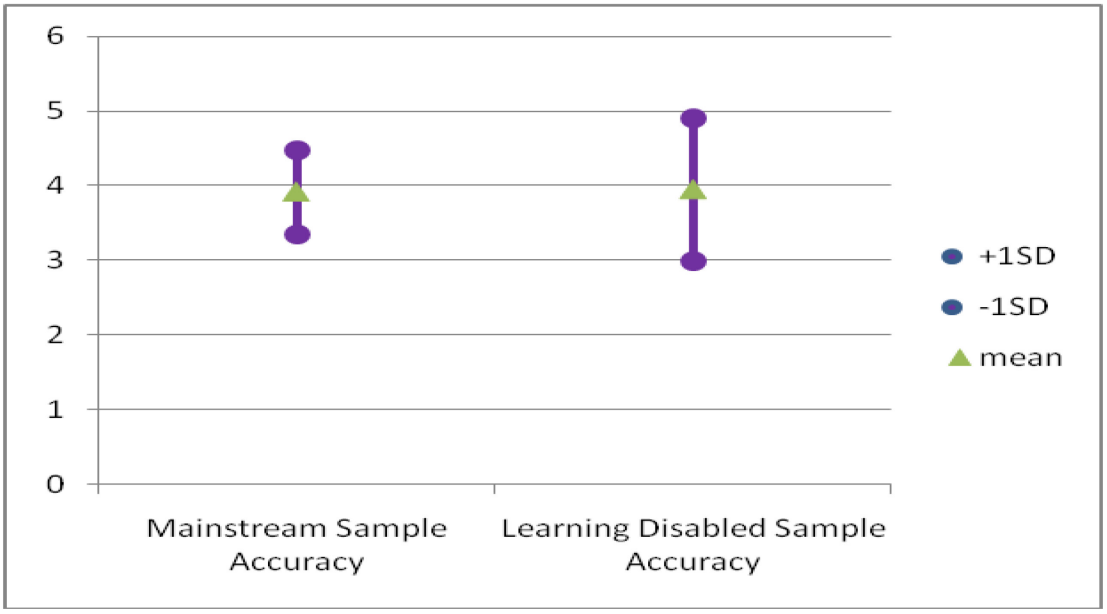


Figure 4.15 Comparison of accuracy between the mainstream sample and learning disabled sample with no assistive devices

As illustrated in Figure 4.15 and Table 4.2 there was no significant difference between the learning disabled and mainstream samples in terms of accuracy (p≤ 0.73); however the scores varied far more in the learning disabled sample.

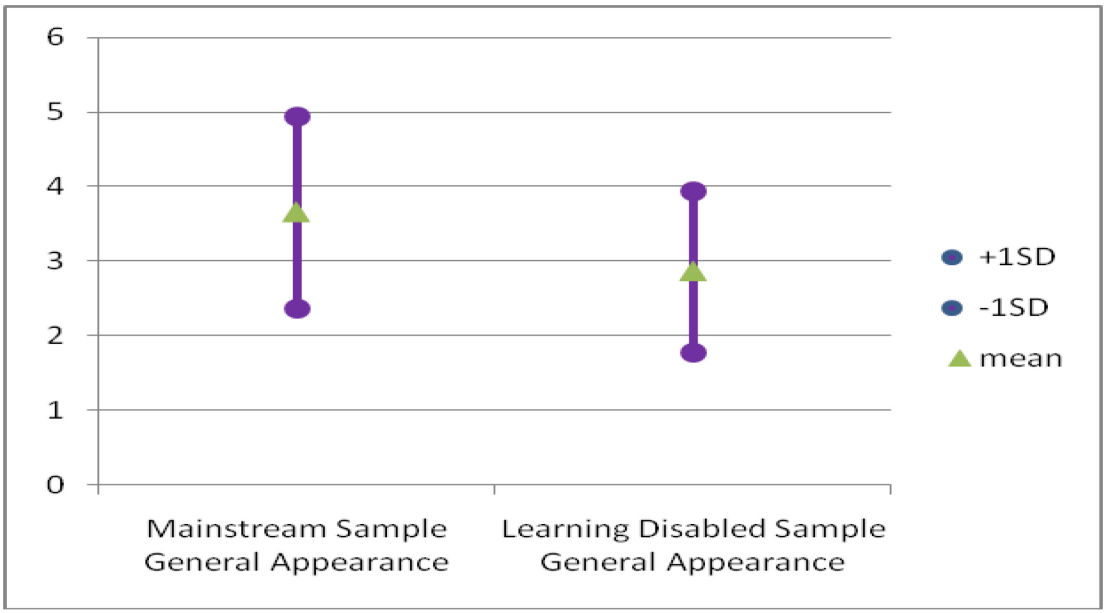


Figure 4.16 Comparison of general appearance between the mainstream sample and learning disabled sample with no assistive devices

As illustrated in Figure 4.16 and Table 4.2, when no assistive devices were utilised, the learning disabled sample scored significantly worse than the mainstream sample (p≤ 0.002) with regard to general appearance.

Table 4.3 Means and standard deviations for learning disabled sample for writing speed and legibility with and without assistive devices.

	None Mean (SD)	**Stetro Pencil grip** Mean (SD)	**Splint** Mean (SD)	**Inclined Surface** Mean (SD)
Speed	51.09 (13.46)	45.54 (9.39)	47.22 (11.97)	48.50 (13.65)
Legibility				
Letter formation	2.73 (0.98)	2.91 (0.87)	2.95 (0.95)	2.73 (0.98)
Spacing between words	4.14 (1.28)	4.00 (1.51)	3.91 (1.27)	4.09 (1.15)
Letter Spacing between lines	2.73 (1.24)	2.64 (1.14)	2.95 (1.05)	2.50 (1.37)
Accuracy	3.95 (0.95)	4.18 (1.01)	3.91 (1.15)	3.86 (1.04)
General Appearance	2.86 (1.08)	2.77 (0.87)	2.64 (0.95)	2.55 (0.91)

It must be noted that changes in time over the four trials were not analysed in Table 4.3 as the assistive devices were applied in a random order to prevent the problems with time and accuracy changes that were observed in the mainstream sample.

Table 4.4 t-test results for writing speed in learning disabled sample for all assistive devices and no assistive device

Assistive Device	Significance Level
none to Stetro pencil grip	p≤ 0.02
none to splint	p≤ 0.01
none to incline	p≤ 0.12
Stetro pencil grip to splint	p≤ 0.35
Stetro pencil grip to incline	p≤ 0.23
splint to incline	p≤ 0.39

Significant p≤ 0.05

NS= not significant

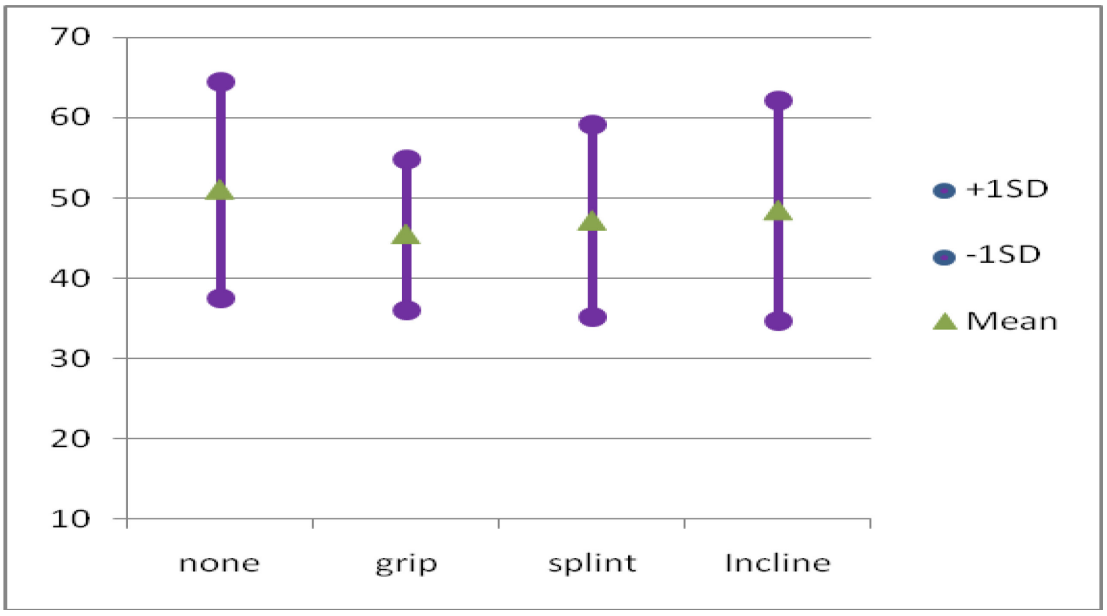


Figure 4.17 Comparison of writing speed with different assistive devices for the learning disabled sample

As can be seen Table 4.4, there was a significant difference in terms of the assistive devices and no assistive device with regard to writing speed. Both the splint (p≤0.02) and Stetro pencil grip (p≤ 0.01) showed a significant difference when compared to no assistive device in terms of hampering the participant's writing speed. When looking at the means in Figure 4.17 and Table 4.3, it is of clinical relevance that the mean was highest when no assistive devices were used.

Table 4.5 t-test results for writing legibility in learning disabled sample for all assistive devices and normal writing.

	None to Stetro Pencil Grip	None to Splint	None to Inclined Surface
Letter formation	p≤ 0.26	p≤ 0.17	p≤ 1.00
Spacing between words	p≤ 0.45	p≤ 0.13	p≤ 0.77
Letter spacing between lines	p≤ 0.67	p≤ 0.38	p≤ 0.26
Accuracy	p≤ 0.42	p≤ 0.89	p≤ 0.77
General appearance	p≤ 0.58	p≤ 0.06	p≤ 0.05

Significant p p≤ 0.05

NS= not significant

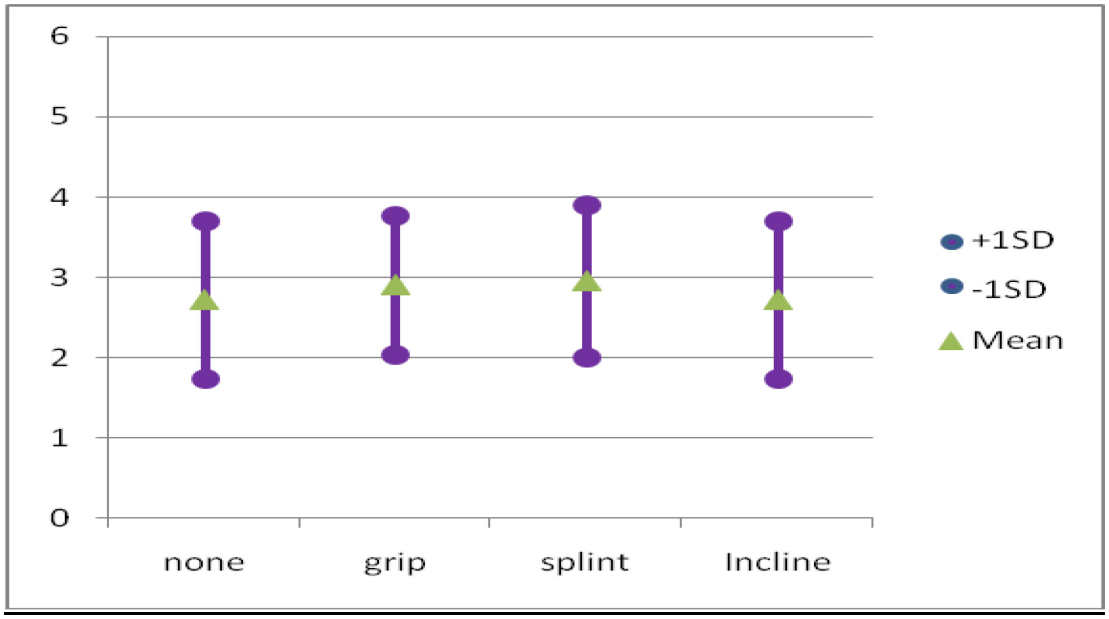


Figure 4.18 Comparison of letter formation with different assistive devices for learning disabled sample

No significant differences are evident between the assistive devices and normal writing in terms of their impact on letter formation as demonstrated in Table 4.5. When looking at the means in Figure 4.18 and Table 4.3 it is of clinical relevance that the children tended to improve slightly when both the Stetro pencil grip and splint were applied. The scatter of scores is fairly similar between assistive devices indicated by a small standard deviation.

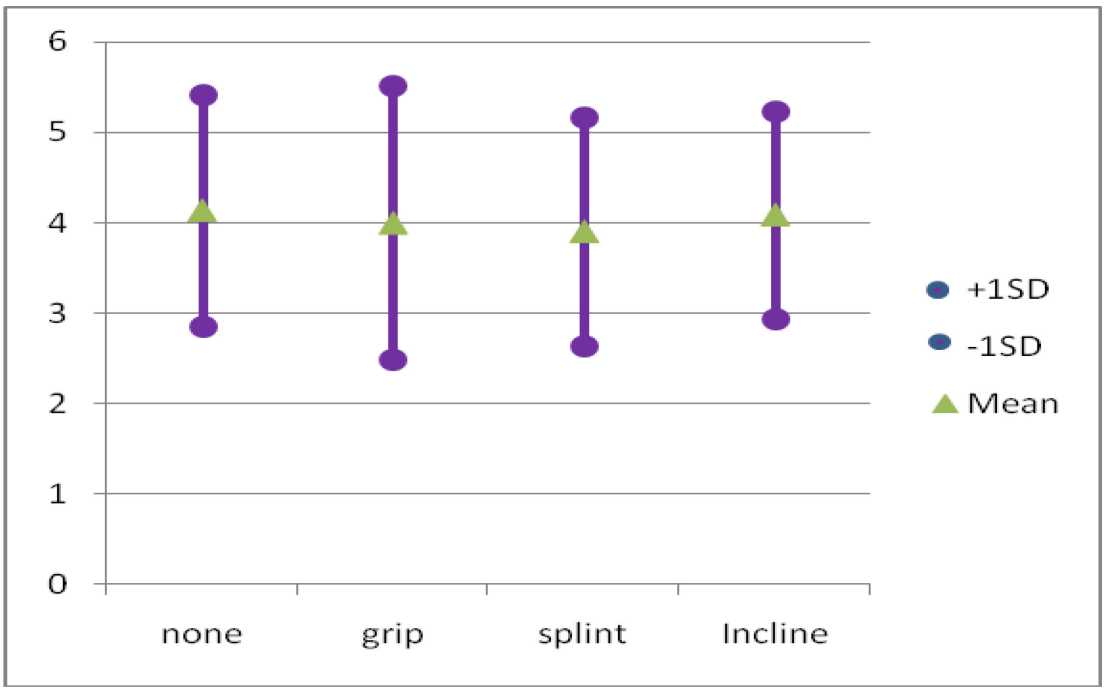


Figure 4.19 Comparison of spacing between words with different assistive devices for learning disabled sample

As demonstrated in Table 4.5, no significant differences are evident between the assistive devices and normal writing in terms of their impact on spacing between words. Figure 4.19 shows that the children's spacing between words was worse when they were wearing the soft splint. The largest scatter among scores is evident when the children were using the Stetro pencil grip.

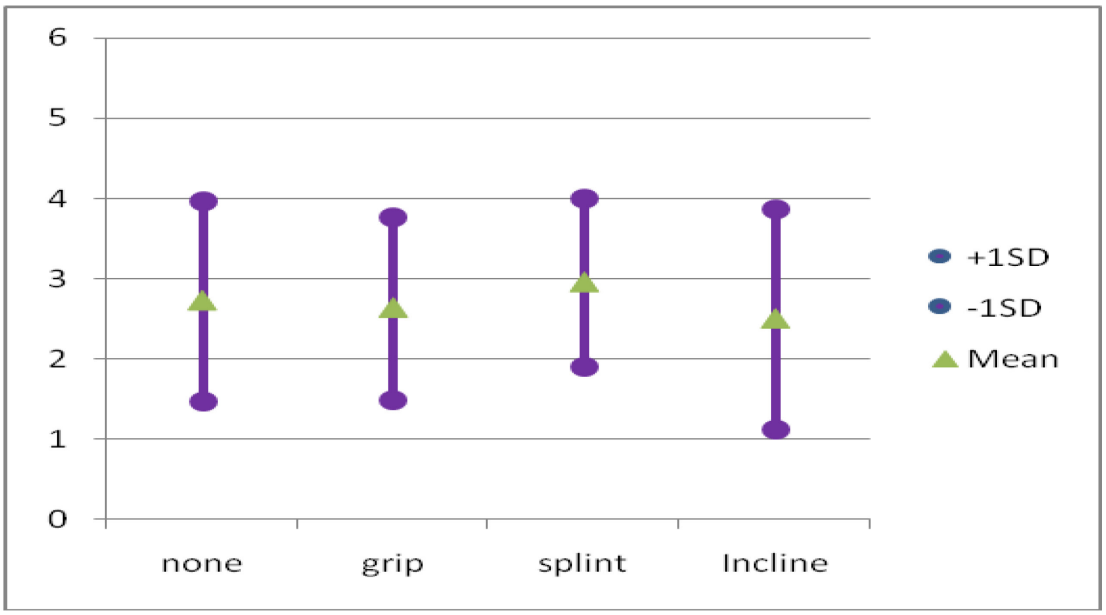


Figure 4.20 Comparison of letter spacing between lines with different assistive devices for learning disabled sample

No significant differences are evident between the devices themselves and to normal writing with regard to letter spacing between lines (Table 4.5). When analysing the scatter in Figure 4.20 one can see that the widest scatter was evident when the children used the incline surface. The means as illustrated in Figure 4.20 and Table 4.3 also demonstrate that the children performed worst when the Stetro pencil grip and inclined surface were used, but the participant performed better when the splint was on then when no assistive device was used.

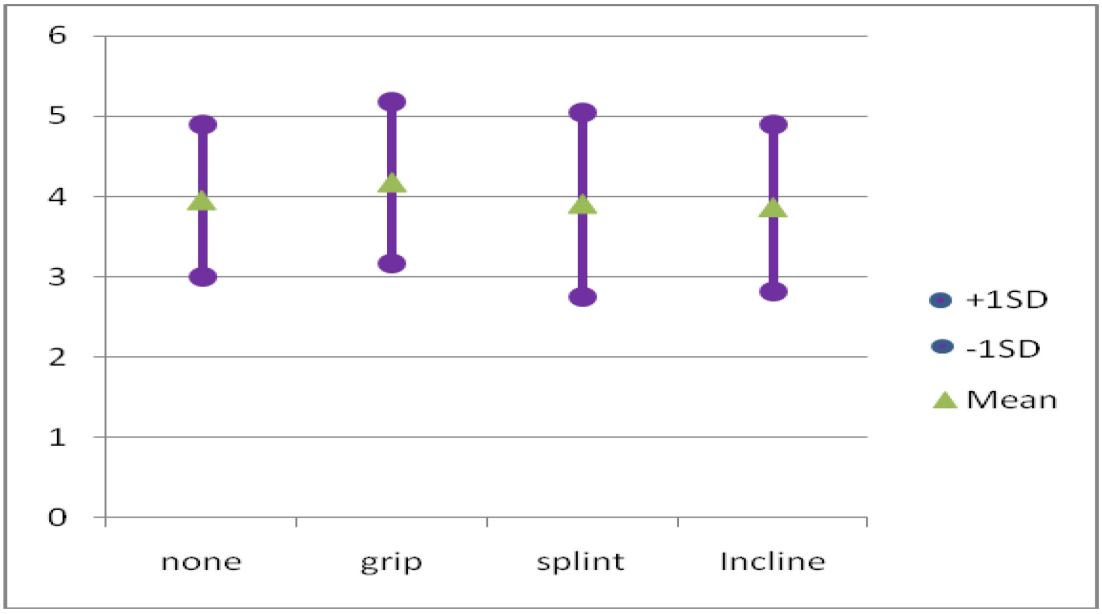


Figure 4.21 Comparison of accuracy with different assistive devices for learning disabled sample

As illustrated in Figure 4.21 the widest scatter of scores was evident when children were using the splint. The splint and incline were seen to impact negatively on the children's accuracy whereas the Stetro pencil grip impacted positively. No significant differences are evident between the devices themselves and to normal writing with regard to accuracy as demonstrated in Table 4.5.

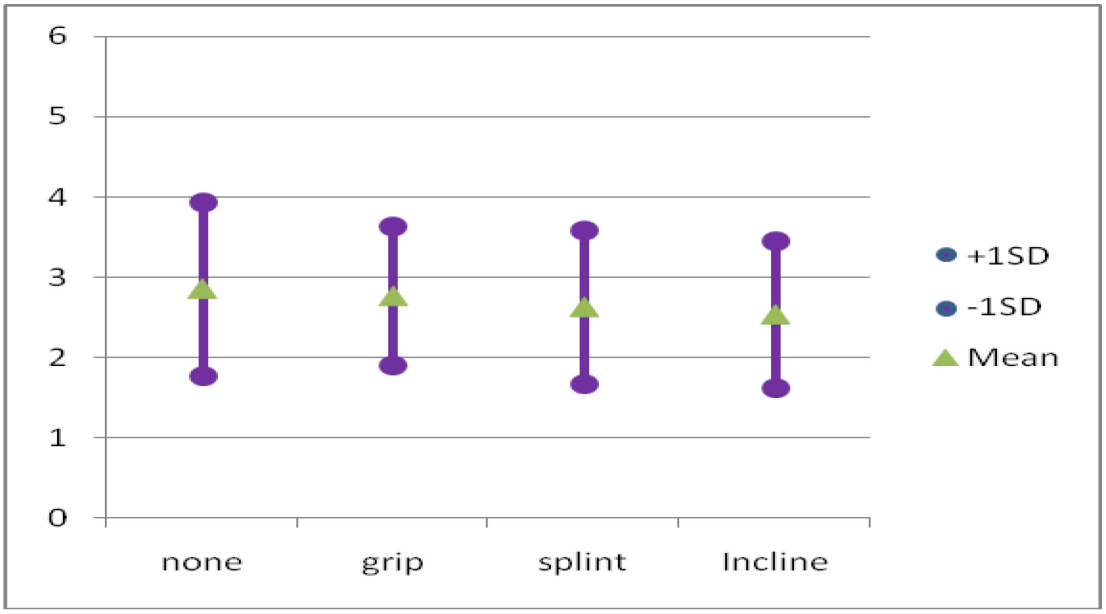


Figure 4.22 Comparison of general appearance with different assistive devicesfor learning disabled sample

As demonstrated in Table 4.5, a significant difference was evident between the normal and inclined surface means ($p \leq 0.05$) in favour of no assistive devices. A significant difference was also demonstrated between the Stetro pencil grip and inclined surface means ($p \leq 0.02$). Therefore this shows that general appearance was made significantly worse when an inclined surface was utilised. The widest scatter was evident for general appearance when the children were not using any assistive devices.

The notes taken of the participants during the performance of the writing samples (APPENDIX T) were evaluated according to the following categories:

- Postural control: Many of the learning disabled participants tended to slouch in their chairs and rest with their hands on their heads. They also tend to rock in their chairs and wrap their feet around the chair legs.
- Fine-motor: Some of the learning disabled participants tend to lock their fingers into extension or fist their fingers into flexion. They demonstrated impaired in-hand manipulation skills.
- Bilateral integration and motor planning: Certain children struggled to plan their writing on the page and form the letters using the correct sequence of movements. Many tended to rest with their heads on their hands rather than stabilising the paper.
- Kinaesthetic awareness: Certain participants exerted reduced or increased pressure on their pencils. They struggled to form their letters properly and to space their letters accurately in the lines.
- Visual perceptual components: Reversals were evident. Poor visual memory was apparent when copying the writing samples as some were only able to revisualise one letter at a time. They struggled with their spacing between letters and words and between the writing lines.

Note was taken of how the different assistive devices impacted on the above components, and differences that were apparent between the mainstream and learning disabled participants with regard to the above criteria. These will be discussed in Chapter 5.

4.2.2 Summary

The findings showed that when comparing the writing speed and legibility of the mainstream and learning disabled participants, there were only significant differences with regard to general appearance and letter formation. The various assistive devices had different impacts on writing speed and the five areas of legibility. Some were found to enhance certain areas of writing such as letter formation when the Stetro pencil grip and splint were used. Other aspects of writing such as general appearance were hampered. No significant differences were found between the Stetro pencil grip, inclined surface and splint in terms of writing speed or any of the five areas of legibility.

CHAPTER 5

Discussion

This discussion will consider the demographics of the samples as well as the difference in pencil grasps between the groups. The writing assessment used will be evaluated before a comparison of the legibility and speed of handwriting between the mainstream and learning disabled samples is considered. Handwriting speed and legibility will also be discussed with regard to the extrinsic and intrinsic occupational therapy components observed, as well as in relation to the assistive devices used with the learning disabled sample.

5.1 Demographics of the sample groups

Age was controlled for in the study so no differences between the groups existed for this factor. When comparing the mainstream and learning disabled samples in terms of gender there was no statistically significant difference ($p \leq 0.06$). There were; however, more males in the learning disabled sample. This is congruent with international literature which suggests that learning disabilities are more common in males than females [1]. In schools and clinics the ratio of males to females with learning disabilities is 4:1 [1]. According to studies by Phipps and Clarizio gender differences were found in terms of learning difficulties, with far more boys than girls being referred for special education placement [2,3]. The finding of this study was possibly due to the small number of participants and convenience sampling.

A statistically significant difference in the handedness between the mainstream and learning disabled samples was demonstrated ($p \leq 0.03$) with a larger percentage of left-handed children being in the learning disabled sample. This reflects the findings in a study by Zelnick and Goez who documented that left handedness is more prevalent in individuals with learning disabilities, dyslexia, autism and developmental coordination disorder than in the general population [4].

A statistically significant difference in terms of pencil grasps was demonstrated between the learning disabled and mainstream samples ($p \leq 0.04$) in this study, with the learning disabled sample demonstrating more atypical grasp patterns. This was unexpected as research suggests that children with and without handwriting difficulties exhibit a variety of pencil grasps [139]. This study categorised pencil grasps with an open web-space as functional and those with a closed web-space as non-functional, which was based partly on a classification by Selin [85]. This was a limitation of the study as the pencil grasps should have been classified further as demonstrated in the literature. The researcher should possibly have commented on the participants' pencil pressure and the placement of their fingers along the shaft of the pencil. Schneck and Henderson classified pencil grasps according to primitive, transitional and mature grips [136]. Benbow and the WRIT classified pencil grasps into six inefficient and three efficient grasps [47]. When analysing the pencil grasps more closely it was apparent that a variety of typical and atypical pencil grasps were evident among both the learning disabled and mainstream samples.

A more detailed comparison between the pencil grasps for both samples would have allowed the relationship between the different pencil grasps and writing speed and legibility to have been further investigated. This is a limitation of the study. In future studies, each individual's specific pencil grasp without the aid of assistive devices could be compared to their speed and legibility scores in order to ascertain if their pencil grasp impacted on these factors.

This relationship between the individual's pencil grasp and the speed and legibility of their writing is still not fully understood and conflicting information regarding this is evident in the literature.

Ziviani & Elkins (1986) and Sassoon et al.(1986) found no relationship between a child's handwriting speed and their pencil grasp [29,131]. This confirmed the findings of Rubin and Henderson (1982) [18]. These findings were congruent with this study. No significant difference ($p \leq 0.24$) was found between the mainstream participants with a functional and non-functional grasp in terms of their writing speed (Table 3.4). However this may possibly be due to the small sample size.

Schneck et al. found a statistically significant difference in the handwriting performance of children with mature pencil grasps versus those with immature grasps [123]. The differing

views of these studies could be based on a number of factors including the length of the writing samples, the complexity of the writing task, the age of the participants and the ways in which the differing pencil grasps were described and measured.

5.2 Measuring tool

The writing legibility score sheet had a number of strengths and limitations.

In terms of the examiner responsible for carrying out the evaluation, many of the handwriting assessments that are presently used are not specific in terms of who is certified to administer them i.e., a teacher or therapist [67] and whether the individual who is administering the assessment requires preparation before carrying out the assessment [67]. The method ensured that the writing samples were carried out by experienced occupational therapists, familiar with handwriting difficulties and the carrying out of handwriting assessments. A limitation of the study was that the occupational therapists administering the writing samples to the learning disabled sample had not practiced using this specific writing assessment before. However, because the instructions were very specific and due to the fact that the researcher was analysing the results this did not have an impact on the scores.

There are also differing views regarding which factors most contribute to the legibility or readability of a child's handwriting as well as the most reliable means of measuring these factors [20,21,67]. Much of the literature suggests that the most significant criteria contributing to writing legibility include: size (height, width), slant, spacing (spaces between letters/words), the degree of line straightness, shape (letter form and shape) and the general appearance of the writing [69]. The five categories utilised in the writing legibility score sheet were based on a number of existing handwriting evaluations, the MHA [65], THS [64] and WRIT [47] and incorporated many of the above-mentioned criteria.

The scoring scales for many handwriting evaluations also differ [24]. Grading criteria that is ambiguous may impact on the reliability of the scale [24]. With regard to the writing legibility score sheet, the researcher made all the scales 6-point scales in order that they were uniform and therefore comparisons could be drawn between the different areas of legibility.

A limitation of the study was that the 6-point scale for spacing between words was not sensitive enough. When looking at other tests, an exact measurement of the space between the words was given [65]. The spaces between letters should have been included as a criteria as this impacts on the general appearance of a child's writing, evident in other tests such as the MHA [65] and the Test of legible Handwriting (TOLH) . This is a limitation of the study.

Certain writing scales do not take into account the complexity of the tasks on the child's handwriting performance [70]. Existing scales require the child to copy shapes, letters and words [71]. Other assessments require the child to copy a paragraph [61,72] or write letters and/or numbers from memory [72]. Evaluation measures also exist that require the child to write a 20 minute essay about a specified topic [73]. The literature suggests that the complexity of the writing task impacts on the speed and legibility [38,50]. Studies by Graham and Weintraub and Martlew have shown that handwriting performance is strongly influenced by the demands of the writing task [38,50].

The researcher therefore chose to use a near-point copying task in this study in order to measure the components of speed and legibility. The literature suggests that children score higher in terms of speed and legibility on a copying task versus a narrative task [36,37]. Younger students often require focusing and increased attention to be paid to aspects such as generating ideas and planning, particularly when composing [35-37]. This impacts on their ability to write neatly as they are often focusing considerably on these other areas [36]. This is particularly evident with regard to learning disabled children [9]. In choosing a copying task the researcher wanted to eliminate these interfering factors so the participants could focus solely on the speed and legibility of their writing. Copying a passage can be seen as a reflection of the speed with which an individual is able to carry out the physical components of writing [47]. Also the participants were familiar with copying tasks as they are typical scholastic tasks required of grade two children. An assumption of this study was that the paragraphs that were used from the Ekwall Reading Inventory-Second Edition and the WRIT were unfamiliar to both the mainstream and learning disabled participants.

The literature suggests that children's scores for speed and legibility differ with regard to the instructions given [24]. Specific and standard instructions regarding the exact method of

administration are also not always available which may impact on the results [68]. A child may perform very differently when asked to write '*as quickly as possible without stopping for corrections*' [70,74] versus a child who is instructed to '*write as you usually do when you try to write well*' [21]. The nature of the instructions given may impact on a child's handwriting performance [24]. When assessing both samples of participants, the instructions given were very specific as follows: '*It is not a race, don't scribble. Just write as you usually do in class*' in order to ensure that the participants knew exactly what to do and what was required of them. The participants were given an opportunity to ask questions if they required and instructions were repeated if necessary.

In certain assessments lined paper [73,72] is utilised and in others unlined paper [18,47,61]. There is conflicting research regarding whether participants write more legibly on lined or unlined paper. According to a study by Trap-Porter et al., both the lines and the absence of lines as well as the width of the lines impacts on a child's handwriting [78]. Many handwriting evaluations lack an explanation regarding why unlined or lined paper is used and there is often little or no regard for the type of paper that the child is using for writing at his/her specific school [24]. When doing the writing samples the researcher ensured that the participants were given Irish lines on which to write, which were the same lines that were being used in their class work. They were also given a specific guideline in the margin to assist them with the spacing of their work.

Much of the research suggests that lined paper improves the legibility of a child's handwriting when compared to using unlined paper [76]. The researcher only made use of lined paper in this study and therefore this comparison could not be drawn.

In many evaluations the writing tool is not specified i.e., pen or pencil and no consideration is given to the specific writing utensil that the child is using in the classroom [24]. Many of the assessments do not specify whether the child is allowed to use an eraser or if they should rather cross out their errors [24]. Erez et al. emphasised that children should not have an eraser when completing the writing samples [72]. An eraser may impact on the time taken to complete a specific task as well as possibly on the general appearance of the written product [24].

When carrying out the writing samples the researcher ensured that the participants used the writing tools which were presently being utilised by them in the classroom. Each child

was given a sharp HB pencil with which to write and no erasers were allowed. This was specified in the instructions. The participants were instructed to '*cross out their work with one line*' if they made an error.

There were interfering variables with regard to the assessment:

- Firstly the children were tested individually, rather than in a group. This needed to be done as various assistive devices were required during the assessment and the children's pencil grasps needed to be observed.

- Secondly, occupational therapists were used to administer the writing samples rather than the researcher. This was done in order that the researcher was able to observe each child, which could not be done if the researcher was required to administer the test as well.

5.2.1 Writing speed measurement

Writing speed is impacted by many factors as previously discussed including: duration and requirements of the writing task, time needed to carry out the task, writing tools used and the instructions given to the child. Existing handwriting tools vary greatly in terms of how writing speed is measured [24]. Certain measures test speed according to the number of letters written in one minute [18] and others in five minutes [63]. The researcher ensured that all the writing samples were carried out for two minutes, which was based on the WRIT scoring criteria. Certain other handwriting evaluations such as Ziviani and Elkins' scale [71] and the Children's Handwriting Evaluation Scale for Manuscript Writing (CHES-M) [62] also assess handwriting speed for a two minute period [71,62].

The limitations of this writing speed measurement are discussed under section 5.3. A near-point copying task was utilised for these participants, as they had done this previously and it was therefore familiar to them. It is also a task utilised in the classroom and it is the simplest task in terms of assessing aspects of writing speed and legibility. Handwriting of students in grades one to six was shown to be more legible during the copying task, than when they were required to create a narrative or write an essay,

therefore confirming that the processes utilised by the child when composing stories, including aspects such as generating ideas, interferes with the processes that are involved in writing neatly [36]. Composing tasks such as writing a story or describing an event are more demanding than copying tasks [37]. Copying tasks can therefore be seen as a reflection of the speed with which an individual is able to carry out the physical aspects of writing [47]. When observing a child's writing speed it is very important to take note of which types of writing tasks are difficult for him/her. Such as copying from the board, writing a poem or writing from dictation. These tasks all require a number of additional cognitive and linguistic skills which are important to take into account. Therefore although the majority of the learning disabled participants performed similar to the mainstream participants in terms of their writing speed, if an alternative task was utilised such as composing a story, very different results may have been apparent.

5.3 Writing speed and legibility

Comparisons were drawn between the mainstream and learning disabled samples in terms of both writing speed and five areas of legibility: letter formation, spacing between words, letter spacing between lines, accuracy and general appearance.

When the learning disabled sample's means for writing speed using no assistive devices were compared to the mainstream sample's means for writing speed, the learning disabled sample's overall mean was slightly higher than the mainstream samples'. The writing speed of the mainstream sample was however affected as it was the average of the performance of the four trials. It can be seen in Table 3.5 and Table 3.6 that the mainstream children's handwriting speed increased significantly over the five trials (Sample A-D and the WRIT) with more letters being written with each sample. This was possibly due to practice. The overall means for the mainstream group for the four trials (Sample A-D) was 48.05 letters written in two minutes and for the learning disabled sample over the four writing samples (Sample A-D) was 48.09 (Table 4.2). The presentation of the paragraphs in the same order to the mainstream participants was a methodological limitation of this study. This resulted in more letters being written in the final paragraph. The paragraphs should have been presented in a random order to get a more comparable measure for each paragraph.

The writing speeds of both the mainstream and learning disabled participants were similar. This is congruent with the research which suggests that children with learning disabilities; exhibit difficulties particularly with regard to their writing legibility [9]. The speed of their writing has also been found to deteriorate when the complexity or volume of the writing task increases [38,82]. With longer writing tasks, various factors including inattention and boredom may impact on an individual's writing speed [23].

The writing speeds of the two samples were therefore similar due to the fact that a short copying task was utilised in the study. If a more complex and longer task was used, there may have been a significant difference between the writing speeds of the two samples, in favour of the mainstream sample. The differences in writing speed means among grade two children demonstrated in the literature can be as a result of a number of factors including differences in the type and duration of the writing tasks, the writing tool used, lined versus unlined paper, and instructions given to the child regarding how the task should be carried out. All of the above-mentioned factors need to be considered when analysing a child's writing speed.

In terms of the legibility scores of the mainstream participants, Table 3.7 indicates that there was a change in legibility scores among the mainstream sample from the first to the last writing sample. This was with regard to two components of legibility, namely, accuracy ($p \leq 0.01$) and general appearance; which both showed a significant decrease ($p \leq 0.05$). The participants may have therefore focused on speeding up their writing at the cost of accuracy and general appearance. This is congruent with the literature which has shown that the legibility of writing does suffer as a result of the speed [36]. This occurs when children make a conscious attempt to speed up their writing [36]. Weintraub and Graham demonstrated that when children were asked to write quickly, their writing legibility decreased [105]. The mainstream participants were also required to copy five paragraphs in one sitting. Although these participants could rest while the next paragraph was read out aloud, this may have not been sufficient, possibly resulting in inattention, fatigue and boredom, which may have led to them making increased errors, impacting on the general appearance and accuracy of their work. They may have been more cautious with regard to completing the first paragraph versus the subsequent paragraphs. This was a limitation of the study. Longer breaks should possibly have been given to the children between the paragraphs in order to ensure greater accuracy and improvement with regard to the general appearance of their work.

The learning disabled sample's means for writing legibility utilising no assistive devices were compared to the mainstream sample's means for writing legibility. The areas where a significant difference was evident between the mainstream and learning disabled samples were with regard to general appearance and letter formation. As can be seen in Table 4.2, when no assistive devices were used, the learning disabled sample scored significantly worse than the mainstream sample with regard to letter formation ($p \leq 0.001$) and general appearance ($p \leq 0.002$). This is congruent with a study in which written stories of learning disabled and typical children were compared. It was found that one of the most significant differences was in letter formation, with the learning disabled children scoring significantly worse in this aspect [97]. The specific aspects of letter formation where the learning disabled sample struggled was with regard to letters having missing parts, sharp points instead of curves on certain letters, gaps between letters formed by a straight line and a curve such as b,d,g,q,m,n,p,r,u,h, broken or unattached lines, heart-shaped o's, lines extended beyond their point of intersection by greater than 1mm and reversals. It was also interesting to note that certain participants did not start their letters at the correct starting points, particularly the 2 o' clock letters (a.o.c.d,q,f, s and g). This was a limitation of the study as incorrect starting points and using the incorrect sequence of movements was not scored as an error unless it impacted on one of the other factors i.e., reversals. The children's reduced letter formation as well as their spacing between words, letter spacing in the lines and accuracy in terms of omissions and cross-outs impacted on the general appearance of their written work.

As illustrated in Table 4.2, there was no significant difference between the learning disabled and mainstream samples in terms of spacing between words ($p \leq 0.42$), letter spacing between lines ($p \leq 0.17$) and accuracy ($p \leq 0.73$). The scores for accuracy; however did vary more among the learning disabled sample. It is interesting to note that the learning disabled participants' mean for accuracy was slightly higher than the mainstream participants'. This may be due to the fact that the mainstream participants tended to rush the last paragraphs as previously mentioned, or the fact that the learning disabled participants were more cautious in copying accurately. It was observed among the learning disabled participants that many of the participants tended to copy the paragraphs word by word or letter by letter in order to ensure accuracy, whereas the mainstream children tended to rely more on their short term memories, trying to remember

three to four words, often at the cost of accuracy. This was apparent from observing a few children during the performance of their writing samples.

In terms of the five areas of legibility, when no assistive devices were utilised, the learning disabled sample's mean for letter formation and letter spacing between lines was the lowest. According to Amundson and Weill, reduced letter formation is one of the most significant factors impacting on the readability of a child's handwriting [9]. Graham et al. also demonstrated in a study, including 61 children with learning difficulties, that letter formation was the most significant variable, contributing to the overall legibility of a child's writing [91]. This literature is congruent with this study, in that letter formation and general appearance (overall legibility) were the two most significant weakness areas among the learning disabled sample.

In summary therefore, writing speed among both samples was fairly similar. With regard to the learning disabled sample, letter formation and general appearance were the two most significant areas of difficulty as compared to the mainstream sample. This is very important to consider when planning occupational therapy intervention for these individuals. A near-point copying task was used in this study; which does not require the complex integration of factors such as planning, generation of sentences and revision [103], requiring the child to use a combination of linguistic, cognitive and sensory-motor skills [9]. In spite of the use of a simple copying task, the learning disabled participants struggled in these two aspects of legibility. It is vital therefore that occupational therapy intervention addresses these aspects, in order that they become automatic before the child is able to focus on higher order cognitive skills such as spelling, grammar and sentence generation.

It is important to note that the origin of these difficulties is multi-factorial and dependent on many aspects including motor, visual perceptual, kinaesthetic and ergonomic factors which will be discussed later. It is essential that the underlying components impacting on the child's writing speed and legibility are comprehensively assessed in order to provide the most appropriate intervention strategies.

The study also showed that writing speed, spacing between words, letter spacing between lines and accuracy were fairly similar between the mainstream and learning disabled groups. It is however important to note that a short near-point copying task was utilised. Further research utilising longer writing tasks as well as dictation, composition and far-

point copying would be interesting in order to ascertain if similar results are obtained when additional cognitive, linguistic and sensory motor demands are placed on the child.

5.4 Intrinsic and extrinsic factors affecting handwriting

Extrinsic factors were controlled as much as possible such as ergonomics and pain and fatigue; however these aspects may still have influenced the participants' scores for both speed and legibility**.** It is very important to identify the biomechanical factors such as desk height and chair height that are involved when children are performing handwriting tasks [16]. These factors were maintained as much as possible during the performance of the writing samples.

The participants used the recommended seating position for writing [16]. On observation many of the learning disabled participants did tend to slouch and rest with their heads on their hands or on the desk. Possibly other modifications such as a wedge cushion on their chair would have eliminated this factor. The inclined surface did; however, result in the majority of children sitting in a more upright position. The background noise could also not be controlled at times, which could possibly have impacted on the participants' scores, particularly the individuals who were easily distracted by auditory stimuli.

An incorrect pencil grasp has been shown to impact on pain and fatigue in the writing hand [13]. The majority of the learning disabled sample exhibited atypical pencil grasps; which may have caused them some pain and fatigue in their writing hands. The learning disabled participants were given three to four minute breaks between the writing samples in order to attempt to eliminate these factors. Pain and fatigue did not seem to impact on their writing speed as when analysing the writing speed means they were fairly consistent from Sample A to D. Fatigue may have possibly impacted on other writing legibility components, specifically letter formation and general appearance, resulting in inattention and decreased concentration.

Other contributing factors that should be thoroughly assessed in future research, to ascertain their impact on the child's handwriting speed and legibility include intrinsic factors such as motor, visual-perceptual, and kinaesthetic components.

The intrinsic factors affecting legibility considered included various motor components. The first of these was postural control. While the participants were seated at their desks, note was taken of their postural control. Children with reduced postural control often exhibit poor handwriting [51]. According to Amundson, difficulties with postural control and upper-extremity stability commonly impact on writing legibility [51].These children struggle to maintain an upright position, especially while seated at their desks and experience difficulty in making the necessary postural adjustments during the performance of handwriting activities [51]. Some of the participants were observed to slouch in their chairs, and rest with their heads on their hands or on the desk. Certain participants tended to rock in their chairs and wrap their feet around the chair legs. Postural control difficulties may have impacted to some degree on the participants' writing speed and legibility scores. The inclined surface in particular tended to enhance most of the participant's postures whilst seated at their desks. They tended to sit more upright and used their supporting hand more when completing the writing samples, as compared to when they were using the other assistive devices. Although their postural control improved, the inclined surface had no positive effect on the participants' writing speed or legibility. The other assistive devices did not aid in improving the participants' postural control.

It is very important to take note of the child's postural control when writing. Alternative modifications could have possibly been provided such as wedge cushions on their chairs and foot rests in order to further facilitate this. During the writing samples it was ensured that the participant's desk and chair were the correct height in order to ensure that the participant had both symmetry and stability[9] while they were performing their written tasks. *Fine motor problems also affect writing speed and legibility. Berninger and Rutberg suggested that finger function is the most significant predictor of handwriting dysfunction [126]. Certain of the participants in the learning disabled sample had fine motor difficulties including difficulties with regard to in-hand manipulation discussed in chapter two, in terms of isolation, grading and timing of movements [128].*

On observation certain participants tended to use compensatory methods when writing such as locking their fingers into extension or fisting their fingers into flexion [128]. This may have been as a result of decreased isolation and grading of finger movements as described by Exner [128]. Certain participants in the learning disabled sample demonstrated handwriting that was slow and jerky, which impacted on their writing speed, letter formation and general appearance scores. Some of the learning disabled participants'

handwriting was also rapid and disorganised, which affected their writing legibility scores. This was particularly evident with regard to their accuracy. They tended to be careless, impacting on their spelling and resulting in letter omissions and cross-outs. It also affected their spacing between words, letter spacing in the lines and the general appearance of their writing. According to Exner this may be due to difficulties with regard to the timing of movements, which may have impacted on the rhythm and flow of the learning disabled participants' handwriting and resulted in incorrect sizing and placement of letters [128]. This may have affected aspects of their writing legibility including spacing between words, letter spacing between lines and the general appearance of their writing. According to Alston and Taylor, fine motor skills are significant, as letters can only be performed accurately if proper force, timing and control of arm, hand and finger movements exists [127].

The Stetro pencil grip and splint impacted positively to some degree on the learning disabled participants' fine motor and in-hand-manipulation skills, leading to the participants manipulating their pencils with a more functional grasp. They had a negative impact on the participants' writing speed; however, the splint did impact positively on the participants' letter spacing between lines and the Stetro pencil grip impacted positively on the participants' accuracy.

Motor planning and bilateral integration are important elements with regard to handwriting performance [51]. Bilateral integration is involved in tasks such as when the child is required to stabilise the paper with the non-preferred hand while they hold the pencil with the preferred hand [51]. It was observed that many of the learning-disabled participants tended to rest with their heads on their non-preferred hands rather than stabilising the paper. Motor planning impacts on handwriting when the child is required to plan, sequence and execute letter forms and sequence letters in words [51]. Tseng and Murray documented in their study that motor planning was one of the most significant predictors of legibility in individuals with poor handwriting [141]. Many of the learning disabled sample exhibited motor planning deficits, which were evident when they were required to plan their writing on the page as well as when forming the individual letters in terms of where to start and utilising the correct sequence of movements. These factors impacted on their letter formation scores as well as their letter spacing between lines and spacing between words.

Kinaesthesia influences the degree of pressure exerted on the pencil, the ability to write within the lines, as well as the directionality of the writing tool [51]. Observations during the

assessment and analysis of the writing samples showed that some of the children either pressed too lightly on their pencils or alternatively exerted too much pressure on their pencils, at times causing the pencil lead to break and making holes in their pages. This could be evident of a kinaesthetic dysfunction [51]. According to Amundson, children with kinaesthetic difficulties may also struggle in terms of forming their letters properly and spacing their letters accurately in the lines as a result of difficulties with regard to directing their pencils adequately [51]. This was evident when observing certain participants in the learning disabled sample. With regard to certain participants, kinaesthetic difficulties did possibly impact on their writing speed and aspects of their writing legibility. The assistive devices that were used did not seem to impact directly on this aspect. Those participants who wrote with increased pressure tended to exert increased pressure throughout all four writing samples. Those children who exerted too little pressure on their pencils did so throughout the course of the assessment irrespective of which assistive device was used. This was a limitation of the study as pencil pressure and its impact on writing speed and legibility should have been assessed further. The pencil pressure of the mainstream participants should also have been observed and commented on further.

Visual motor integration (VMI) is an important factor with regard to handwriting performance and strong correlations have been documented in the research between visual motor integration and handwriting legibility [75,141,142]. Visual motor integration is particularly important when copying from the text to either cursive or manuscript writing [25]. During the copying tasks, difficulties with regard to visual motor integration may have impacted on the handwriting legibility of certain participants, particularly in terms of their letter formation.

Although the connection between visual perception and handwriting performance is not fully clear [143], aspects of visual perception may have impacted on several of the participants' handwriting performance, thus impacting on their writing speed and legibility scores. This was specifically in terms of position in space which impacts on a child's spacing between letters and words and between the writing lines (horizontal alignment) [51]. Although the children were provided with a spacing cue in the margin (dot, dot, bunny log), some still struggled with regard to spacing their letters accurately within the lines and knowing which letters to place in a particular line.

Form constancy impacts on the child's ability to discriminate between similar letters, numerals or words such as b/d, was/saw, 2/5 which can impact significantly on a child's handwriting [51]. This impacted on the letter formation section where reversals were apparent. Poor visual memory on the other hand results in problems with regard to recalling the formations of letters and numbers i.e., with regard to revisualising the letters and numbers without the aid of visual cues [145]. This impacted greatly on the participants' writing speed and accuracy. Many had to copy the paragraph letter by letter which resulted in decreased writing speed. Certain participants who tried to memorise the words demonstrated reduced spelling impacting on their accuracy scores. Some ended up crossing out words as they made many errors impacting on their accuracy and general appearance scores.

According to Hagin, the upright orientation of the inclined surface may decrease directional confusion, as on the inclined surface, up means up and down means down, whereas on a horizontal surface up means away from the body and down means toward the body [146]. This was not observed in the study, as many directional confusions were still apparent even with the aid of the inclined surface; which had a negative effect on the learning disabled participants' letter formation scores.

Many existing handwriting evaluations do not inform the examiners of specific behaviours to be aware of when observing participants writing such as fatigue which can impact significantly on their handwriting performance [24]. When the participants were undertaking the writing task, the researcher ensured that note was taken of their handedness and the pencil grasps they were using. Brief notes were also taken regarding their posture, use of their non-preferred hand in terms of stabilising the paper and their pencil pressure. The researcher possibly could have been more specific in terms of analysing their pencil grasps as discussed previously in section 5.1 and factors such as postural control could be looked at more closely. This was a limitation of the study.

When compiling the writing legibility score sheet additional aspects should have been included as is evident in other existing handwriting evaluations [65,47]. This is a limitation of the study, as aspects not included in the score sheet may have impacted on the mainstream and learning disabled participants' legibility. Although brief notes were written regarding factors such as the participant's postural control, stabilisation with the supporting hand, handedness, pencil grasp, pencil pressure and visual perceptual

components, a detailed checklist should have possibly been included, with additional space to record detailed information regarding the participant's postural control, fine-motor and in-hand manipulation skills, fatigue, visual perceptual components (visual memory, directionality), motor planning, bilateral integration and kinaesthetic components. More detailed information on the intrinsic factors impacting on the participants' writing speed and legibility would be extremely valuable in ascertaining the exact causes of their difficulties in order that the appropriate intervention methods can be carried out.

5.5 Assistive devices

When analysing the various assistive devices and the impact that they had on writing speed in the learning disabled sample, there was no significant differences between the Stetro pencil grip, inclined surface and the splint on the learning disabled participant's writing speed. There was; however, a significant difference in writing speeds when the children were using the assistive devices versus when no assistive devices were utilised.

As demonstrated in Table 4.4 both the splint ($p \leq 0.02$) and Stetro pencil grip ($p \leq 0.01$) showed a significant difference when compared to no assistive devices in terms of making the participants write at a slower speed. The following factors could have impacted on this:

- Many of the participants were unfamiliar with these assistive devices and therefore had no previous experience in using them.
- For certain participants with an atypical grasp pattern, such as a closed web-space, these assistive devices forced the child to hold their pencils with a tripod grasp, a non-habitual finger position; which may have impacted on the speed of their writing. It was ensured by the researcher that the participants held the Stetro pencil grips with a tripod grasp.
- The splint is made out of fabric and therefore it may have affected participants with tactile sensitivity as they did not enjoy the texture against their skin. They therefore may have been preoccupied with that, impacting on their attention and thus their writing speed.
- Anxiety may have played a role, due to the unfamiliarity of the assistive devices.

The literature suggests that inclined surfaces provide the appropriate hand and wrist position required for the performance of fine-motor and handwriting skills [46]. It was evident that although, the inclined surface; facilitated better posture in the participants, it had a negative effect on the participant's writing speed; making them write at a slower speed.

The literature reports no changes in writing performance related to pencil grips or a change in the pencil diameter [151]. This was not congruent with this study in that a negative change in handwriting speed was noted with regard to the Stetro pencil grip.

In terms of writing legibility, the five aspects were considered separately. Figure 4.18 illustrates the impact of the various assistive devices used in this study on letter formation. As can be seen in Table 4.5 no significant difference was apparent either when the participants were using assistive devices versus when they were writing with no assistive device. When analysing the means in Table 4.3 it can be seen that the participants tended to improve slightly when both the Stetro pencil grip and splint were applied; however the inclined surface did not impact at all on the children's letter formation with the average means for no assistive devices and the inclined surface being identical. The scatter of scores was also fairly similar between assistive devices. Therefore, although the inclined surface did result in the children sitting more upright and did place their writing in a better line of vision, it had no impact on their letter formation. This suggests that there are possibly a number of intrinsic factors; which may be impacting on the children's letter formation, including visual-perceptual components, visual-motor integration skills, fine-motor skills and kinaesthetic factors, which will be discussed further on.

The impact of the various assistive devices on spacing between words is illustrated in Figure 4.19. No significant differences were evident between the assistive devices and no assistive device in terms of their impact on spacing between words (Table 4.5). Figure 4.19 and Table 4.3 illustrate that the learning disabled participants' spacing between words was reduced when they were wearing a splint and best when no assistive devices were used. The largest scatter among scores was evident when the children were using the Stetro pencil grip.

The criteria which were used to measure spacing between words on the writing legibility score sheet, was a limitation of the study. The scoring criteria should have included an

exact measurement of the space between words in centimetres. The spaces between letters should have also been included, as this impacts on the overall appearance of the child's handwriting. This scoring criteria is evident in other existing handwriting evaluations [65]. Tests such as the Minnesota Handwriting Assessment (MHA) and the Test of Legible Handwriting (TOLH) give a more specific measurement of spacing between words through the use a ruler. This would have eliminated factors such as small and large spaces; which still scored a point. The spaces from the farthest point of a word to the nearest point of the following word should have been measured. Spacing between words impacted on the general appearance of both the mainstream and learning disabled samples.

When considering letter spacing between lines the effect of the various assistive devices is illustrated in Table 4.5. The Stetro pencil grip, inclined surface and splint had no significant impact on letter spacing between lines compared to no assistive devices. When analysing the scatter in Figure 4.20 it can be seen that the widest scatter was evident when the participants used the inclined surface. The means shown in Table 4.3 also demonstrate that the participants performed worst when the Stetro pencil grip and inclined surfaces were used. The participants' letter spacing between lines was best when they were wearing the splint, indicating that the participants were able to space their letters better in the lines when they were wearing the splint as compared to using no assistive device. The splint placed the participants' hands in a more functional position, encouraging the balance of stability and mobility needed for a functional pencil grasp [130]. This may have assisted them in spacing their letters more accurately in the lines.

As illustrated in Figure 4.21, the widest scatter of scores with regard to accuracy was evident when the participants were using the splint. Table 4.3 demonstrates that the splint and inclined surface were seen to impact negatively on the participants' accuracy whereas the Stetro pencil grip impacted positively with a higher mean obtained for accuracy when the Stetro pencil grip was used than when the participants were not using any assistive devices. The participants tended to write slower when they used the Stetro pencil grip. Their improved accuracy scores could therefore be related to the Stetro pencil grip itself which impacted on their speed and consequently on their accuracy, or alternatively that the children were more focused on writing accurately and therefore as a result their speed became slower.

There was a significant difference in the participants' general appearance with and without the use of assistive devices (Table 4.5). Handwriting was significantly worse when the inclined surface was used ($p \leq 0.05$). A significant difference was also demonstrated between the Stetro pencil grip and inclined surface ($p \leq 0.02$) with the use of the Stetro pencil grip resulting in a better general appearance in the participants' writing. The means in Table 4.3 indicate that the participants' general appearance was best when no assistive devices were used. The participants' general appearance incorporated many of the other aspects including letter formation, spacing between the lines, spacing between words and accuracy. The inclined surface tended to have a negative impact on all these factors and therefore consequently on the participants' general appearance.

The lack of familiarity with the assistive devices utilised in the study may have impacted on the learning disabled participants' handwriting speed and legibility scores. Some of the learning disabled participants; however would possibly have been exposed to certain of the assistive devices as all the children were receiving therapeutic services. Intrinsic factors such as motor, kinaesthetic and visual perceptual elements were not taken into account; which may also have impacted greatly on the results.

5.6 Summary

When providing occupational therapy services for these children it is important to observe them in their classroom environment in order to ascertain exactly which writing tasks are causing the child difficulty and impacting on both their writing speed and legibility. These include:

- copying tasks (near-point) -required when copying from a nearby model, either on the same page or the same horizontal writing surface [9].
- copying tasks (far-point)- required when copying from the blackboard to the writing surface [9].
- dictation [9]
- composing stories and poems [9]
- answering questions [9]

Once the child has been observed in the classroom during the performance of the above-mentioned tasks and the exact cause of their handwriting difficulties determined, then the

appropriate occupational therapy intervention can be provided or necessary referrals made. Occupational therapists need to be cautioned about prescribing a specific assistive device for a child such as a prosthetic pencil grip, splint or inclined surface, unless the child has a specific difficulty in terms of their handwriting speed and legibility, which will be enhanced through using a specific assistive device. For example a child with poor writing legibility could be given a splint to improve their letter formation and letter spacing between lines.

CHAPTER 6

Conclusion

Handwriting difficulties, in terms of writing speed and legibility are a significant concern particularly among learning disabled children [39]. Currently little conclusive evidence exists on the contribution of prosthetic pencil grips i.e. Stetro grips, inclined surfaces and splints to the enhancement of speed and legibility in writing.

This study aimed to provide more in-depth information regarding the effectiveness of Stetro pencil grips, inclined surfaces and splints on the speed and legibility of handwriting, through the use of writing samples. The study also aimed to confirm which of these assistive devices is the most effective in enhancing the speed and legibility of handwriting.

When comparing the mainstream and learning disabled samples in terms of writing speed and five components of legibility it was found that there was a significant difference only in the areas of letter formation and general appearance.

In analysing the results and through observation it was demonstrated that the various assistive devices have different impacts on writing speed and the five areas of legibility discussed in this study. No significant differences were found between the Stetro pencil grip, inclined surface and splint in terms of writing speed or any of the five areas of legibility discussed in this study.

The splint did seem to help the participants slightly in terms of the areas of letter formation and letter spacing between lines when compared to using no assistive devices; however these differences were not significant. The splint negatively affected the participants' writing speed, making it significantly worse. The Stetro pencil grip improved the participants' accuracy slightly when comparing the means to no assistive devices. The Stetro grip; however affected the participants' writing speed; making it significantly worse.
On observation, the inclined surface improved the participants' sitting posture while working; however had no impact on their writing speed and legibility, making their general appearance significantly worse.

Therefore before assistive devices are recommended by occupational therapists and educators, one needs to carefully assess the child's handwriting in order to specify which particular aspect the child is experiencing difficulty with i.e., writing speed, letter formation, spacing between words, letter spacing between lines, accuracy, general appearance or if the individual has underlying motor, kinaesthetic, visual-perceptual, cognitive or psycho-social difficulties that may be impacting on their handwriting performance. Once the child has been thoroughly assessed and their specific handwriting difficulties ascertained, the appropriate intervention strategies can be provided.

Although certain assistive devices did impact slightly on specific aspects of writing legibility, one must take into account that the writing samples were undertaken for two minutes. Therefore further practice with the Stetro pencil grip, inclined surface and soft splint needs to be carried out with the participants in order to assess the true benefits or harm of utilising them for specific handwriting difficulties over a longer duration.

Occupational therapists should be cautioned about implementing a strategy as a quick fix as there are not instant results and it seems that a period of habituation and adaptation is needed to ascertain the true impact of using a specific assistive device to remediate handwriting difficulties.

Occupational therapists need to deal specifically with handwriting difficulties, if not referral to another professional is recommended i.e., with regard to spelling and comprehension difficulties.

6.1 Future Research

Future research could possibly be aimed at assessing the learning disabled participants for a longer time period, in order that they have had practice and familiarity with regard to the use of the different assistive devices. This will enable occupational therapists to ascertain if the assistive devices are in fact beneficial in enhancing the participants' writing speed and specific aspects of writing legibility.

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APPENDIX A WRIT Grade Two Copy Passage

The big fat brown dog chased the old black cat. Zip jumped over the gate and quickly ran up the tree in the zoo garden. He saw a large zebra asleep under the tall tree. He slipped down the trunk quietly and hid next to the black and white striped beast.

APPENDIX B Example of Principals Letter

Dear Sir/Madam,

I am an Occupational Therapist and am doing a Masters Research Project, whereby I will require writing samples from grade two children. The writing samples will be assessed in terms of writing speed and legibility as the study aims to ascertain the impact of assistive occupational therapy devices on these factors.

I would appreciate it if I could obtain permission to perform the writing samples on your grade two children.

Consent will be obtained from all the parents of the students and the students themselves involved in the study, prior to the samples being carried out.

Kind Regards,

_____

Taryn Levin
Occupational Therapist

Principal School

Printed name Signature Date and Time

APPENDIX CI Ekwall Reading Inventory Sample A

Bob and his father like to work on old cars. His father has five old cars that belong to him. One of them is black with a white top.

Bob is very young, so none of the cars belong to him. He would like to have his own car when he gets big.

Sometimes Bob and his father go to a car show.

At the car show there are many old cars.

One time Bob's father took his black and white car to the car show. One of the men looked at the cars to see which one was best. He gave Bob's father a prize because his car was so pretty.

112 words

APPENDIX C2 Ekwall Reading Inventory Sample B

Kay was waiting by the door for the postman to come. Her father had promised to write her a letter. He told Kay the letter would have a blue stamp on it.

Kay saw the postman walking toward the house. The man was carrying a big bag on his side. The man reached in his bag and gave Kay some letters. One of the letters had Kay's name on it. When Kay read the letter she was very happy. She was so happy when she read it that she began to jump up and down. In the letter Father told Kay he was going to buy her a pony.

109 words

APPENDIX C3 Ekwall Reading Inventory Sample C

Dale lives on a large animal farm with his father and mother. His father has many cows, horses, sheep, and pigs on the farm. One of the animals belongs to Dale. It is a pet pig. The pig is black with a white ring around its back. It has a very short curly tail.

When Dale goes for a walk the pig likes to walk with him. Sometimes when Dale goes to school his pig will follow him. The children at school all laugh when they see the pig with Dale. Many of the boys and girls say they would like to have a pet pig too.

107 words

APPENDIX C4 Ekwall Reading Inventory Sample D

Emily has a little black dog with curly hair. The little dog's name is Chester. He has long ears and a short tail. He lives in a little house behind Emily's big house. Sometimes when he is extra good he gets to come in the big house.

The dog does not like cats. Sometimes when he sees a cat he will run after it. The cat can run faster than the dog, so he does not catch it.

When the dog is hungry he begins to bark. When Emily hears him barking she brings him some food.

97 words

APPENDIX D Ethical Clearance Certificate

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Levin

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER M080540**
PROJECT	The effect of assistive devices on writing speed and legibility in grade two learning disabled children
INVESTIGATORS	Miss T Levin
DEPARTMENT	Occupational Therapy
DATE CONSIDERED	08.05.30
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 08.06.11 **CHAIRPERSON** .....
(Professor P E Cleaton Jones)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Ms D Franzsen

DECLARATION OF INVESTIGATOR(S)

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

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX E Parent Information Sheet Mainstream Sample

Dear Parent

I am Taryn, an Occupational Therapy Masters student at the University of the Witwatersrand, executing a Research project. The title of the Research project is: **The effect of assistive devices on writing speed and legibility in grade two learning disabled children.**

Writing speed and legibility are common problems existing particularly among learning-disabled children. Currently there is a lack of conclusive evidence on the functional importance of vertical surfaces, prosthetic pencil grips such as Stetro grips and soft splints on these factors. This study intends to provide more in-depth information regarding the effectiveness of these assistive devices on writing legibility and speed, through the use of writing samples. The study also intends to confirm which of these assistive devices is the most effective in enhancing the above-mentioned factors.

In order to implement my research, I would value the involvement of your grade two child. The research would involve performing writing samples on your child, in order establish a number of samples that are comparable with each other in terms of writing speed.

The writing samples will be carried out during the child's allocated therapy time, or at a time deemed appropriate by the child's teacher. Each sample will take two minutes to complete.

Your child's participation in this study is voluntary and they are under no obligation to partake in it. Your child will be free to discontinue at any time. Should your child discontinue they will not be penalised in any way.

Your child's details and writing samples will be coded in order to ensure anonymity, and these codes will be made available only to the researcher.

I trust that you will consider this research in order to develop a greater understanding of the impact of assistive devices on your child's handwriting speed and legibility and that you will therefore allow me the opportunity to include your grade two child in the above-mentioned research.

If you agree for your child to participate in this study, you will be required to sign the informed consent form attached. Feedback on the study will be made available on request.

Yours sincerely,

_____

Taryn Levin
Occupational Therapist

APPENDIX F Informed Consent Mainstream Sample

"The effect of assistive devices on writing speed and legibility in grade two learning disabled children."

The purpose of the study has been explained to me in the information sheet and I understand what is required of me. I understand that participation is voluntary and that I am free to withdraw my child from the research at any time without my child being penalised in any way. My child's information and writing samples will remain confidential and will be used for research purposes only.

MY CHILD'S NAME

_____

PARENT/LEGAL GUARDIAN

Printed name	Signature	Date and Time

CONTACT DETAILS

Researcher: Taryn Levin **073-3516258**

Supervisor: Denise Franzsen **011-7173701**

School Number: **011-7884670**

APPENDIX G Verbal Assent Mainstream Sample

"The effect of assistive devices on writing speed and legibility in grade two learning disabled children."

The purpose of the study has been explained fully to the participant and he/she understands what is required of them. He/she understands that participation is voluntary and that he/she is free to withdraw from the research at any time without being penalised in any way. The writing samples will remain confidential and the information gathered will be used for research purposes only.

PARTICIPANT:

Printed name	Signature/ Mark	Date and Time

RESEARCHER:

Printed name	Signature	Date and Time

WITNESS:

Printed name	Signature	Date and Time

APPENDIX H Introduction Mainstream Sample

Hello my name is Taryn. I am an Occupational Therapist and am doing a special study on handwriting. Would you mind if I did some handwriting activities with you in order to see how quickly and neatly you can write. You can ask questions if you do not understand anything. The activities will help me to understand why certain parts of handwriting may be difficult for you.

I will ask you to copy a few paragraphs using an ordinary pencil, a pencil with a grip on it, on a slanted board and with a special splint on your writing hand.

You do not have to be in the study if you do not want to be. If you decide that you don't want to be in the study after we begin, that's okay too. Nobody will be angry or upset. I have discussed the study with your parents and you should talk to them about it too.

If you decide you want to be in this study, please write your name on the next page.

Thank You

APPENDIX I Instructions In Carrying Out Writing Samples

Equipment

Participant:

- chair and desk of correct height
- Irish lined paper
- sharpened HB pencil (no erasers allowed)
- sample paragraphs to copy

Therapist:

- stopwatch
- paper and pen

Instructions to be read to participant

- *When I say **go** I want you to copy this piece until I say **stop.** It is not a race, don't scribble. Just write as you usually do in class."*
- *Cross out the word with one line if you make a mistake*

After two minutes say stop

APPENDIX J Writing Legibility Score Sheet Original

Letter Formation

Score	Criteria
0	Child is unable to copy any letters with any degree of accuracy, for example distortion, missing parts, added parts and angles for curves and visa versa
1	Child made one of the following errors (on any letter)-closure (lines not coming together at the correct point of intersection), lines broken and unattached, parts of a letter unattached or double lines for single line.
2	Child made one of the following errors (on any letter)- overextended lines beyond point of intersection, worked-over lines(no space between these lines) or broken lines but attached.
3	Child could execute all letters with a high degree of accuracy and near precision and is similar to the stimulus letter.

Spacing between words

Score	Criteria
0	Child does not leave any spaces between words.
1	Child leaves spaces between 3 or less words
2	Child leaves spaces between 4-5 words
3	Child leaves spaces between 6-7 words
4	Child leaves spaces between 8-10 words, at least one word is not accurately spaced, or at least one word does not start accurately against the margin.
5	All words are accurately spaced. Words start accurately against the margin.

Letter spacing between lines

Score	Criteria
0	No letters touch the correct lines. All letters are too large or too small.
1	5 or fewer letters touch the correct lines. (Other letters are too large or too small).
2	6-10 letters touch the correct lines. (Other letters are too large or too small).
3	11-20 letters touch the correct lines. (Other letters are too large or too small).
4	More than 20 letters touch the correct lines. (Few letters are too large or too small)
5	All letters touch the correct lines.

Accuracy

Score	Criteria
0	Child omits or adds 10 or more words while copying or crosses out 10 or more words.
1	Child omits or adds between 5-9 words or crosses out 5-9 words.
2	Child omits or adds between 2-4 words or crosses out 2-4 words.
3	Child omits, adds or crosses out 1 word.
4	Child omits or crosses out at least one letter.
5	No omissions or cross-outs.

General Appearance

Score	Criteria
0	Child's writing has all the following criteria: Messy look/Several overwrites/Crossings-out/Difficult to read or decreased formation of all letters and no spacing between words.
1	Child's writing is messy and has many overwrites and crossings our or most letters are formed incorrectly and few spaces are left between words, making it difficult to read.
2	Child's writing is reasonably easy to read but has 6 or more overwrites or crossings-out. Or many letters are formed incorrectly and spacing is reduced.
3	Child's writing has 2-5 overwrites or crossings-out, but is neat and easy to read. Spacing is not optimal.
4	Child's writing has one overwrite or crossing out but is neat and easy to read.
5	Child's writing has all the following criteria: Neat/No overwrites/No crossings-out/Easy to read.

APPENDIX K Writing Legibility Score Sheet Final

Letter Formation

Score	Criteria
0	**Child is unable to copy any letters with any degree of accuracy**
1	**Child made errors (see below) on 10 or more letters.**
2	**Child made errors (see below) on 6-9 letters.**
3	**Child made one of errors (see below) on 2-5 letters.**
4	**Child made an error (see below) on 1 letter.**
5	**Child could execute all letters with a high degree of accuracy and near precision.**

Errors

- Letter must contain no extra lines
- Letter must have no missing parts
- Lines that should be curved must not have sharp points.
- Letters that are formed by a straight line and a curve should not have a gap greater than 1mm (b,d,g,q,m,n,p,r,u,h)
- Lines should not be broken or unattached
- Three points of W do not have a gap greater than 1mm
- Curve of f must not be elongated so that it touches the line
- Letters with a straight line and curve must have obvious change of direction
- Reversals
- The letter o must not be heart-shaped
- No letters must be unattached
- Letters must not contain a double-line instead of a single line
- Line should not be extended beyond their point of intersection by greater than 1mm

Spacing between words

Score	Criteria
0	**Child does not leave any spaces between words.**
1	**Child leaves spaces between 3 or less words**
2	**Child leaves spaces between 4-5 words**
3	**Child leaves spaces between 6-7 words**
4	**Child leaves spaces between 8-10 words, at least one word is not accurately spaced, or at least one word does not start accurately against the margin.**
5	**All words are accurately spaced. Words start accurately against the margin.**

Letter spacing between lines

Score	Criteria
0	**No letters are within the 1mm line on either side. All letters go beyond the outer 1mm line or rest above the inner 1mm line.**
1	**15 or more letters go beyond the outer 1mm line or rest above the inner 1mm line. At least one letter is spaced accurately within the lines.**
2	**11-14 letters go beyond the outer 1mm line or rest above the inner 1mm line.**
3	**6-10 letters go beyond the outer 1mm line or rest above the inner 1mm line.**
4	**5 or fewer letters go beyond the outer 1mm line or rest above the inner 1mm line.**
5	**All letters are within the 1mm line on either side**

- The t and f cross must be 1mm within correct line
- The curve of letters that are formed by a straight line and a curve should not (b,d,g,q,m,n,p,r,u,h) must be within 1mm of the correct line.

Accuracy

Score	Criteria
0	**Child omits or adds 10 or more words while copying or crosses out 10 or more words.**
1	**Child omits or adds between 5-9 words or crosses out 5-9 words.**
2	**Child omits or adds between 2-4 words or crosses out 2-4 words.**
3	**Child omits, adds or crosses out 1 word.**
4	**Child omits or crosses out at least one letter. No uppercase letter at the beginning of a sentence or an uppercase letter that is used instead of a lowercase letter.**
5	**No omissions or cross-outs.**

General Appearance

Score	Criteria
0	**Child's writing has all the following criteria:** • Messy look • overwrites or crossings-out • Difficult to read • Decreased formation of many letters • Reduced spacing between words and in the lines.
1	**Child's writing is difficult to read and has:** • Many letters formed incorrectly • Greatly reduced spacing between words and in the lines. (May or may not have crossings out/overwrites)
2	**Child's writing has:** • Some letters formed incorrectly • Spacing between words or in the lines. • At least one crossing-out/over-write
3	**Child's writing has:** • Some letters formed incorrectly • Spacing between words and in the lines is not optimal. • No crossings-out/overwrites
4	**Child's writing is easy to read and has:** • Good letter formation • Adequate spacing between the words and in the lines • One crossing-out/over-write
5	**Child's writing has all the following criteria:** • Neat • No overwrites • No crossings-out • Easy to read • Good spacing between words and in the lines. • Good letter formation

APPENDIX L1 Letter Formation Scoring Sheet Sample A

Child Number:

Sample A

B		o		t	
o		l		h	
b		d		a	
				t	
a		c			
n		a		b	
d		r		e	
		s.		l	
h				o	
i		H		n	
s		i		g	
		s			
f				t	
a		f		o	
t		a			
h		t		h	
e		h		i	
r		e		m.	
		r			
l				O	
i		h		n	
k		a		e	
e		s			
				o	
t		f		f	
o		i			
		v		t	
w		e		h	
o				e	
r		o		m	
k		l			
		d		i	
o				s	
n		c			
		a			
		r			
		s			Total :

APPENDIX L2 Letter Formation Scoring Sheet Sample B

Child Number:

Sample B

K		p		t	
a		o		o	
y		s			
		t		w	
w		m		r	
a		a		i	
s		n		t	
				e	
w		t			
a		o		h	
i				e	
t		c		r	
i		o			
n		m		a	
g		e.			
				l	
b		H		e	
y		e		t	
		r		t	
t				e	
h		f		r.	
e		a			
		t		H	
d		h		e	
o		e			
o		r		t	
r				o	
		h		l	
f		a		d	
o		d			
r				K	
		p		a	
t		r		y	
h		o			
e		m		t	
		i		h	
		s		e	
		e			
		d			Total :

APPENDIX L3 Letter Formation Scoring Sheet Sample C

Child Number:

Sample C

D		h		m	
a		i		a	
l		s		n	
e				y	
		f			
l		a		c	
i		t		o	
v		h		w	
e		e		s,	
s		r			
				h	
o		a		o	
n		n		r	
		d		s	
a				e	
		m		s,	
l		o			
a		t		s	
r		h		h	
g		e		e	
e		r.		e	
				p,	
a		H			
n		i		a	
i		s		n	
m				d	
a		f			
l		a		p	
		t		i	
f		h		g	
a		e		s	
r		r			
m				o	
		h		n	
w		a			
i		s		t	
t				h	
h				e	
					Total :

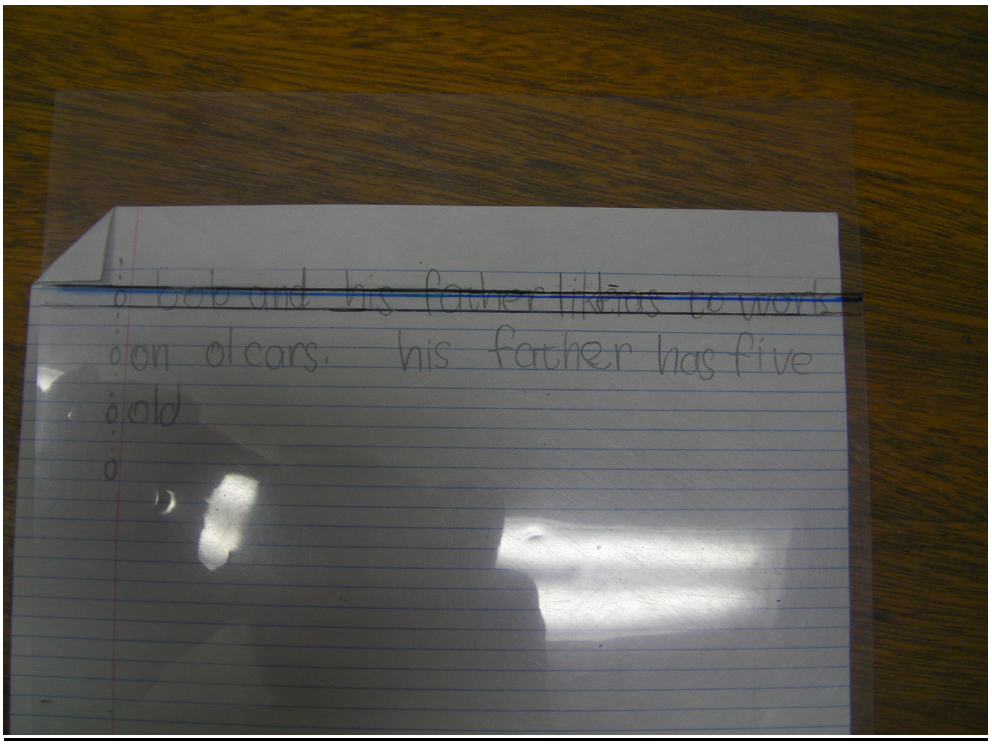
APPENDIX L4 Letter Formation Scoring Sheet Sample D

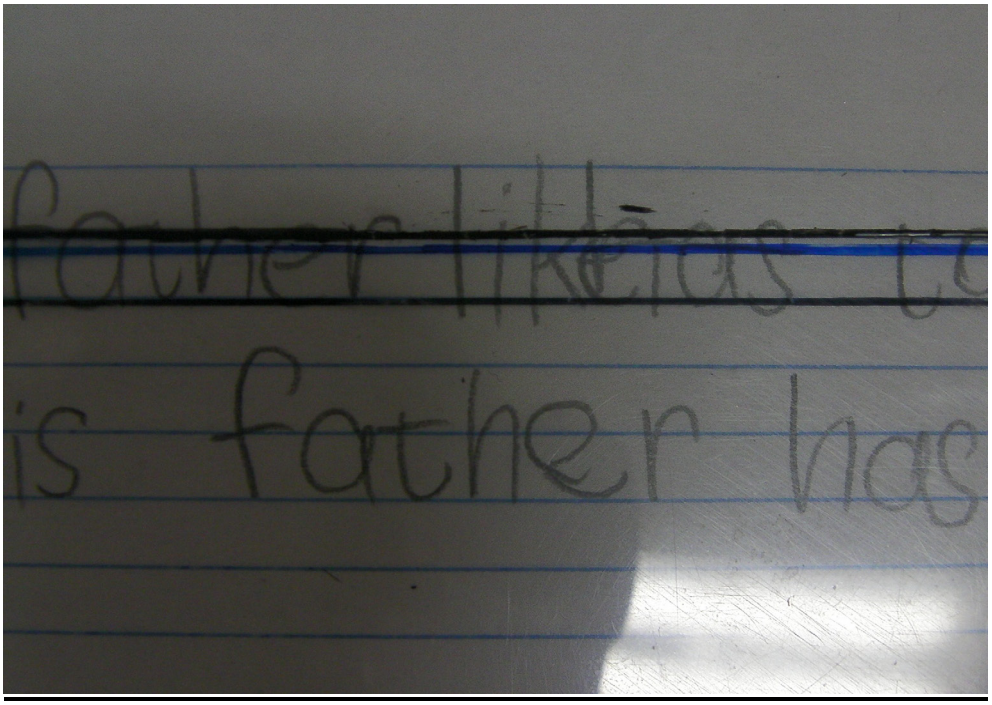
Child Number:

Sample D

E		c		C	
m		u		h	
i		r		e	
l		l		s	
y		y		t	
				e	
h		h		r.	
a		a			
s		i		H	
		r.		e	
a					
		T		h	
l		h		a	
i		e		s	
t					
t		l		l	
l		i		o	
e		t		n	
		t		g	
b		l			
l		e		e	
a				a	
c		d		r	
k		o		s	
		g			
d		s		a	
o				n	
g		n		d	
		a			
w		m		a	
i		e			
t				s	
h		i		h	
		s		o	
				r	
				t	
					Total:

APPENDIX M Scoring Letter Spacing Between Lines





APPENDIX N Examples of Pencil Grasps

Pencil grasps of the mainstream sample

A1



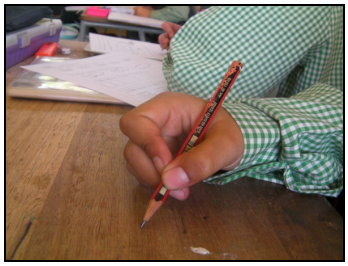
B1



C2



D2



Pencil grasps of the learning disabled sample.

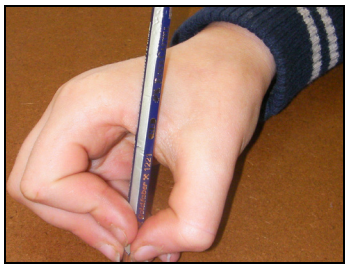
A2



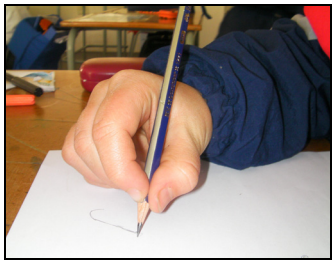
B2



C2



D2



A1-A2: A closed web-space with a thumb wrap (non-functional)
B1-B2: A lateral tripod grasp (non-functional)
C1-C2: A quadrupod/four-finger grasp (functional)
D1-D2: A dynamic tripod grasp (functional)

APPENDIX O Parent Information Sheet LD Sample

Dear Parent

I am Taryn, an Occupational Therapy Masters student at the University of the Witwatersrand, executing a Research project. The title of the Research project is: **The effect of assistive devices on writing speed and legibility in grade two learning disabled children.**

Writing speed and legibility are common problems existing particularly among learning-disabled children. Currently there is a lack of conclusive evidence on the functional importance of vertical surfaces, prosthetic pencil grips such as Stetro grips and soft splints on these factors. This study intends to provide more in-depth information regarding the effectiveness of these assistive devices on writing legibility and speed, through the use of writing samples. The study also intends to confirm which of these assistive devices is the most effective in enhancing the above-mentioned factors.

In order to implement my research, I would value the involvement of your grade two child. The research would involve analysing and comparing the effectiveness of the above-mentioned assistive devices on your child's writing.

Your child will be required to complete four writing samples. The writing samples will be carried out during the child's allocated therapy time, or at a time deemed appropriate by the child's teacher.

Your child's participation in this study is voluntary and they are under no obligation to partake in it. Your child will be free to discontinue at any time. Should your child discontinue they will not be penalised in any way.

Your child's details and writing samples will be coded in order to ensure anonymity, and these codes will be made available only to the researcher.

I trust that you will consider this research in order to develop a greater understanding of the impact of assistive devices on your child's handwriting speed and legibility and that you will therefore allow me the opportunity to include your grade two child in the above-mentioned research.

If you agree for your child to participate in this study, you will be required to sign the informed consent form attached. Feedback on the study will be made available on request.

Yours sincerely,

_____

Taryn Levin

Occupational Therapist

APPENDIX P Informed Consent LD Sample

"The effect of assistive devices on writing speed and legibility in grade two learning disabled children."

The purpose of the study has been explained to me in the information sheet and I understand what is required of me. I understand that participation is voluntary and that I am free to withdraw my child from the research at any time without my child being penalised in any way. My child's information and writing samples will remain confidential and will be used for research purposes only.

MY CHILD'S NAME

_____

PARENT/LEGAL GUARDIAN

Printed name	Signature	Date and Time

CONTACT DETAILS

Researcher: Taryn Levin **073-3516258**

Supervisor: Denise Franzsen **011-7173701**

School Number: _____

APPENDIX Q Verbal Assent LD Sample

"The effect of assistive devices on writing speed and legibility in grade two learning disabled children."

The purpose of the study has been explained fully to the participant and he/she understands what is required of them. He/she understands that participation is voluntary and that he/she is free to withdraw from the research at any time without being penalised in any way. The writing samples will remain confidential and the information gathered will be used for research purposes only.

PARTICIPANT:

Printed name	Signature/ Mark	Date and Time

RESEARCHER:

Printed name	Signature	Date and Time

WITNESS:

Printed name	Signature	Date and Time

APPENDIX R Introduction Learning Disabled Sample

Hello my name is Taryn. I am an Occupational Therapist and am doing a special study on handwriting. Would you mind if I did some handwriting activities with you in order to see how quickly and neatly you can write. You can ask questions if you do not understand anything. The activities will help me to understand why certain parts of handwriting may be difficult for you.

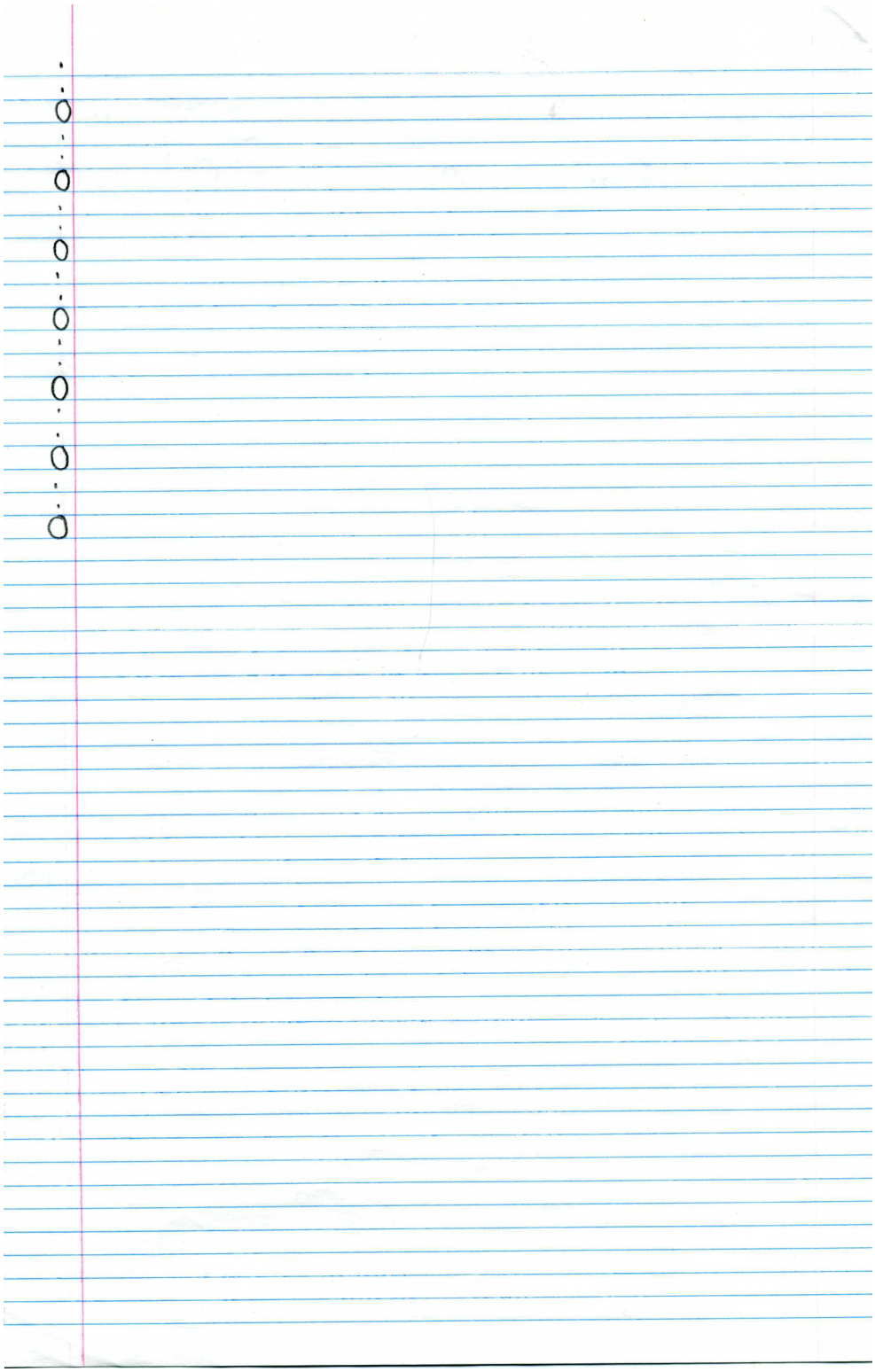
I will ask you to copy a few paragraphs using an ordinary pencil, a pencil with a grip on it, on a slanted board and with a special splint on your writing hand.

You do not have to be in the study if you do not want to be. If you decide that you don't want to be in the study after we begin, that's okay too. Nobody will be angry or upset. I have discussed the study with your parents and you should talk to them about it too.

If you decide you want to be in this study, please write your name on the next page.

Thank You

APPENDIX S Dot Dot Bunny Log Margin Cue



APPENDIX T Observation Form Fieldnotes

OBSERVATION FORM

Child Number: 9 (M/F)

Handedness: Right ✓ Left _____

Pencil Grasp: Functional _____ Non-Functional ✓

Thumb wrap. With index finger quite extended, good angle of pencil.
When holding stetro, able to keep fingers on correct spaces throughout duration.

Posture:

good posture, stabilised well with (L) Hand. Posture didn't alter during performance with all AD's, head adequate distance from page. Posture very good with inclined surface.

Other Observations:(finemotor, bilateral integration, motor planning, kinesthetic, visual perceptual)

pencil pressure slightly increased
(R) side of paper slightly up during performance of writing with splint.
visual memory? → Able to memorize few words at time when writing.
Able to identify and correct self, when left out word. forgot capital letters at times.
visual tracking? - lost space on work at times.
writing neat and well spaced -
found splint comfortable -
Said found it easier to write on vertical surface.