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THE DEVELOPMENT OF A HANDWRITING SCREENING ASSESSMENT FOR ACADEMIC ACCOMMODATIONS AT THE UNIVERSITY OF WITWATERSRAND

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A thesis submitted to the Faculty of Health Sciences, School of Therapeutic Sciences, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy.

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Declaration

I, Denise Franzsen hereby declare that this thesis is my own work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

19th Day of , 2017.

Dedication

To my family for their love and support

Publications and Presentations arising from this study

Publication

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Abstract

A small percentage of students at the university are academically compromised by their handwriting. Various components of handwriting and performance skills have been associated with dysgraphia and inefficient handwriting such as posture and the presentaion of handwriting in terms of corrections made, which are not include in handwriting assessment for students in higher education. The current study addressed the development of a new screening assessment to be used in awarding concessions for examinations to university students with dysgraphia or handwriting deficits which therefore evaluated observable motor and process performance skills related to handwriting in three sections, an Observation Checklist, a Writing Checklist and for Handwriting Outcomes (copying speed, legibility and automaticity of writing).

The study was completed in three phases with the first phase addressing a pilot study on the development of the Handwriting Screening Assessment based on steps in instrument development and criteria for screening assessment development. Item validity was established using a review of the records of 287 students who had been referred for handwriting assessment. The Handwriting Screening Assessment was piloted for content validity and item and subtest validity as well as dimensionality using Rasch subtest analysis after adjustments to items on both checklists. Construct validity of the items on the three sections of the Handwriting Screening Assessment and the unidimensionality of the checklists were considered satisfactory for field testing with typical students and those referred for handwriting assessment in Phase 2.

In the second phase the Handwriting Screening Assessment was tested for construct validity and reliability on a sample of 298 typical students and 61 students referred for assessment of handwriting or dysgraphia. Construct validity of the items and subtests were confirmed for this sample of students using Rasch analysis for the checklists. Differences for known group factors and between the two groups of students indicated construct validity and reliability were satisfactory although not all subtests differentiated between the typical students and the students referred for handwriting assessment.

The Rasch subtest analysis resulted in low person separation index scores which did not allow for students to be identified for different levels of risk for dysgraphia or handwriting deficits using the scores on the Observation and Writing Checklists. A similar result was found for the Handwriting Outcomes. This was due to individual differences and not all students presenting with deficits in all the subtests of the three sections of the Handwriting Screening Assessment.

Therefore normative scoring cut-off points and “at risk quotients” (ARQS) were established for the each subtest so students’ level of risk for handwriting deficits or dysgraphia could be identified. Significant differences between the typical students and the students referred for handwriting assessment were found for the three sections of the Handwriting Screening Assessment confirming satisfactory construct validity based on the ARQs. The clinical accuracy of the Handwriting Screening Assessment assessed on the ARQs indicated adequate negative predictive values for all sections and adequate specificity for all sections except legibility. While the assessment eliminated those without handwriting deficits and dysgraphia the low sensitivity meant that some students with handwriting problems may be missed.

The Handwriting Outcomes - copying speed and automaticity were convergent with reference assessments of handwriting speed and oculomotor dysfunction, Detailed Assessment of Handwriting Speed 17+ and the Developmental Eye Movement, confirming the validity of this subtest in the Handwriting Screening Assessment. All other subtests had divergent validity with the reference assessments indicating they assessed different components related to handwriting problems not usually assessed in students in higher education which were found to identify them at risk for handwriting deficts and dysgraphia.

The usability and utility of the Handwriting Screening Assessment was established in Phase 3 of the study. A detailed analysis of the results for the students referred for assessment of handwriting dysfunction was completed to inform the usability in terms of interpretability of the screening assessment and guidelines for further assessments. The profile of the students referred for handwriting assessment and demographic factors and items on the Handwriting Screening Assessment that placed them at risk for dysgraphia or handwriting deficits were determined. These results indicated that the subtest for pen grasp should be discarded but that other subtests which did not differentiate the students referred for handwriting assessment from typical students should be retained as they were moderately or strongly correlated with the risk for dysgraphia.

The utility of the Handwriting Screening Assessment in terms of the types of dysgraphia to guide concessions that should be awarded and the benefit of the assessment in terms of academic outcomes were analysed.

The Handwriting Screening Assessment can be used to identify students in higher education at risk for dysgraphia handwriting deficts and to suggest further assessment and guide concessions required but the validity can be improved with further adjustment and revision of items and scoring.

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Operational Definitions

Academic Concessions or Accommodation (also referred to as academic adjustments) “describe an alteration of environment, curriculum format, or equipment that allows an individual with a disability to gain access to content and/or complete assigned tasks; does not alter what is being taught” and the same grading scale for students with disabilities can be used. Includes extra time for examinations, typing examinations and use of appropriate voice recognition and text to speech software.[Disabilities Opportunities Internetworking and Technology, 2015]

Client Factors –“Specific capacities, characteristics, or beliefs that reside within the person and that influence performance in occupations. Client factors include values, beliefs, and spirituality; body functions; and body structures” [American Occupational Therapy Association, 2014]

Dysgraphia from the Greek "dys" meaning "impaired" and "graphia" meaning "making letter forms by hand," is a disorder “of writing ability. In its broadest definition, dysgraphia can manifest as difficulty writing at any level, including letter illegibility, slow rate of writing, difficulty spelling” [Chung and Patel, 2015]

Dyslexia ' is a learning difficulty that primarily affects the skills involved in accurate and fluent word reading and spelling. Characteristic features of dyslexia are difficulties in phonological awareness, verbal memory and verbal processing speed” [The British Dyslexia Association, 2014]

Handwriting - “a style or manner of writing by hand, especially that which characterizes a particular person; penmanship” [Dictionary.com, 2013]

Norm referenced assessment “is an assessment system in which students are compared with each other and placed in rank order on a (normally!) normal distribution curve. Only a proportion of students will obtain a particular grade or class of degree” [Yorke, 1996]

Performance Skills “Goal-directed actions that are observable as small units of engagement in daily life occupations. They are learned and developed over time and are situated in specific contexts and environments” [Fisher and Griswold, 2014]. Performance skills include motor and process skills amongst others

> **Motor Skills—**“Occupational performance skills observed as the person interacts with and moves task objects and self around the task environment” (e.g., activity of daily living [ADL] motor skills, school motor skills”; (Schell et al., 2013
>
> **Process Skills “**Occupational performance skills [e.g., ADL process skills, school process skills] observed as a person (1) selects, interacts with, and uses task tools and materials; (2) carries out individual actions and steps; and (3) modifies performance when problems are encountered” [Schell et al., 2013]

Specific Learning Disability - “Specific learning disorder is diagnosed through a clinical review of the individual’s developmental, medical, educational, and family history, reports of test scores and teacher observations, and response to academic interventions. The diagnosis requires persistent difficulties in reading, writing, arithmetic, or mathematical reasoning skills during formal years of schooling. Symptoms may include inaccurate or slow and effortful reading, poor written expression that lacks clarity, difficulties remembering number facts, or inaccurate mathematical reasoning. Current academic skills must be well below the average range of scores in culturally and linguistically appropriate tests of reading, writing, or mathematics. The individual’s difficulties must not be better explained by developmental, neurological, sensory (vision or hearing), or motor disorders and must significantly interfere with academic achievement, occupational performance, or activities of daily living”.[American Psychiatric Association, 2013]

Screening assessments “are used to determine whether students may need specialized assistance or services” [Great Schools Partnership, 2014]

Standardised assessment “an assessment “that uses uniform procedures for administration and scoring in order to assure that the results from different people are comparable” [Bond, 1996].

Usability of assessments usability refers to the quality of a user's experience when interacting with an assessment. This is related to the practicality of administering the assessment, the cost, the acceptability to the stakeholders who need to interpret the results and the validity and reliability for the target population. Those involved with the students being screened and the students should be able to understand the implications associated with various screening outcomes [Glover and Albers, 2007].

Utility of assessments - screening assessments should improve the guiding of treatment decisions resulting in recommendations for additional measurement or the provision of services. The recommendations generated as a result of screening should be contextually relevant and feasible. The benefits associated with the screening instruments' use should be evident especially for the target population [Glover and Albers, 2007].

Abbreviations

ADHD	Attention deficit hyperactive disorder
AERA	American Educational Research Association
ANJ	averaged normalized jerk
ANOVA	Analysis of variance
AMPS	Assessment of Motor and Process Skills
ARQ	At risk quotient
AUC	Area under the ROC curve
BHK	Brave Handwriting Kinder
BOLD	blood-oxygen-level-dependent
CHAT	Chinese Handwriting Assessment Tool
CHES-M	Children's Handwriting Evaluation Scale-Manuscript
CHES-C	Children's Handwriting Evaluation Scale-Cursive
CHWC	Campus Health and Wellness Centre
DASH 17+-	Detailed Assessment of Handwriting Speed 17+
DAST	Dylexia Adult Screening Test
DCD	Developmental coordination disorder
DIP	distal interphalangeal
DIF	differential item functioning
DRHP	Diagnosis and Remediation of Handwriting Problems
DSM- V	Diagnostic and Statistical Manual of Mental Disorders 5th edition
EFA	Exploratory factor analysis
EMG	electromyography
ETCH –C	Evaluation Tool of Children's Handwriting- Cursive
ETCH - M	Evaluation Tool of Children's Handwriting - Manuscript
fMRI	functional magnetic brain imaging
FOTIM	Foundation of Tertiary Institutions of the Northern Metropolis

HPSQ-C	Handwriting Proficiency Screening Questionnaire for Children
ICF	International Classification of Functioning, Disability and Health
IDEA	Individuals with Disabilities Education Act
IEB	independent examination board
IHL	institutions of higher learning
IP	interphalangeal
IQ	intelligence quotient
IRT	item response theory
JCQ	Joint Council for Qualifications
KMO	Kaiser Mayer Olkin
LD	learning disabilities
LSEN	Learners with special educational needs
MHA	Minnesota Handwriting Assessment
MPT	Maximal Potential Thesis
NVRS	numerical verbal rating scale
NSC	National Senior Certificate
OERI	Office of Educational Research and Improvement
OTPF III	Occupational Therapy Practice Framework III
PATOSS	Professions Association of Teachers of Students with Specific Learning Disabilities
PIP	proximal interphalangeal
POET	the Penmanship Objective Evaluation Tool
PSI	person separation index
RAN	Rapid automatised naming
RUMM	Rasch Unidimensional Measurement Models
SIMS	Student Information Management System
SLD	specific learning disabilities
SME	subject matter expert

TOLH	Test of Legible Handwriting.
USA	United States of America
UK	United Kingdom
VAS	visual analogue scale
VMI	Visual Motor Integration
WSAM	Writing Speed and Accuracy Measure

CHAPTER 1 INTRODUCTION

1.1 Introduction

In line with disability rights and legislation, universities worldwide are expected to support and accommodate students with disabilities [Matshedisho, 2007; Mullins and Preyde, 2013]. This includes providing academic adjustments or concessions in the form of "reasonable accommodations" for students with physical, and psychological disabilities as well as disabilities related to learning problems so that these students are not disadvantaged in their studies [Lesaux et al., 2006].

The number of students with disabilities, including those with specific learning disabilities (SLD), being admitted to universities and requesting academic concessions, particularly "extra time for tests and examinations" is increasing [Ward, 2006]. The difficulty in providing the appropriate concessions requested by the students in institutions of higher learning (IHL) is highlighted in the literature. It appears that problems and controversy exist in all aspects of assessment, decision making in terms of adequate adjustments for assignments, classroom adaptations and suitable concessions for examinations for students with disabilities [Mullins and Preyde, 2013]. This is an international problem with litigation reported in the United States against Ivy League universities including demands that the length of time to write examinations be doubled [Kolowich, 2010; Siegel, 1999b].

One of the main problems facing universities and other IHL is a lack of clear criteria both internationally and in South Africa as to exactly how students with disabilities should be assessed and on what basis academic concessions should be awarded. Institutions of higher learning have had to develop their own procedures and policies for awarding academic concessions based on guidelines in disability and education policies [Thomas, 2000]. This makes decisions about providing extra time and other academic concessions difficult even when standardised assessments are used to determine the effects of disabilities. The decision as to the academic concession to be awarded must be defensible, to accommodate for each student's specific disadvantage related to their disability [Ofiesh et al., 2005].

Students with long standing disabilities often learn in primary and secondary education situations, to use a variety of strategies to compensate for their disabilities, which may mask difficulties they experience. This makes the assessment of disabilities and awarding of concessions for examinations difficult particularly for SLD such as dyslexia and dysgraphia [Casale, 2009]. Assessments of students with disabilities used in higher education must therefore allow for informed decisions to be made about not only the presence and severity of deficits, but which academic concessions would allow a student to reach their potential without being advantaged in terms of their peers [Zuriff, 2000].

Controversy about the definitions in the SLD domain as well as other conditions, which affect students' ability to complete timed examinations, complicate the awarding of concessions at a university level [Lindstrom, 2007]. This is particularly true for dysgraphia, which presents as deficits in various components related to handwriting as well as the mechanics and automaticity of handwriting. Dysgraphia has recently been listed in the Diagnostic and Statistical Manual of Mental Disorders 5th edition (DSM-V) as a separate specific learning disorder [American Psychiatric Association, 2013]. This disorder has previously not been considered separately from dyslexia [Berninger and Richards, 2008; Richards et al., 2015] so the specific assessment of handwriting deficits has rarely been recommended in higher education.

The guidelines provided by the Joint Council for Qualifications in the United Kingdom (UK) on tests to be used for the assessment of handwriting in higher education students recommend only one standardised assessment. This assessment, the Detailed Assessment of Handwriting Speed 17+ (DASH 17+) supports recommended concessions based on the assessment of writing speed and automaticity alone [Barnett et al., 2010; Joint Council for Qualifications, 2015]. It is usually suggested that handwriting should be further assessed using non-standardised assessments. Therefore, there is little clarity on exactly how handwriting deficits should be assessed, when students request concessions for handwriting problems [Patoss, 2012]. The use of standardised tests has been recommended when assessing handwriting especially if specific academic concessions are to be supported and justified. These assessments should allow differences to be determined on a continuum of human ability that separates the students within the normal range of ability, from those who have deficits related to handwriting [Westling, 1995]. Most research on standardised testing and concessions has been published by educational psychologists and consider intelligence quotient (IQ) as well as academic skills like reading and cognitive processing. These studies consider written language dysfunction rather than the mechanics of handwriting, which has been more commonly researched, assessed and treated in occupational therapy [Duff and Goyen, 2010].

Occupational therapy research initially concentrated on the different body functions (or client factors) needed for prewriting and the non-linguistic aspects of writing. Later studies considered client factors as well as presentation and outcomes of handwriting in children [Pollock et al., 2009; Rosenblum and Livneh-Zirinski, 2008]. Research has indicated that the client factors that need to be intact if handwriting is to be efficient, include amongst others fine motor control and visual perception. Components of handwriting associated with handwriting deficits or dysgraphia include a tight inefficient pen grasp which may look awkward, the inability to sustain writing without fatiguing quickly, mouthing or subvocalizing words that are being written, difficulty with punctuation and spelling as well as poor organisation of written work on the page. Problems in handwriting have been associated with deficits in the automatic retrieval of letters and words and the accuracy of copying. Poor posture, with awkward orientation of the arms and wrists with decreased efficiency in handwriting may be associated with pain and discomfort when writing [Berninger and Wolf, 2009; Crouch and Jakubecy, 2007].

The assessment and intervention for these components of handwriting have been recognised in occupational therapy, particularly at a pre-primary and primary education level. There is very little evidence related to the assessment and intervention for handwriting deficits at a higher education level in this profession however [McCluskey and Lannin, 2003; van Drempt et al., 2011]. Therefore, it is not clear what effect deficits in the components of handwriting, which influence handwriting in the lower grades at school, may have on students who have been writing for at least 12 years by the time they attend university. Benbow (2006) suggests that many of the deficits do remain and become habituated in adults, indicating the importance of considering these components in the assessment of handwriting, if problems are to be confirmed in the writing performance of students in higher education. This includes the observation of writer and other components which impact on the ability to write [Benbow, 2006; Parush et al., 1998]. Studies have investigated single deficits but a comprehensive assessment of the components of handwriting for this population has not been considered [Chang et al., 2015; de Almeida et al., 2013; Lohman, 1993].

Most handwriting assessments which score handwriting outcomes or the speed, automaticity and legibility of writing, are not adequate in identifying components of handwriting that need to be addressed in intervention. For instance, posture, pain, errors and changes in the presentation of writing which have been shown to be associated with dysgraphia and handwriting deficits are rarely reported in handwriting assessments [Berninger and Amtmann, 2004; Rosenblum et al., 2004]. These components need to be considered however if appropriate intervention and concessions are to be recommended when assessing handwriting in students in higher education. This is supported by research that indicates the assessment of writing speed and automaticity does not always significantly differentiate between poor and proficient primary school writers [Dennis and Swinth, 2001; Schoemaker and Smits-Engelsman, 1997]. It has been suggested that children and students with handwriting deficits may use different movement strategies to achieve adequate speed or legibility in their writing, while still not achieving the productivity required in academic contexts such as examinations [de Almeida et al., 2013; Rosenblum and Livneh-Zirinski, 2008; Schoemaker and Smits-Engelsman, 1997].

In occupational therapy, it is recognised that an assessment of handwriting should present an appropriate challenge if the capacity of the writer in terms of the process and performance of handwriting is to be observed and assessed adequately [American Occupational Therapy Association, 2014]. To understand the demands of a handwriting task, which support or impede performance, performance skills should be observed. A framework of performance skills which includes motor and process skills has been described by Fisher and Griswold (2014). Since these performance skills require the observation of the interaction between the individual and the tools used in the task as well as the client factors, this framework is appropriate for observing and assessing the process and performance of handwriting. Performance skills such as Grips (holds and efficiently uses task objects) and Aligns (interacts in task without propping and leaning) provide the means to identify and analyse an individual's capacity or ability related to handwriting within a specific environment as well as the presentation of their writing over the duration of the execution [American Occupational Therapy Association, 2014; Fisher and Griswold, 2014]. This framework is consistent with the concepts in the International Classification of Functioning, Disability and Health (ICF) [World Health Organization, 2001].

1.2 The Current Situation at the University of the Witwatersrand

The criteria for allocation of academic concessions for examinations at the University of the Witwatersrand (Wits), where this study was conducted, is based on the needs of students with various disabilities [University of the Witwatersrand, 2015b]. In line with national legislation, support for students with disabilities is provided by the Disabled Students' Programme and Disability Rights Unit [University of Witwatersrand, 2013]. The programme offers concessions for examinations based on international recommendations which may include a quiet testing room with few distractions, the use of speech recognition and text reading software, typing and scheduled breaks during tests and examinations where the break time is not counted as part of the examination time [Healey, 2014; Lindstrom, 2007].

However, the provision of concessions for extra time in relation to examinations, is regulated separately and applications are made though the Campus Health and Wellness Centre (CHWC) with the final decision and approval being made by Faculty Deans. Regulations place the responsibility for making recommendations for extra time with the health professions working at CHWC that include doctors and nursing sisters [University of the Witwatersrand, 2012]. These health professionals are unable to formally assess deficits related to SLD and other injuries. Therefore, the services of the Department of Occupational Therapy in the School of Therapeutic Sciences, along with those of the psychologist working at the Disability Rights Unit have been included in this process. The professionals in these departments screen and assess students reporting handwriting and reading dysfunction, who are requesting extra time and other concessions for examinations. Presently, students are screened for dyslexia at the Disability Rights

Unit at Wits and students with possible handwriting problems are referred to the Occupational Therapy Department for assessment. These assessments are offered in particular to two thirds of the approximately 33,000 students on bursaries, scholarships or financial aid [Nkosi, 2015] who cannot afford expensive assessments in the private sector as this type of service is not available in public health and education sectors which these students access.

From experience in dealing with requests for academic concessions, it is clear that students from different faculties at Wits are faced with different challenges. The length of examinations, emphasis on correct spelling and grammar and the use of examination question types can all affect the type of concessions needed. The amount of writing and reading expected in examinations appears to increase as students progress through different courses. There are thus a number of factors that must be considered once an assessment has been completed before recommending the actual extra time concession, which can vary from an extra 5, 10 or 15 minutes per hour.

Lindstrom (2007) indicated that the use of valid and reliable assessments is essential at a university level, when determining and defending concessions to be awarded and which students will benefit from them [Lindstrom, 2007]. It has been suggested that assessments for concessions in students with learning disabilities and other disabilities at university should be related to the type of academic skills the student is required to fulfil. A handwriting assessment should be used to screen for handwriting deficits based on a student or lecturer reporting a handwriting problem which affects the students' academic outcomes.

1.3 Statement of the Problem

The number of student requesting assessment for concessions related to handwriting deficits increased from 9 to 42 (500%) from 2002 to 2013. This is in line with international trends and has been attributed to better understanding of the needs of children with SLD at school. More schools are offering support in terms remediation and concessions for SLD and other disabilities which allows more students with disabilities to achieve their potential and obtain entrance into IHL [Gregg, 2007]. At Wits, this may also be due to the formalisation of services provided by the Disability Rights Unit, the awareness campaigns run by the unit, the unit policy to recruit students with disabilities and the support offered to these students.

When requesting academic concessions at Wits, the onus lies with the student to provide evidence of the disability which interferes with completing examinations. Students therefore present a large number of different referrals and assessments, from various health professionals as proof of deficits, qualifying them for extra time and other concessions. The health professionals at CHWC review these assessments and refer approximately 30-40 students to the Occupational Therapy Department every year for assessment of handwriting deficits. These assessments are time consuming and labour intensive and therefore the need for a short standardised handwriting screening assessment was identified. The assessment could be used to determine if students requesting concessions for examinations do present with dysgraphia or handwriting deficits before a full assessment is completed or whether these students need to be referred to other professionals, for assessment unrelated to handwriting.

1.4 Purpose of the study

The purpose of this study was to develop a suitable occupational therapy screening assessment for the identification of dysgraphia or handwriting deficits, specifically for students applying for academic and examination concessions. The screening assessment needed to differentiate students with handwriting deficits or dysgraphia from those who do not perform academically for other reasons such as an inadequate academic ability and limited English proficiency [Siegel, 1999b]. This is particularly important in a country like South Africa, with 11 official languages and where various levels of educational support is offered in schools [van der Berg, 2008].

Thus, the study needed to provide information about factors placing students at risk for handwriting deficits or dysgraphia in a short assessment period. Many students have learnt to compensate for their handwriting problems and can write without obvious deficits in their actual handwriting. Assessing handwriting outcomes such as speed and legibility was not considered sufficient to provide defensible evidence that students require concessions. The handwriting assessment needed to screen all components affecting performance while writing including postural deficits and fatigue related to the student or writer and components such as spelling related to the presentation of the handwriting. Identifying the type of dysgraphia, the students presented also needed to be considered so that appropriate concessions could be recommended. This study therefore, proposed to develop an assessment that was unique in that it screened for the risk of dysgraphia and handwriting deficits in students in higher education, based on the observation of performance skills and handwriting components inclusive of the writer, the presentation of the writing and the handwriting outcomes of speed, legibility and automaticity.

1.5 Research Question

Is it possible to develop a valid and reliable screening assessment of handwriting based on the performance skills framework that can differentiate between Wits students with and without handwriting deficits, and identify the risk level and characteristics of handwriting deficits in undergraduate university students?

1.6 Aim and objectives of the Study

The overall aim of this study was to develop and establish the psychometric properties and usability of a handwriting screening assessment for undergraduate university students at Wits to identify those at risk for handwriting deficits or dysgraphia. The study was completed in three phases.

1.6.1 Phase 1: Development of the screening assessment and confirmation of items and subtests

1.1.6.1 Aim

This phase was used to analyse handwriting constructs based on the motor and process performance skill framework [American Occupational Therapy Association, 2014] to identify domains and develop and validate the items on a **Handwriting Screening Assessment** for students in higher education. To achieve this, the screening assessment was divided into separate sections using descriptors related to the observation of the students or writers (**Observation Checklist**) as well as the presentation of their handwriting (**Writing Checklist**). A third section was based on the criteria for **Handwriting Outcomes** in terms of speed, automaticity and legibility. The first phase was completed in two parts.

1.6.1.2 Objectives

Part 1: Development of the screening assessment

- To identify domains based on motor and process performance skills, associated with handwriting components and client factors that may be observed in Wits students in an Observation Checklist and their writing in a Writing Checklist as well as in subtests related to Handwriting Outcomes.
- To compile a Handwriting Screening Assessment which was used to screen observable components of handwriting to screen for risk of dysgraphia or handwriting deficits in Wits students on the Observation Checklist, the Writing Checklist and Handwriting Outcomes.

Part 2: Pilot study to confirm item and subtest validity and checklist dimensionality of the Handwriting Screening Assessment

To use a retrospective record review: -

- to establish a demographic profile of students referred for handwriting assessment between 2008 and 2012.
- to establish the item validity for the three sections of the Handwriting Screening Assessment and dimensionality of the Observation Checklist and the Writing Checklist.

The item validity of the three sections of the Handwriting Screening Assessment was found to be satisfactory. Therefore, the assessment developed in Phase 1 was field tested on both typical students and those referred for handwriting assessment to determine norms and the validity and reliability of the assessment in Phase 2.

1.6.2 Phase 2: Psychometric properties of the Handwriting Screening Assessment

1.6.2.1 Aim

The aim of phase 2 was to establish the psychometric properties of the Handwriting Screening Assessment in terms of the validity and reliability as well as determining the cut off scores which indicate handwriting deficits. This phase was analysed in three parts.

1.6.2.2 Objectives:

Part 1: Construct validity and reliability of the Handwriting Screening Assessment

- To establish the construct validity of the Handwriting Screening Assessment by determining: -
- To establish the reliability of the Handwriting Screening Assessment by determining the internal consistency and interrater reliability for the three sections of the Handwriting Screening Assessment.

Part 2: Cut off points and at risk quotients for the Handwriting Screening Assessment

- To establish the norms and cut off points related to at risk quotients (ARQs) to identify students at risk for handwriting deficits on the Observation Checklist, the Writing Checklist and the Handwriting Outcomes.

Part 3: The validity of the Handwriting Screening Assessment based on at risk quotients

- To establish the validity of the Handwriting Screening Assessment based on the ARQs by determining: -

1.6.2.3 Null hypotheses

Known group factors

- There will be no difference for the subtest scores on the three sections of the Handwriting Screening Assessment based on the known group factors of age, gender and school attended.

Typical students and those referred for handwriting assessment

- There will be no difference in the subtest scores and ARQs of typical students and those referred for handwriting assessment on the three sections of the Handwriting Screening Assessment.

Once the psychometric properties of the Handwriting Screening Assessment were found to be satisfactory in Phase 2, analysis of the data for the target population of students referred for handwriting assessment was completed in Phase 3. The usability of the screening assessment in identifying the handwriting deficits in this sample of students and determining the need for further assessments as well as the utility of the assessment for recommending concessions and the possible benefits of the assessment were established.

1.6.3 Phase 3: Usability of the Handwriting Screening Assessment for the target population

1.6.3.1 Aim

The aim of this phase of the study was to increase the usability of the Handwriting Screening Assessment by determining the characteristics of the problems related to handwriting and deficits in the handwriting components as well as their relationship to the risk for dysgraphia, so the need for further assessment and referral to other services could be for those administering the assessment. The utility of the Handwriting Screening Assessment was explored to guide the recommendation of appropriate concessions based on different types of dysgraphia and the benefit of concessions awarded in terms of the students' academic outcomes.

This phase of the study was done in two parts.

1.6.3.2 Objectives

Part 1: Clarification of deficits related to handwriting in students referred for assessment

- To determine if factors assessed on the history of handwriting problems questionnaire differentiated students in terms of scores on the Handwriting Screening Assessment and the risk for dysgraphia.
- To determine the frequency of deficits of components of handwriting assessed by the items and subtests in the Handwriting Screening Assessment and their association with the risk for dysgraphia to establish the clarify the need of the type of further assessment and referral to the services required.

Part 2: Utility of the Handwriting Screening Assessment for students identified with dysgraphia or handwriting deficits

- To establish the utility of the Handwriting Screening Assessment: -

1.7 Justification for the Study

Recent studies indicate on-going problems with the consistent identification of students with disabilities with handwriting and those with SLD in IHL. Katusic et al. (2009) indicate that there is very limted research on disorders related to handwriting deficts including dysgraphia and only 1% of studies published are in this field whereas reading disorder studies are much more common [Katusic et al., 2009]. This study will therefore add to the research on the identification and assessment of components of handwriting in students in higher education. The study provided a comprehensive view and advanced knowledge about the components of handwriting which are associated with dysgraphia and handwriting problems in students in higher education.

The development of a screening assessment for handwriting, and the analysis of handwriting deficits in students referred for and identified with handwriting deficits or dysgraphia presented can be used to benefit the stakeholders in the process of awarding concessions in IHL. The screening assessment allows for the identification of students with handwriting problems and guides the appropriate referral for further assessment to confirm deficits that require the awarding of academic concessions. The recommendation for concessions including extra time can be further facilitated by identifying the type of dysgraphia with which the student presents. The use of a screening assessment could also reduce the workload for those involved in evaluating the students and the costs of unnecessary assessments.

1.8 Definition of handwriting

The definition of handwriting and dysgraphia in the context of the current study was confined to that presented by Tseng and Chow (2000) and Berninger (2009) in that It does not consider any components of written language disorder or components of syntax, composition skills or the content of what is written [Chung and Patel, 2015]. It does include orthographic coding by the assessment of the retrieval of letters from visual memory, spelling and adequate motor output [Berninger, 2009; Tseng and Chow, 2000].

1.9 Overview of the Study

Chapter 1 - Introduction

An introduction to the importance of standardised assessments to facilitate the awarding of concessions for examinations in higher education and the problems with awarding these are presented. The need for a screening assessment to identify handwriting dysfunction or dysgraphia in students is argued and the context at Wits is presented in terms of providing concessions as well as the statement of the purpose, research questions, aims, objectives and justification of the study.

Chapter 2 – Review of the literature

This chapter reviews the literature on the effect of dysgraphia and handwriting deficits and concessions in higher education. The importance and development of handwriting as well as handwriting problems and what constitutes dysgraphia and other handwriting deficits is also included. The assessment of handwriting, and criteria for screening assessments are considered as well as the motor and process performance skill framework and the association of the framework to components of handwriting for the writer, presentation of handwriting and handwriting outcomes.

Chapter 3 – Overview of the Study and Phase 1 Methodology

This chapter presents the outline for the development of an instrument and the methodology for each of the three phases of the study.

Phase 1 Development of the screening assessment and confirmation of items and subtests

This phase was presented in 2 parts: -

Part 1 Development of the assessment - following the steps of instrument development the criteria followed to develop the Handwriting Screening Assessment were outlined.

Part 2 Confirmation of item validity and assessment dimensionality – a retrospective record review of 287 students, who were referred for handwriting assessments, was used to obtain data for item analysis. Factor analysis and Rasch analysis were used with the Observation Checklist and the Writing Checklist that the items were suitable for Rasch analysis and the test was multidimensional.

Chapter 4 Phase 1: Results

The results were presented separately for each part of this phase of the study.

Part 1 Development of the assessment

Following Steps 3-7 of instrument development combined with the criteria for developing and evaluating a screening assessment the process of developing the Handwriting Screening Assessment was described as well as the changes made after the screening assessment was piloted for content validity.

Part 2 Confirmation of item validity and assessment dimensionality

The results of the retrospective record review were analysed using factor analysis and Rasch analysis. Subtest analysis was required to achieve fit of the Observation Checklist and the Writing Checklist to the Rasch model. The checklists were found to be multidimensional.

Chapter 5 – Phase 1 Discussion

This discussion includes the definition of a screening assessment and the target population as well as Rasch analysis. Item analysis and the implication of using subtest analysis to determine the item validity and dimensionality of the Handwriting Screening Assessment were considered. The results showed satisfactory results.

Chapter 6 – Phase 2 Methodology

Phase 2 Psychometric properties of the Handwriting Screening Assessment

This chapter includes the field testing of the **Handwriting Screening Assessment** on Wits students. The sample included 289 typical students and 61 students referred for assessment of handwriting problems. This phase was analysed in in three parts.

Part 1: Construct validity and reliability of the Handwriting Screening Assessment - data for known group factors for the typical students and students referred for handwriting assessment were collected on the three sections of the Handwriting Screening Assessment. Data were collected on the students referred for handwriting assessment using the DASH 17+ and the DEM.

Part 2: Cut off points and at risk quotients for the Handwriting Screening Assessment -the normative data for the typical students for each subtest using z scores was analysed to determine “at risk quotients” and cut off points to identify students at risk for handwriting deficits for each subtest on the Handwriting Screening Assessment.

Part 3: The validity of the Handwriting Screening Assessment based on at risk quotients - Difference between the ARQs for the typical students and those referred for assessment were determined as well as the clinical accuracy of each subtest based on the ARQs. Hypotheses for the convergent and divergent validity of the Handwriting Screening Assessment and other standardised tests were determined.

Chapter 7 Phase 2: Results

This chapter presents the results of Phase 2 which were analysed in three parts to confirm the validity and reliability of the Handwriting Screening Assessment and to determine norms and cut off points which indicate the risk for dysgraphia or handwriting deficits.

Part 1: Construct validity and reliability of the Handwriting Screening Assessment - the differences for known group factors for the typical students and those referred for handwriting assessment were established as well as the differences between the two groups of students for the scores on the three sections of the Handwriting Screening Assessment.

Part 2: Cut off points and at risk quotients for the Handwriting Screening Assessment -the normative data for the typical students for each subtest using z scores was presented. The use of “at risk quotients” and cut off points to identify students at risk for handwriting deficits for each subtest on the Handwriting Screening Assessment was introduced.

Part 3: The validity of the Handwriting Screening Assessment based on at risk quotients - The results indicated a significant difference between the ARQs for the typical students and those referred for assessment. Satisfactory clinical accuracy based on the ARQs, for the specificity of the Handwriting Screening Assessment was found. Hypotheses for the convergent and divergent validity of the Handwriting Screening Assessment and other standardised tests were accepted with the exception of those related to visual function.

Chapter 8 – Phase 2 Discussion

This chapter discusses the findings in Chapter 6 and considers the demographics of the typical students and those referred for handwriting assessment as well as the construct validity of the **Handwriting Screening Assessment**. The validity studies were reported in three phases

- *This Part 1: Construct validity and reliability of the Handwriting Screening Assessment* – discussion of the construct validity and reliability found indicated these were satisfactory but they could be improved with revision of some subtests.
- *Part 2: Cut off points and at risk quotients for the Handwriting Screening Assessment* - the use of a common score allowed for the identification of risk based on different components of handwriting.
- *Part 3: The validity of the Handwriting Screening Assessment based on at risk quotients* - the implications of the clinical accuracy of the assessment was discussed as well as the convergence to handwriting outcomes only. Other assessments are needed to evaluate components of handwriting related to the writer and the presentation of writing.

Chapter 9 - Phase 3: Methodology and Results

Phase 3 Usability of the Handwriting Screening Assessment for the target population

This phase was presented in 2 parts: -

Part 1 Deficits related to handwriting in students referred for assessment - The data in Phase 2 were further analysed to determine the characteristics of the components of handwriting identified by the Handwriting Screening Assessment for the target population. The items in each subtest of the Observation Checklist, and the Writing Checklist as well as the subtests of the Handwriting Outcomes were further analysed for the sample of students referred for assessment of handwriting

Part 2 Utility of the Handwriting Screening Assessment for students with dysgraphia or handwriting deficits - the utility of the Handwriting Screening Assessment included identifying the types of dysgraphia with which students referred for handwriting assessment presented to guide the recommendation of concessions. The outcomes of the concessions were explored in terms of the students' academic achievements

The results are presented in two parts. The first part is based on data of students referred for handwriting assessment and the second part on students who were identified with dysgraphia or handwriting deficits.

Part 1 Deficits related to handwriting in students referred for assessment - The characteristics of the factors related to the history of handwriting problems questionnaire and the items and subtests with deficits as well as their correlation to the level of risk for dysgraphia or handwriting deficits is presented.

Part 2: Utility of the Handwriting Screening Assessment - The analysis of subtests related to the different types of dysgraphia was presented. The difference for the academic outcomes of the students who received extra time concessions over two years was established.

Chapter 10 - Phase 3: Discussion

This chapter discussed the factors related to the history of handwriting problems and which significantly affect handwriting and the risk for dysgraphia confirmed the results of Phase 1 for this aspect. The characteristics of deficits in components with which students referred for assessment present, on the three sections of the Handwriting Screening Assessment were considered as well as some components of handwriting which have a moderate or strong correlation with the risk for dysgraphia. These deficits are paired with suggested assessments to confirm the presence of components affecting handwriting.

The type of dysgraphia related to this target population with recommendations for concessions were discussed. The academic outcomes of the students over two years indicated that for students who received extra time concessions the number of students who repeated courses decreased.

Chapter 11 – Overview of the study and Conclusion

This chapter presents a summary of the findings of the study for the three phases in a sequential manner. The strengths and contributions of the study as well as the limitation for all phases are presented as well as the limitations of the study for all three phases. Recommendations for further research are included.

CHAPTER 2
REVIEW OF THE LITERATURE

2.1 Introduction

This chapter reviews the literature on handwriting in higher education and the effect of deficits in handwriting and dysgraphia as well as awarding of concessions for these deficits. The background and importance and need for handwriting as well as the literature on types of dysgraphia and the assessment of hand writing are considered. There is a paucity of literature on handwriting in typical adults and students in higher education and therefore literature on handwriting deficits in children have been considered in order to present the background to deficits in handwriting. The assessment of handwriting was examined, mostly in relation to children. The components of handwriting were presented within the framework of motor and process performance skills and client factors required for handwriting in relation to the writer, the presentation of writing and handwriting outcomes.

Literature was sourced form the following databases: Science Direct, Elsevier, EBSCO Host, Proquest, ERIC, MEDLINE, CINAHL PsycInfo databases and Pubmed. The following keywords were used for this literature search: handwriting, dysgraphia, assessment of handwriting, academic concessions or accommodations in higher education, handwriting in occupational therapy practice.

2.2 Handwriting in Higher Education

Although a marked increase in the use of technology since the 1990s has decreased the need for handwriting in higher education, handwriting still appears to be the most common form of examination assessment used in universities. It appears that different and innovative forms of assessment suggested in research for use in higher education have rarely been adopted [Bronowicki, 2014]. There is little published on the type of examinations used in higher education, with only one study by Iannone and Simpson in 2012, on assessment of mathematics in UK universities, finding that between 45%-96% of marks are still awarded for closed book written examinations [Iannone and Simpson, 2012]. Internationally university websites indicate examinations are mostly of the closed book type with imposed time limits and little or no choice of questions. Depending on the course, short or essay type questions are used to assess application and critical analysis of information particularly in the later years of study [Brown et al., 2013]. Typed, computer based examinations used in the United States of America (USA) in many law schools and the law bar examinations [Mogey et al., 2008], are not offered in South Africa. In this country universities and regulatory boards for accounting and law as well as medical specialities all still provide qualification by means of long written examinations [Legal Education and Development, 2015; The Colleges of Medicine of South Africa, 2016; The South African Institute of Chartered Accountants, 2015].

This means that students presenting with handwriting deficits or dysgraphia are at a disadvantage when they are assessed using written examinations. Nearly a third of the 6% of students declaring their disabilities when entering higher education in the USA still present with deficits related to SLD including dysgraphia. This is due to deficits related to SLD persisting into adulthood. Research has found that although intervention can influence certain areas of the brain affected by learning disabilities there is no evidence that it can normalise the functional connectivity of all brain systems [Stein et al., 2011].

2.2.1 Dysgraphia in Higher Education

It is not uncommon to find dysgraphia or handwriting deficits in intellectually gifted individuals who achieve a place at university [Berninger and May, 2011], but these students have to exert extra effort to achieve academically at the same level as their peers [Berninger and Wolf, 2009]. These students have usually been well supported, have had concessions while at school or have managed to compensate in some other way for their deficits. Inclusion policies have therefore been extended to universities to assist with the transition of students with disabilities including dysgraphia or handwriting deficits into higher education [Reis et al., 2000].

This is not always successful and these students may still have to repeat years or change courses. Success at university therefore still depends on the support provided for these students if they are to achieve according to their potential. The compensation strategies these students have used previously may no longer be adequate due to the increased need for self-management and the academic work load. These students often manage at the school level and even if they do not meet their potential at school often their SLD is only recognised for the first time at university. They may also face social isolation due to the longer hours they need to complete the work assigned, as well as associated low self-esteem, as they often feel they should perform better [Casale, 2009]. Glenn et al. (1997) found, when they screened students in a graduate medical programme, that a number presented with previously unrecognised milder learning disabilities, which students had compensated for by using note taking services, changing courses to avoid those with a large volume of reading or putting in extra study hours. They found a prevalence of 15% for some types of learning disability in their sample [Glenn et al., 1997] which is much higher than the 1-2% previously reported for medical students [Walters and Croen, 1993]. The study by Glenn et al. (1997) included a small sample of 84 participants who self-reported learning deficits on a 50 item questionnaire. The authors felt the results were affected by the stringent expectations medical student set for themselves compared to other university students so these results must be interpreted with caution.

A study on disability units in South African universities estimate that less than 1% of students utilise the services of these units [Healey et al., 2011] Part of the support that should be offered by disability units is to provide guidance and compensation to assist with completion for written examinations (Pirttimaa et al., 2015). The provision of this support may be hampered by the limited awareness of students and staff at universities, about dysgraphia and the availability of services for students with these problems. In order to provide timeous adequate concessions and reasonable accommodations for students, adequate assessments for disabilities as well as policies should be formalised [Healey, 2014; Heiman and Kariv, 2004; The Organization for Economic Cooperation and Development, 2011].

2.2.2 Effect of dysgraphia in higher education

The term dysgraphia was not found in relation to higher education in the databases searched but a number of studies on dyslexia which included writing problems, but not the effect of the handwriting process, were sourced. Poor handwriting in these studies has been shown to result in lower marks as markers can misunderstand the written text or symbols of students with poorly presented or illegible handwriting [Graham et al., 2007]. Research by Chase (1986) and Hughes et al. (1983) on college students found that marks were affected by both the legibility and presentation of the students' handwriting and an inability to finish examinations due to poor writing speed [Chase, 1986; Hughes et al., 1983]. Results in this field of research are however controversial and Eames and Loewenthal (1990) found that university lecturers were more lenient in terms of poor handwriting than school teachers and that the quality of handwriting did not affect students' marks in higher education [Eames and Loewenthal, 1990]. A later systematic review by Graham et al. (2011) on dysgraphic handwriting in higher education found that handwriting deficits were associated with a drop in marks from the 50th percentile to between the 48th and 23rd percentile [Graham et al., 2011].

Gregg et al. (2007) discounted the effect of the legibility of handwriting on marks by assessing essay writing in a limited time, on a sample of 130 university students with and without dyslexia. They found that the presentation of writing in terms of ability to spell and use sophisticated vocabulary rather than legibility affected the students' marks [Gregg et al., 2007]. A study in 2015 confirmed the role layout and presentation of the written work. The marks of students in an engineering faculty, trained on effective presentation were compared to those of students who were not trained. The trained students received significantly higher marks indicating markers are also influenced by layout and presentation of answers in written examinations [Awasekar and Halkude, 2015]. Thus, dysgraphic students who present written answers that are poorly laid out, with corrections and additions may be disadvantaged in terms of marks, irrespective of the legibility of their writing.

2.2.2.1 Effect of dysgraphia in examinations

Students with dysgraphia and handwriting deficits can be compromised in a number of ways by handwritten examinations particularly when there are time constraints. The more than expected sustained effort to produce writing [Berninger et al., 2008a] has been associated with an aversion to writing and the need to use working memory to produce the writing. This includes the need for more attention and visual feedback than is expected when executing, what is assumed in adults to be, an automatic skilled motor task [Tucha et al., 2008]. In this case, the amount of working memory used to produce letters and writing distracts from the working memory available for higher-level processes such as the coherence and complexity of composed text. The students may lose focus especially if they write slowly and are not be able to keep up with their ideas and their train of thought is lost before it is written down. A lack of automaticity in handwriting also means that higher cognitive processes are not freed up for the generation of ideas and retrieval of information in examinations [Medwell and Wray, 2007].

Thus, students may not be able to complete or perform well in examinations requiring complex cognitive processing and may also not be able to finish examinations due to deficits in handwriting components. Writing may be slowed down, in an attempt to make it legible or prevent errors to preclude the loss of marks due to poorly presented or illegible answers. Students may be constrained by the lack of automaticity and dysfluency of their writing and an inability to use the required higher level processes required for answering examination questions, further affecting their academic progress and emotional wellbeing [Chase, 1986; Graham et al., 2011; Gregg et al., 2007; Hughes et al., 1983].

Since dysgraphia and handwriting deficits are difficult to remediate once a student has reached a tertiary education level, adaptations or accommodations have been shown to be preferable for these students with a high level of academic ability [Reis et al., 2000]. The intervention suggested at this stage, is to provide appropriate concessions. Temporary concession may be needed for dysgraphia related to other conditions such as hand injuries [International Dyslexia Association, 2012; Jones, 1999].

2.2.3 Concessions in higher education

Concessions are awarded in higher education to prevent students with disabilities from being compromised in achieving academic success [Scott, 1997; Truell et al., 2004]. An argument has been presented that academic concessions, particularly extra time for examinations, disadvantages other typical students [Zuriff, 2000]. Research on whether awarding extra time or typing concessions could be considered fair to other students found that overall it appeared that students identified without a disability did not benefit from extra time in most examinations. Ofiesh (2000) found that if typical students were offered extra time for examinations, they either did not use the time or if they did write for a longer time, the extra time made no difference to the marks they achieved [Ofiesh, 2000]. According to the Maximum Potential Thesis (MPT) described by Zuriff in 2000, students without a disability were able to work at their maximal potential in timed examinations and therefore did not achieve better results if extra time was offered. This was supported by Truell et al. (2004), using a 2 X 2 Latin square quasi-experimental design to determine if concessions might benefit 64 post-secondary students without learning problems. They found that when a typing concession using a word processing programme was provided the students completed an essay examination more quickly but no higher marks were awarded. When the students were offered a combined typing and extra time concession they wrote substantially longer essays for which they were awarded higher marks, compared to those who had extra time but hand wrote their essays. Based on these findings it was agreed that the awarding of any single concession to these students did not benefit them and that concessions for students with identified problems should not be restricted [Truell et al., 2004; Zuriff, 2000]. Students with learning or other disabilities, who process information more slowly or in a disorganised way as well as those who have inefficient motor skills affecting motor output, needed the extra time or other concessions to achieve their maximal potential [Zuriff, 2000].

The literature makes it clear however, that when awarding concessions, the student should be offered support in terms of assisting with studying as well as examination technique. This process should be a partnership between the disability units on university campuses and the student. It is also important that the student uses the concessions and further develops their own skills to deal with their academic challenges in writing assignments and examinations. Programmes offered assistance should be individualised for each student [Pirttimaa et al., 2015].

Internationally criteria that determine the regulations for eligibility for academic concessions in examinations are legislated for secondary education, by various educational bodies. At a secondary level both the Independent Examination Board (IEB) [IEB Assessment Matters, 2014] and Provincial Education Departments [Gauteng Department of Education, 2012] have an assessment list and official procedures for academic concessions for handwriting deficits and dysgraphia. These include concessions similar to those offered at Wits [Ferrier et al., 2013] but may include the use of a scribe or amanuensis to complete the examinations. There is no legislation detailing assessments at a post-secondary or university level in South Africa. As for other universities, Wits has developed its own policy and criteria to accommodate students with disabilities and learning disabilities [Healey, 2014; Riddell et al., 2007].

In secondary education, criteria for the application of concessions based on standardised assessments which include processing speed, reading and handwriting include standard scores below 85 (-1 SD below the mean or scaled score of 7). Students should have standard scores below 70 (-2 SD below the mean or scaled score of 3) to be awarded a 100% time concession of 15 minutes per hour. Students with illegible handwriting and severe spelling or grammar problems who do not have writing speed problems below a standard score of 85 may still be awarded a scribe concession [Ferrier et al., 2013], However, no such clear cut off points exist for awarding academic concessions at universities. Legislated guidelines in the USA state that students should receive accommodations, so that their examination results reflect their achievement level, rather than the level of their impairment with the JCQ in the UK awarding concessions of 25% and 50% more time for examinations [Joint Council for Qualifications, 2015].

2.2.3.1 Assessment for Concessions

The extensive use of IQ tests that occurs in secondary education to identify learning disability is controversial at a university level and is considered unnecessary, with systematic assessment of the indicated difficulties being recommended [Siegel, 1999a]. It is suggested that standardised tests be used as a means of comparing the students' performance against that of their peers, so that a fair allocation of concessions can be decided.

Lindstrom (2007) suggests that the following steps be followed in assessing students for accommodations

Step 1 Review current research so decisions can be based on evidence,

Step 2 Use standardised testing to determine the nature and severity of the disability,
Step 3 Identify the academic function affected,
Step 4 Get a history of previous accommodations,
Step 5 Select appropriate accommodations making sure there is a match to course demands and the students' ability,
Step 6 Evaluate the effectiveness of the accommodation

2.3 Handwriting

As a background to the need for the assessment of handwriting in higher education the continued role of handwriting in education and the development of handwriting were reviewed.

2.3.1 Importance of Handwriting

Even in this technological age the findings from the 2012 Educational Summit on Handwriting in the 21st Century indicated that there can be lifelong negative implications if children do not acquire adequate handwriting skills. The preparation of learners for tertiary education may be affected if they do not learn to write in primary school. Problems with memory for letters, reproducing letters, spelling, reading comprehension and contextual interpretation of words and phrases are associated with teaching only keyboarding too early at school. It was emphasised that handwriting instruction should continue after Grade 1 until consolidated and that keyboarding should only be taught in more senior years when automaticity in composition of written work has developed [Saperstein Associates, 2012]. This is because the cerebral representation of letters is not solely visual; it also includes a sensory-motor component. Thus, although there is an increase in the use of tablets and computers the importance of learning to manually form letters, for the visual processing of letters cannot be underestimated [James, 2010]. The mastery of the skill of writing, one of the most complex human functions, is therefore considered critical to academic success and everyday functioning when composing text [Graham, 2008; Rosenblum et al., 2004; Saperstein Associates, 2012]. Graham (2008) reported that handwriting is still used by many students, when learning by summarising and writing notes [Graham, 2008]. It has been shown that writing helps memorising, organizing and processing of information so there are sound reasons for students to write as it is handwriting not typing, that facilitates learning in long-term memory [Longcamp et al., 2006].

Most adults still report using handwriting when communicating with others, for creative writing and to record facts [McMahon, 2008]. In their research with adults, Longcamp et al. (2008) reported that a longer-lasting recognition of newly taught characters which had been written by hand compared to those that were not. Visual recognition of graphic shapes and letters, in four to five year old children, has been associated with the specific movement used when learning to write [Longcamp et al., 2005]. Activation of areas of the brain in Broca's area and the bilateral inferior parietal lobules regions only occur when writing and not when typing, indicating these activities do not rely on the same neural pathways and result in different types of learning and skill development [Longcamp et al., 2008]. James and Engelhardt (2012) showed that when children learn to read they recruit areas of the fusiform gyrus, posterior parietal cortex, and the inferior frontal gyrus during letter processing only after handwriting practice and not after other tasks requiring the use of a pencil, like drawing [James and Engelhardt, 2012].

A reduction in the time for the teaching handwriting in primary schools has resulted in a lack of emphasis on handwriting quality and efficiency [Peverly, 2006]. The majority of teachers in the USA and South Africa are reported to be spending less than 15 minutes a day on handwriting skills [Bennett, 2009; Province of the Eastern Cape Education Department, 2011]. This is supported by Santangelo and Graham (2016) in their meta-analysis of handwriting instruction. They reported that in conditions where there is added time for handwriting instruction learners develop better legibility and automaticity in their handwriting. Legibility in particular was improved by individual instruction and the use of technology in the teaching of handwriting [Santangelo and Graham, 2016]. The poor quality in handwriting in primary schools may reflect in a decline in writing quality in higher education which may cause problems for students in studying from illegible notes as well as for lecturers when marking students' examination and test scripts.

It has been shown that those with handwriting dysfunction may experience long term personal and economic consequences, due to the mismatch between intellectual ability and possible reduced opportunities for tertiary education, especially if written examinations are used to confirm entry level competence. They may also fail to achieve their potential in their studies with the added cost for repeating years of study [Graham, 2008].

2.3.2 The development of writing

Initially communication that represented ideas occurred in pictographic or stylised pictures rather than words. Alphabetic or phonologic writing has since developed in most cultures and uses a limited number of symbols to represent the phonemes of a given language. Thus, language can be represented as writing or a “phoneme to grapheme” conversion according to the orthographic or spelling rules of the given language.

The Latin alphabet is used throughout the Western world and languages are defined by specifically prescribed spelling. English speaking countries use similar but not exactly the same spelling rules to represent the language. Unlike the ability to draw, which develops spontaneously from the age of two and half years, writing needs to be taught usually from the age of five to seven years [Deuel, 2001].

2.3.2.1 Development of handwriting

Writing is a highly complex developmental process, which involves the integration of attention, memory, motor skill, language, knowledge and higher cognitive function. Research into handwriting skills and the underlying performance components developed in occupational therapy in the 1990’s. This may be related to the increased frequency of referrals of children with handwriting problems [Reisman, 1991] attributed to increased demands placed on children at school with the effective drop off in handwriting instruction [Graham, 2008].

From an occupational therapy perspective handwriting is considered as a motor skill where the motor component relates to letter production and process skills related to orthographic coding, visual perception as well as memory are used in producing the shape of the letters. Writing requires learning the motor and visual representation of letters which only becomes automatic after hours of practice. Handwriting acquisition therefore requires years of formal instruction [Bara and Gentaz, 2011].

The ability to develop skill in handwriting depends on the neuro-maturational and motor functions which underlie the development of client factors that support initial steps in learning to write [American Occupational Therapy Association, 2014]. Writing readiness based on the consolidation of these skills is essential if a child is to benefit from being taught handwriting at school [Feder and Majnemer, 2007]. Klien (1990) lists the prerequisite client factors a child should have before writing can be taught. These include the development sensory, perceptual and cognitive body functions and client factors. Included is the ability to differentiate shapes and sizes, and the understanding of abstract concepts. Motor client factors that must also be consolidated are good balance in sitting with the arms free, shoulder and wrist stability to facilitate distal control, dominant use of one hand and bilateral integration so the non-dominant hand is used to stabilize the paper [American Occupational Therapy Association, 2014; Klien, 1990]. In 1992 Benbow et al. added midline crossing with the dominant hand, proper posture and pencil grip to the client factors required for handwriting [Benbow et al., 1992].

Handwriting skills need to be taught and practiced with the goal of enabling fast and legible handwriting [Vinter and Chartrel, 2010]. These skills include the ability to produce the alphabet letters, the building block of written language, accurately and automatically. As in the development of all skills, feedback plays an important role and being able to write letters that reflect the writing conventions of the language being taught. Children initially draw letters, but in Grade 1 with practice, visually guided graphic motor patterns related to letter production and the ability to write on a horizontal line become established. The development of several components is also essential in learning to write and includes the graphemic buffer, where letters are held in working memory while movements are planned and executed. While the graphemic system guides motor planning [Rapcsak, 1979], it is the allographic mechanism in which upper and lower case, styles of writing and differentiation among similar shaped letters are remembered [Ellis, 1982]. In typically developing children research has shown that handwriting continues to develop from Grade 1 to Grade 5. The steadiness of the writing trace becomes smooth in the lower grades with an emphasis on letter production changing from printed letters as cursive writing is introduced in Grade 3. From then on writing scripts are consolidated, as a result of changes in the movement patterns used.

From Grade 4, writing becomes more automatic and requires less effort. Each child develops their own style of handwriting as writing becomes automatic in the adolescent years and the quality of handwriting developed at this stage may affect performance in secondary and post-secondary education [Hamstra-Bletz and Blote, 1993].

Reviews by van Drempt et al. (2011) and a study by Gozzard et al. (2012) suggest that demographics, client factors related to hand function, co-ordination, fine motor control and handwriting movements remain important in producing handwriting as an adult writer and deficits in handwriting may be related to these client factors [Gozzard et al., 2012; van Drempt et al., 2011].

2.4 Deficits in Handwriting

The number of children reported to have problems with handwriting vary but a prevalence of 23% and 27% has been indicated [Hammerschmidt and Sudsawad, 2004]. These difficulties may result in poor development of academic skills related to producing written communication [Graham and Harris, 2009], although children with dysgraphia often exhibit good academic achievement in subjects that do not require written essay type answers [Richards, 1999].

Problems with handwriting in adulthood may continue from childhood or may result from other acquired deficits. There is limited research on the effects of handwriting deficits in adults since keyboarding is the common method of written communication [National Handwriting Association, 2014]. Handwriting may become a problem at any age and present as deficits in handwriting outcomes as well as the components which affect the ability to sustain handwriting over time. The placement of writing on the page and the position of words and letters in relation to each other as well as poor spelling and automatic letter formation writing may continue to influence handwriting efficiency [Berninger, 2009].

Handwriting deficits or dysgraphia related to SLD, while often identified in childhood, may not need to be accommodated in terms of academic concessions until the individual is an adult. These deficits have been shown to be co-morbid with other disabilities such as attention deficit hyperactivity disorder (ADHD) and development coordination disorder (DCD) [Berninger and May, 2011] therefore, when assessing dysgraphia a history of signs of other co-morbidities should be noted [Chung and Patel, 2015]. Other conditions in which handwriting difficulties present are not necessarily related to SLD. Some of the other conditions associated with poor handwriting include injuries to the hand, brain injury, focal dystonia or writer’s cramp and hypermobile joint syndrome [Frohlich et al., 2012; Silva-Fernández and Sanz, 2011].

Many students no longer get to practice writing on a daily basis as a large number of them are using keyboards and for the majority of students examinations are the only time they are expected to produce handwritten work [Connelly et al., 2005]. This lack of practice appears to exacerbate deficits in production of letters and motor fluency required for handwriting in students with handwriting problems or dysgraphia. These students may develop cumulative trauma or repetitive strain injury, resulting in pain so severe that it affects their ability to write even for short periods. Due to lack of handwriting practice these students report being further compromised when writing as well as experiencing more fatigue and pain, especially since handwriting must be executed fast within time constraints in examination contexts [Paton, 2014; Peverly, 2006] .

2.4.1 Defining handwriting deficits or dysgraphia

In the health science domain, where recognised diagnostic texts are used and in some other official state bodies providing concessions, poor handwriting and spelling without evidence of other writing difficulties have not yet all recognised as separate from dyslexia [Osmon et al., 2007]. However based in part on the research over 30 years by Berninger and her colleagues a distinction between disorders of reading and written expression or dyslexia and disorders of handwriting or dysgraphia is now becoming accepted [Berninger et al., 2008a].

Dysgraphia includes skills related to the production of handwriting excluding other high level cognitive skills required in written expression of ideas [Berninger, 2009; Rosenblum et al., 2010]. Most authors reporting research on handwriting agree that dysgraphia is a writing disability concerned with the mechanical skill and automaticity of writing, resulting in deficits of handwriting components and outcomes of handwriting such as legibility [Chung and Patel, 2015; Deuel, 2001].

The importance of considering dysgraphia as a separate SLD was confirmed by Richards et al. in 2015 using neuroimaging, by comparing 40 children and adolescents identified with dyslexia and dysgraphia, while they completed two written language tasks. This study found decreased white matter integrity with significant differences in the areas of the brain affected in dysgraphic participants when compared to dyslexic participants. Perpendicular radial diffusivity (RD) in seven fibre tracts were found on the right side of the brain in the participants with dyslexia and on the left for participants with dysgraphia [Richards et al., 2015]. This study even with a small sample size presents rigour in the methodology which makes a significant breakthrough in identifying dysgraphia as a separate SLD. An important contribution in confirming that dysgraphia can be diagnosed, is different from dyslexia and requires individually assessments and interventions has been presented. The study also indicates that the handwriting and spelling problems related to dysgraphia persist into adolescence supporting the need for specific assessments of handwriting for older students.

It is still disputed however whether spelling and grammar errors related to orthographic coding should be included in the definition of dysgraphia [Nicolson and Fawcett, 2011]. This controversy may be addressed in some part by considering the evidence for different types of dysgraphia. Richards et al. (2015) did find unexpected correlations between white matter integrity and grey matter functional connectivity in their participants with dysgraphia, during neuroimaging in a spelling task. This finding supports the view that those with a primary handwriting impairment may also present with an associated spelling problem where no reading problem exists [Richards et al., 2015].

Assessments of handwriting are therefore now more widely recognised in establishing the eligibility for special services or concessions, for individuals of at least average intelligence. The assessments need to identify factors associated with the students inability to produce acceptable handwriting, even with instruction and practice, regardless of the ability to read [Berninger et al., 2008b; Berninger and Wolf, 2009].

2.4.2 Types of dysgraphia

Different types of dysgraphia have been described by a number of authors and although there is no text comparing these, this review found that different types of dysgraphia can be categorised into three types.

The first type of dysgraphia is associated with motor dysfunction and was described as apraxic dysgraphia, which presents as a disturbance of writing in the absence of spelling and other general language problems [Alexander et al., 1992]. Gubbay and de Klerk (1995) describe this as motor apraxia which results in untidy writing [Gubbay and de Klerk, 1995]. Motor dysgraphia as described by Deuel (2001) is similar to apraxic dysgraphia and is characterised by motor clumsiness with abnormal finger tapping speed and poor legibility in free and copied written text but no spelling problems [Deuel, 2001]. This is similar to graphomotor problems described by Berninger in 2009 [Berninger, 2009]. Gubbay and de Klerk (1995) added a component in this type of dysgraphia which includes an ideational component or the ability to correctly write letters and words that are copied.

The second type relates to dysgraphia with related language problems first described by Gubbay and de Klerk in 1995 as aphasic dysgraphia related to poor handwriting, language disorders and spelling errors. This represents the impaired orthographic coding which was described as part of dysgraphia by Berninger in 2008 [Berninger, 2008; Gubbay and de Klerk, 1995]. This description aligns with Dueul's (2001) classification of dyslexic dysgraphia, where free spontaneously written text is illegible although copied written text is relatively preserved. Spelling is severely abnormal but fine motor function or finger sequencing is intact with finger-tapping speed being generally normal [Deuel, 2001].

The third type of dysgraphia described by Deuel (2001) is spatial dysgraphia, which appears to be similar to constructional dysgraphia described by Gubbay and de Klerk (1995). This type of dysgraphia is related to poor understanding of space and visuospatial problems where there is poor organisation and legibility of free and copied text but preserved spelling and normal finger tapping speed [Deuel, 2001; Gubbay and de Klerk, 1995].

According to this classification of dysgraphia it must be accepted that an individual may present with more than one type of dysgraphia [Deuel, 2001]. Individuals with dysgraphia find writing requires great effort and some manage to achieve legible writing may never attain the automaticity expected. It is clear therefore, that writing associated with dysgraphia or handwriting deficits may not be illegible or slow but sometimes when writing is illegible, speed may be faster than expected but with numerous errors present [Berninger, 2008].

Any of these outcomes and deficits may also be found in individuals that present with handwriting difficulties related to conditions other than SLD that are related to other medical conditions [Chung and Patel, 2015]. This includes neurological and psychosocial conditions such as depression. The side effects of medication can also result in the use of less force when writing and slower handwriting [Tucha et al., 2002]. In order to establish the presence of components affecting handwriting and dysgraphia, free writing and copying of age appropriate information is required.

2.5 Assessment of Handwriting

In the studies on the assessment of handwriting presented below, it needs to be understood that some of the most recognised researchers in this field are based in China and Israel and therefore these studies have been undertaken on scripts other than the Latin script used in this study [Chan and Lee, 2005; Chang et al., 2015; Cheng-Lai et al., 2013; Engel-Yeger and Rosenblum, 2010; Rosenblum and Livneh-Zirinski, 2008]. It has been indicated that for the skill of handwriting the scripts can be considered similar however [Chan and Lee, 2005]. It was therefore accepted that these findings could be considered in the development of the handwriting assessment being undertaken in this study even though writing occurs in a different direction in both scripts which may affect wrist and arm movement.

Due to the importance of handwriting in achieving academic success, a number of handwriting assessments have been published in the last 35 years [Saperstein Associates, 2012]. Although some assessments include students up to the age of 17 years most are designed to assess children when they are learning to write in the lower grades as this is the most appropriate time to offer intervention. A review of these assessments is important in determining the skills and components as well as the strengths and limitations of the assessments when developing an assessment for adults. Other standardised occupational therapy handwriting assessments available for use with adults such as the Handwriting Assessment Battery for Adults are inappropriate for use with higher education students [Faddy et al., 2008]. This is because assessments have been developed to use with clients with known conditions such as stroke and Parkinson's disease which may result in more severe deficits in cognitive and motor function. These assessments therefore lack discriminatory power when used with adults of high ability due to their ceiling effects [Sparks and Lovett, 2009].

2.5.1 Standardised assessments of handwriting

The assessments of handwriting difficulties are usually based on the outcomes of handwriting which include the legibility and speed of writing. Therefore, a number of handwriting assessments commonly reported in the literature that became available commercially in the 1980's and 1990's emphasize the objective assessment of these handwriting outcomes. The assessments measure the quality of the letters and writing when scoring legibility as well as time needed to write a number of letters. More recent assessments also consider the automaticity of writing.

The properties of these handwriting assessments as well as more recently commercially available assessments are presented in Table 2.1 based on the criteria on the COSMIN checklist [Feder and Majnemer, 2003]. Due to the length of time since some of the tests were first published some validity and reliability data for the tests could not be retrieved. Factor analysis and handling of missing data were also not reported for the handwriting assessments.

The assessments reviewed were tested on adequate samples ranging from 1723 to 161 participants although one had a very small sample of 33 participants. Many of these assessments are still used for research and accommodate different scripts for Chinese and Hebrew writing but the use of these assessments in South Africa has not been reported.

Table 2.1 Summary of Handwriting Assessments

	Concise Evaluation Scale for Children's Handwriting (Brave Handwriting Kinder – BHK), [Hamstra-Bletz et al., 1987]	The Children's Handwriting Evaluation Scale-Manuscript (CHES-M) and cursive (CHES-C) [Phelps and Stempel, 1987]	Test of Legible Handwriting TOLH [Larsen and Hammill, 1989]	Minnesota Handwriting Assessment (MHA) [Reisman, 1993]	Evaluation Tool of Children's Handwriting (ETCH) Manuscript (ETCH-M) and cursive (ETCH–C [Amundson, 1995]	Hebrew Handwriting Evaluation (HHE), [Erez and Parush, 1999]	The Print Tool [Olsen and Knapton, 2008]	Handwriting Assessment Protocol (Pollock et al., 2009)	Detailed Assessment of Speed of Handwriting (DASH) [Barnett et al., 2007]	Detailed Assessment of Speed of Handwriting 17+ (DASH 17+) (Barnett et al., 2010)
n for standardisation	161 over 5 years	643	1723	565			33	n/a	546	393
Type of test	Evaluation	evaluation	evaluation	evaluation	evaluation	outcome	outcome	clinical guide	evaluation	evaluation
reference		norm	criterion	norm	criterion	norm/ criterion	criterion	criterion	norm	norm
Range	Grades 4-5	Grades 1-6	7 - 17 years	Grades 1-2	Grades 1-6	Grades 4-5	Grades 0-4	Grades 3-6	9-16 years	17-25 years
Test Domains										
Alphabet writing	X				X	X	X		X	X
Numeral writing	X				X		X			
Near-point copying	X	X			X	X		X	X	X
Far-point copying and dictation				X	X			X		
Free writing			X	X	X	X			X	X
Handwriting speed	X	X		X	X	X	X	X	X	X
Legibility	X	X	X	X	X	X	X			
Automaticity						X	X		X	X
Scoring										
	13 criteria on writing	10 criteria – score 100	5 samples on 3 guides	5 letter scoring categories	7 criteria	3 criteria 1-4 point scales	5 scales with set criteria	criteria - each component	2 criteria- 5 scales	2 criteria- 5 scales
Percentile		X	X	X			X		X	X
Standard /Scale			X	X					X	X
Total scores	X		X		X	X	X		X	X
Psychometrics										
Reliability: Interrater	r (0.76-.0.89)	ICC (0.85 - .0.93)	r (0.96)	r (0.87-0.98)	r (0.75-0.92))	r (0.75-0.79)	Still in progress		ICC (>0.80)	ICC (>0.90)
Inter-rater		ICC (0.65 - 0.81)		r (0.93-0.99						
Test retest			r (0.97	r (0.68-0.94	r (0.63-0.77)				r (0.50- 0-.92)	r (0.78 - 0.96)
Validity Supported										
Criterion-related	yes		yes		yes					
Construct			yes	yes	yes				yes	yes
Content			yes	yes					yes	yes

Reviews of the handwriting assessments listed in Table 2.1 presented some concerns which include the objectivity and training of the evaluators, different modes of assessment, types of writing as well as the criteria using for scoring [Feder and Majnemer, 2003; Rosenblum et al., 2003b]. Limitations and strength of the assessments are considered in terms of their usability and psychometrics

Very few assessments present studies that indicate differences between typical children and those with handwriting deficits which is important to determine the construct validity of the assessment in norm referenced assessment as most assessments were criterion related. This makes the identification of dysgraphia or handwriting deficits in relation to the performance of peers difficult as norm reference assessments are preferable for identifying individuals who require concessions for handwriting deficits [Rosenblum et al., 2003b]

A number of handwriting assessments such as the Print Tool [Olsen and Knapton, 2008], Evaluation Tool of Children's Handwriting (ETCH) [Amundson, 1995], the Children's Handwriting Evaluation Scale (CHES) [Phelps and Stempel, 1987] and Minnesota Handwriting Assessment (MHA) [Reisman, 1993] were designed for children learning to write in primary school. This resulted in the development of strict criteria against which each letter was measured and scored [Rosenblum et al., 2003b]. While the use of these scoring criteria have made the assessments more objective, the Print Tool [Olsen and Knapton, 2008] and the ETCH [Amundson, 1992] in particular have been criticized for of the time required to score the handwriting on all the criteria.

The criteria for the evaluation of the writing according to form, alignment, size and spacing as well as the scoring for legibility of letters or words, also differs for each assessment making it difficult to compare results. This also limits the development of a data base for norms against which handwriting can be compared in the classroom. The assessments also use different modes of writing like copying and free writing with copying being the most common form of assessment (Ziviani & Elkins, 1984).

The handwriting assessments differ in their purpose with most being evaluation assessments intended to identify children with dysgraphia or handwriting deficits.

Very few handwriting assessments are outcome measures intended to determine the effect of intervention of handwriting. The intended purpose of some tests has however, been extended in research. The Concise Evaluation Scale for Children's Handwriting (Brave Handwriting Kinder-BHK) [Hamstra-Bletz et al., 1987] for instance has been used as an outcome measure to assess the effectiveness of physiotherapy on handwriting speed in an experimental study on 35 children [Smits-Engelsman et al., 1996].

The psychometric properties of some of the handwriting assessments are limited, with most assessments not considering different demographic factors. Interrater reliability and test-retest reliability range from low to high and not all assessments have sufficient reliability. Many assessments have incomplete validity studies except for the TOLH [Larsen and Hammill, 1989] and the recently developed DASH and DASH 17+[Barnett et al., 2007, 2010]. Few provide detailed objective information about handwriting components and what affects the child's ability to write.

2.5.2 Usability of Handwriting Assessments

Although the use of handwriting assessments is reported in research it appears that due to the limitations described above, the usability of these assessments in clinical settings by therapists and teachers is limited as they still rely more on subjective observation of handwriting [Rosenblum et al., 2004]. There is no recent literature on the use of handwriting assessments by occupational therapists although these findings are supported informally in a blog. The blog indicates that only a more recent developed assessment, the Print Tool is used in the USA by some therapists who provide intervention for handwriting deficits [The Anonymous OT, 2013].

Research on the use of handwriting assessments with university students has been reported by Summers and Catarro (2003) who used the Handwriting Speed Test (HST) [Wallen et al., 1996] developed in Australia, Li Tsang et al. (2011) using the Chinese Handwriting Assessment Tool (CHAT) and Shah and Gladson in 2015 who used the MHA [Li-Tsang et al., 2011; Shah and Gladson, 2015; Summers and Catarro, 2003]. All these assessments were developed to be used with children and assess the speed and legibility of handwriting. This indicates the lack of appropriate assessments inclusive of other handwriting components for adult students and the need for an assessment specifically developed for this population.

2.5.3 Assessment of Handwriting Outcomes

2.5.3.1 Legibility of handwriting

There is no ideal scale for the assessment of legibility. There are also no normative data or gold standards for the assessment of legibility in adult or children's handwriting. While standards for legibility have been set in the forensic analysis of adult handwriting, these are arduous and time consuming and are aimed at distinguishing between different writers. The legibility or the readability of handwriting is the most difficult component to score objectively and is a controversial issue in research as the interpretation of what is legible is dependent on the individual reading the written work [Dennis and Swinth, 2001]. This subjective interpretation of legibility as well as the variation in handwriting has affected the reliability of legibility scores [Rosenblum et al., 2003b].

A number of different scales have been developed to define the legibility of handwriting and include either global rating scales or evaluations that analyse the writing on predetermined criteria [Rosenblum et al., 2003b]. A number of studies have reported on the evaluation of handwriting according to scales or a set of criteria with most agreeing that these should be letter formation, size, slant and the spacing of letters as well as how straight the line of writing is [Bruinsma and Nieuwenhuis, 1991]. The scales include those developed by Rubin and Henderson (1982) as well as the Alston Evaluation Scale (1983) which have been found to have good construct validity and high test-retest reliability (r=0.63-0.97) and interrater reliability (r=0.64-0.95). However the scales have been shown to require revision as their association with global legibility was poor [Graham and Weintraub, 1996; Rubin and Henderson, 1982]

An attempt to address the subjectivity of assessing legibility has been made in handwriting assessments such as the Print Tool [Olsen and Knapton, 2008] and the ETCH [Amundson, 1992] where clear specific criteria are provided for aspects such as letter size, spacing and letter slant. Various other aspects of legibility such as letter formation are considered in detail including the length and width of letters and the alignment of letters to the line. In other assessments such as the CHES [Phelps and Stempel, 1988] , the MHA [Reisman, 2004] and the HHE [Erez and Parush, 1999], legibility is judged on a Likert scale. The CHES [Phelps and Stempel, 1988] uses a five-point scale for letter shapes, slant, rhythm, spacing, and general appearance [Phelps and Stempel, 1988] which has been criticized for not being sensitive enough to identify small changes in writing [Graham, 1986]. A four-point scale is used in the HHE [Erez and Parush, 1999] and MHA [Reisman, 2004] to measure legibility, shape, line-straightness, size, and spacing which is measured in millimetres. However, in the DASH and the DASH 17+ [Barnett et al., 2007, 2010] where the focus is the assessment of speed of writing no specific criteria are given for the identification of illegible words and letters and the evaluator is required to use clinical judgement to assess and count these.

It is impractical to use these criteria to assess the writing of adults who may write with smaller, more individualised letters and a mixture of cursive and printed text more loosely aligned with the lines on the page [Shah and Gladson, 2015]. Letter formation may also deteriorate as handwriting develops an individual style in both adolescence and adulthood so criteria applied in earlier years for assessing individual letters for legibility no longer apply [Weintraub et al., 2007]. Thus, none of the criteria used in these assessments for legibility are suited to assessing handwriting in adults.

In the assessment of adult handwriting, simpler assessments of legibility have been advocated and include the use of transparent overlays to judge letter formation and alignment of writing as well as global legibility scales. The overlays have an acceptable interrater reliability (r=0.86 - 0.97) [Collins et al., 1980] but were not found to be valid as they lacked sensitivity in identifying small improvements [Graham, 1992; Graham and Weintraub, 1996]. The Print Tool makes extensive use of these overlays but reliability data were not available for this assessment [Olsen and Knapton, 2008].

Assessing the legibility or readability of handwriting by identifying unreadable words using global rating scales has been recommended by a number of authors. There is controversy however, about the reliability of these scales, especially the interrater reliability which is usually the only type of reliability available for the scales (Table 2.2).

Table 2.2 Summary of Handwriting Global Rating Scales for Legibility

	Four-Point Scale (FPS) [Akoria and Isah, 2009; Rodrıguez-Vera et al., 2002]	Modified four point scale (mFPS) [Au et al., 2012]	Seven point scale of global legibility [Weintraub et al., 2007]
n	117/50	30	134
referenced	criterion	criterion	criterion
Scoring	1-4	1-4	1-7
	Legible to illegible	Legible to illegible	Legible to illegible
	Descriptors for each score	Descriptors for each score	
Psychometrics			
Reliability: Interrater	ICC (0.60 - 0.85)	letters ICC (0.50) words ICC (0.39).	r {0.83)
Internal consistency	Cronbach's Alpha (0.65)	Cronbach's Alpha (0-37-0.75)	
Test retest			
Validity Supported			
Criterion-		yes	
Construct		yes	
Content			

The four point scale (FPS) [Rodrıguez-Vera et al., 2002] has been used in research when assessing handwriting in typical adults by Gozzard et al. (2012) with 16 participants between the ages of 20 and 24 years. The participants all scored 3 (many words legible; the meaning of the text can be understood) or 4 (most or all words legible) on the FPS indicating a ceiling effect. This study was flawed by the small sample size and participants who had legible handwriting which indicates some of the problems with global scales [Gozzard et al., 2012].

The more sensitive seven-point scale of global legibility suggested by Weintraub et al. (2007) is more sensitive and probably provides less of a ceiling effect in typical adults. A study found that letter formation and spatial organisation of letters most affected global legibility, and these factors accounted for 24% of the variability in the legibility using the seven-point scale [Graham et al., 1989; Weintraub et al., 2007]. Therefore, this scale presents the best option for the assessment of legibility in adults in relation to the number of unreadable words for each of the seven points on the scale.

2.5.2.2. Speed of handwriting

Handwriting speed is commonly assessed as the average number of letters or words written per minute or the length of text produced within a specific time [Graham et al., 1998]. Normative data for adult handwriting speed has been reported on writing letters in the alphabet and the 24 letter sentence in the Jebsen–Taylor Hand Function Test [Jebsen et al., 1969]. Other speed norms for adults on this test were published in the 1980’s [Agnew and Maas, 1982] and 1990’s [Hackel et al., 1992] with most normative data for adults based on copying sentences rather than self-generated text [van Drempt et al., 2011].

In the study by Gozzard et al. (2012) the normal handwriting speed for 16 adults between 20-24 years is 112.2 letters per minute (LPM) which changed to 137.2 LPM when writing as fast as possible. They found no significant relationship between factors such as gender, legibility and writing style [Gozzard et al., 2012]. Li-Tsang et al. (2011) in their study of writing using digital tablets found typical students in Hong Kong had a writing speed for English (Latin) letters of 137.5 LPM. They indicated this was faster than the speed reported by other Western studies and indicated the cultural and contextual aspects which need to be taken in to account when assessing handwriting speed, as well as the need to develop norms for each country [Li-Tsang et al., 2011].

Other studies reported on written words per minute (WPM), making it difficult to compare the speed of writing across the various studies. Barnett et al. (2010) reported speeds of between 24-25 WPM for self-generated free writing and 25-35 WPM when copying for students between the ages of 18 and 25 years [Barnett et al., 2010]. Summers and Catarro (2003) found students wrote between 34-51 WPM on a short 3 minute writing test but only 9-26 WPM in long two hour examinations indicating that there is great variety in the number of words written in different circumstances [Summers and Catarro, 2003].

The revised York Adult Assessment Battery, although essentially an assessment of dyslexia for use with students in higher education with learning disabilities, has a component for writing speed. When the assessment was used with university students Warmington et al. (2013) found a significant difference (p=0.002) in writing speed WPM between students identified with dyslexia or a learning disability (mean= 27.02 WPM, SD 4.34) and typical students (mean= 31.42 WPM, SD 4.20);[Warmington et al., 2013]. These studies provide a range of WPM for typical students when copying against which results for South African students can be compared.

2.5.2.3 Handwriting automaticity

In 1991 Berninger, Mizokawa, and Bragg described a simple standardised assessment for the automaticity of handwriting, the Writing Speed and Accuracy Measure (WSAM). This consisted of writing out as many of the 26 letters of the alphabet in sequence as quickly as possible, in one minute. The interrater reliability for the WSAM was 0.99 [Berninger et al., 1991]. Rodríguez and Villarroel (2016) found that as children learn to write, the alphabet task unlike spelling tasks continues to test orthographic knowledge and probably working memory as well as automaticity in handwriting [Rodríguez and Villarroel, 2016]. The numbers of letters written in the WSAM or Alphabet Task has been shown to be associated with the young child's ability to compose text (r= 0.73) [Jones and Christensen, 1999].

Assessing the speed, legibility and automaticity of students' handwriting has been used to determine if their handwriting compromises their ability to finish examinations. A review of the performance skills handwriting in section 2.7 indicate components of handwriting and client factors should also be considered in identifying the reasons for the deficits and that handwriting outcomes alone are not an adequate reason for providing concessions. By identifying and scoring these handwriting components in a screening assessment, related client factors can be specifically identified and targeted using other standardised assessments.

The observation of the performance of the writer and the presentation of the writing should also be included in a comprehensive screening assessment for dysgraphia and handwriting deficits.

2.5.2.4 Assessments of other components of handwriting.

Some of the standardised tests of handwriting do require the observation of components related to the writer, but these are not formally scored [Barnett et al., 2007, 2010]. Pencil pressure, pencil grasp and pencil manipulation are observed in the ETCH as well as the Handwriting Assessment Protocol which provides a checklist and norms for various primary school grades [Amundson, 1995; Pollock et al., 2009]. Only in the HHE which assesses writing in Hebrew, are criteria set to measure the ergonomic factors, body posture, pressure on the pencil, positioning of the paper and repositioning of the grip on the pencil. These components are scored on a four point scale and the scores are considered separately from the writing speed and legibility scores [Erez and Parush, 1999]. Errors in writing related to the identification of specific learning disabilities are also scored on the HHE [Rosenblum et al., 2003b; Stott et al., 1987].

The use of descriptors or detailed statements to describe actions and behaviour associated with handwriting have been researched and explained in the occupational therapy literature since 1983. Most studies have considered pencil grasp descriptors with 1 indicating a dysfunctional grasp and 2 indicating functional grasp. Ziviani (1983) first used descriptors in handwriting assessment with descriptors related to flexion of the index PIP joint, the number of fingers on the pencil, the pad to pad opposition of the thumb to the fingers as well as the pronation of the forearm being observed [Ziviani, 1983]. Other studies included a description of the position of the distal interphalangeal joint (DIP) of the index finger. Sassoon et al. (1986) observed 294, 7 year old learners and added descriptors for the upper body posture, paper orientation and paper position [Sassoon et al., 1986].

Blöte and Dijkstra (1989), extended the use of descriptors to assess posture and writing movements in preschool children. The descriptors were equivalent to yes (actions and behaviour observed) and no (behaviour not observed);[Blöte and

Dijkstra, 1989]. Further descriptors associated with pencil grasp were added by Lyytinen-Lund (1998) in a study including 503 learners between 7 to 12 years of age. The checklist of pencil grip descriptors she developed used a scale with between two and four categories with 01 for functional descriptors. The checklist was tested for interrater and test retest reliability by photographing the children's hands. The results for the reliability for the checklist are not reported in available literature.

These studies confirm the use of descriptors based on a scale of two to four points provide an option for the assessment of components of handwriting related to the writer including their pencil grip, posture, and paper position as well as finger positions. These descriptors have not been used to assess adult hand writers and it is unknown if deficits are seen in similar components in students in higher education.

2.5.4 Digital handwriting assessments

Rosenblum and her colleagues reported their concern that handwriting assessments relate mostly to the written output and not to the process of or performance during handwriting. These authors considered these aspects as important in achieving an overall view of the individual writer's ability to write efficiently. They developed an assessment the Penmanship Objective Evaluation Tool (POET) in Israel for evaluating the handwriting process using a digital tablet [Rosenblum et al., 2003b]. This technologically based handwriting assessment measures the force, velocity and direction of movements related to handwriting [Rosenblum et al., 2004]. It also allows for a more objective measure of efficient handwriting movements in terms of speed and includes assessment of individual aspects of letter and word formation and allows analysis of the dynamic movements in the hand of children with and without dysgraphia or handwriting deficits [Rosenblum et al., 2003a]. A similar assessment, the CHAT which assesses the speed, writing pressure and accuracy of both Latin letters and Chinese characters, has been developed in China [Cheng, 2010].

The results of assessments using digital tables have found specific differences in temporal and spatial characteristics between children and older students with and without handwriting difficulties including the time participants’ pens were not on the writing surface (in air time). Children with writing difficulties have been reported to have longer in air time as well as motion of the pen while it is in the air. A review of 12 studies on dysgraphia assessed on digital tablets, indicate that research using this assessment method is able to focus on specific measures including movement fluency [Danna et al., 2013a].

Even assessment of handwriting using digital tablets is not without problems however. Assessments such as the POET requires access to the technology and software as well as training with the assessment having little usability in the clinical and educational field for those who assess and work with children and students with dysgraphia [Rosenblum et al., 2006]. There has been no standardisation in terms of the stylus used [Danna et al., 2013a] and in many of the assessments the tablet is placed vertically affecting the position of the hand. Writing with a stylus on a tablet also differs from writing on paper with a pen or pencil. There is still little clarity on the differences between normal fluctuations in speed and those which occur as a result of variations and pauses due to motor deficits [Danna et al., 2013a; van Galen et al., 1993].

2.5.5 Screening Assessments

Screening assessments designed for educational settings are developed to correctly identify students who need specific services. Problem identification on screening assessments provided information for further assessment and intervention for the specific deficit or disorder.

2.5.4.1 Criteria for screening Assessments

Screening assessments need to be developed according to a set of clearly defined steps recommended for instrument development. These steps differ slightly depending on the reference used but according to Schultz and Whitney, (2005), McCoach (2013) and Laver Fawcett, (2013) fall into: determining what is to be measured; specifying the type of measure; identifying the primary purpose of the assessment; selection and definition of domains to generate an item pool; identifying behaviours that represent the construct or domains and establishing the dimensionality of the assessment and domains.

The measurement format must then be established with the number of items and scoring defined. The items should be validated and reviewed before field testing on a large group to determine the psychometric properties of the assessment and to evaluate reliability and validity. After adjustments, have been made according to these outcomes guidelines for administration, scoring and interpretation of the assessment should be drawn up [Laver Fawcett, 2013; McCoach et al., 2013; Schultz and Whitney, 2005]. According to Glover and Albers (2007) adequate validity studies for a screening assessment should include "(a) content, (b) convergent and discriminant power, (c) internal structure, (d) the relationship with other performances, and (e) assessment consequences" p123 [Eignor, 2013; Glover and Albers, 2007]. A screening assessment for students in higher education should have suitable tasks for adults that can provide information for stakeholders and services the students access in relation to the concessions available at a university level [Glover and Albers, 2007].

2.5.4.2 Validity and reliability of screening assessments

In establishing content validity a precise definition of the domains assessed should be provided with a rationale for the inclusion of these so the content can be checked by experts [Salvia et al., 2012]. This is important as the role of the expert is to rate the relevance of each item, in order to determine whether it is measuring the construct it sets out to measure, and whether it is clear and succinct. At least two subject matter experts (SMEs) should review all items [Davis and Morrow, 2004].

Construct validity for screening assessments be supported by factor analysis or Rasch analysis. Rasch analysis is a one-parameter logistic model where the actions and behaviours as well as the writing of the students (abilities) are located on the same measurement scale as the scores on the items (difficulty). A logarithmic transformation is used to achieve this, so items and persons can be plotted on the same continuum in person-item plots of the underlying constructs, or the variable that the assessment is intended to measure. In the current study this is either components of handwriting related to the writer or the presentation of the handwriting.

The Rasch model calculates these traits on the assumption that students with less ability will have less chance of meeting the criteria set by the assessment [Andrich et al., 2010]. If the data meet the criteria of the Rasch model the scores result in interval scales where scores are evenly spaced and more precise in identifying deficits in the students' handwriting compared to the ordinal scale [Osteen, 2010]. The use of this method allows for the analysis of the items to check the internal structure of the assessment. Rasch analysis also provides evidence of subtest correlation coefficients used to indicate whether the assessment measures the same overall construct or whether the assessment can be considered multidimensional measuring a number of constructs in different sections [Cheng et al., 2008]. The same review of the internal structure of the items can provide evidence of where screening assessment performance may differ as a function of known group variables that the test is designed to assess. Therefore checking for difference based on differential item functioning (DIF) for various known group variables such as gender and age should also be completed [Salvia et al., 2012].

In addition, when performance is assessed, evidence should be obtained to indicate if the items determine differences between those that are considered typical and those that are at risk for deficits. Validity can be further confirmed by determining the convergence or divergence of scores on the screening assessment with comparable performance on equivalent assessments.

A screening assessment has little usability or usefulness unless it provides information about a students' risk status in terms of their performance on the construct being measured. It is suggested that norms for performance are provided for comparison to a similar group of peers to accurately predict performance in identification of students at risk of deficits, Sensitivity and specificity which provide information about the accuracy and the criterion validity of the screening assessment should be reported. Specificity indicates whether the assessment excludes those not at risk while the sensitivity and positive predictive value indicate how accurately the assessment identifies those who are at risk for certain deficits [Glover and Albers, 2007].

Thus the screening assessment should be appropriately standardised for the target population and have reliability related to the consistency of the measurement of the construct involved [Stewart and Kaminski, 2002]. Internal consistency provides information about the consistency and estimates whether the items or subtests on the assessment are measuring the same construct. Interrater reliability provides a basis for administration of the assessment by multiple evaluators. The stability of the assessment scores over time as measured by test retest reliability are not as important as other forms of reliability in a screening assessment which is used as an initial measure to identify students at risk and is not usually used for reassessment purposes [Eignor, 2013; Salvia et al., 2012].

Appropriate accommodations must be available to the population who are assessed using the screening assessment which should be useful to the stakeholders in providing services for the population for which the screening assessment is designed [Eignor, 2013]. Thus documented evidence of the results of the assessment which support the screening assessment can be used to evaluate the usability and value of the screening assessment by providing evidence of the deficits requiring further assessment and providing information to guide referral to the services required [Glover and Albers, 2007].

Although no screening assessments for handwriting are available for adults two occupational therapy screening assessments related to handwriting difficulties in young children, that meet some of the essential features of screening assessments provided by Glover and Albers (2007), are available. The Screener of Handwriting Proficiency is a one page group screening assessment which can be used with an entire class to identify which aspects of handwriting in preschool and school children need further assessment and intervention [Handwriting Without Tears®, 2016]. The Shore Handwriting Screening: for Early Handwriting Development (SHS) is used identify the causes of handwriting deficits in relation to handwriting readiness skills. The assessment screens paper-and-pencil tasks, fine motor tasks, and visual-motor tasks, rather than handwriting per se. The assessment has a short check-list for children 3-6 years but has no scoring criteria [Shore, 2003]. The content validity of the SHS has been established for 4-5 year old children [Donica and Francsis, 2015].

While these screening assessments have tasks that are appropriate for a target population of young children neither are suitable for screening students in higher education for dysgraphia to determine if they need further in depth assessment of the components related to handwriting. In occupational therapy screening assessments should not be used for global screening, but used with students referred for assessment and should be suitable for screening the student's current problems [Occupational Therapy Association of South Africa, 2006]. It is however important to screen all components the student reports as a problem which may be related to performance skills affecting their handwriting. This might include pain, fatigue, visual problems spelling, making a lot of corrections as well as slow or untidy writing. Students should be made aware that a screening assessment can only confirm their risk for a condition such as dysgraphia and that if they are found to have a handwriting deficit further assessment will be required [Laver Fawcett, 2013].

It is important that the content of the screening assessment is theoretically supported, with an appropriate model or framework. This should be used in guiding the development of the screening assessment. In the current study the of motor and process performance skills framework from the OTPF III was used [American Occupational Therapy Association, 2014].

2.6 Framework of Motor and Process Performance Skills

The underlying components which affect hand writing and result in dysgraphia need to be determined, if reasonable accommodations are to be provided. In terms of occupational therapy the performance skills affecting handwriting aligned with components of handwriting and client factors are presented below, based on observation of the writer, the presentation of the writing and the handwriting outcomes.

Other studies consider handwriting deficits or dysgraphia in relation the handwriting outcomes and client factors or body structures and functions described in the International Classification of Functioning, Disability and Health (ICF) [World Health Organization, 2001]. For the purposes of the current study components of handwriting were considered in relation to a framework of performance skills developed in occupational therapy for the Assessment of Motor and Process Skills (AMPS) [American Occupational Therapy Association, 2014; Fisher and Griswold, 2014]. A performance skill describes the use of a combination of client factors to perform an activity, in a learnt manner and analyses the quality of participation in activities by evaluating the performance of the individual based on criteria set for different skills [American Occupational Therapy Association, 2014].

On review of the components of handwriting it was found that they could be analysed and associated with the motor performance skills such as Grips (effectively pinches or grasps task objects) and Manipulates (uses dexterous finger movements). These skills can then be further analysed according to body structure and function or client factors, such as fine motor control, bilateral and visual–motor integration, praxis, in hand manipulation, proprioception and visual perception [American Occupational Therapy Association, 2014]. Process performance skills which consider the ability to monitor performance and recognise errors such as Accommodates (prevents ineffective task performance and Heeds (carries out and completes the task as specified) with no mistakes [Fisher and Griswold, 2014] are rarely reported in relation to handwriting assessment. Deficits in these aspects are however associated with dysgraphia in children. The specific client factors associated with the performance skill deficits can be identified when handwriting problems occur, so appropriate intervention or adaptation can be implemented.

The client factors are divided and presented under specific motor or performance skills for the ease of reading in this review, but any one client factor may affect a number of performance skills. Client factors are divided into categories with neuro-musculoskeletal relating to the body functions and structures which form the basis of specific actions and include aspects like strength, sensation, oculomotor function and mobility of the upper limb. The category of sensory client factors relates to the body functions and structures for registering sensory input.

In the current study, proprioceptive and kinaesthetic client factors, which involve the awareness of the body position in the environment, were considered. The cognitive processes needed to attend to, perceive and interpret information fall under the mental client factors. These were considered in relation to the client factor of visual perception and visual attention in the current study [American Occupational Therapy Association, 2014].

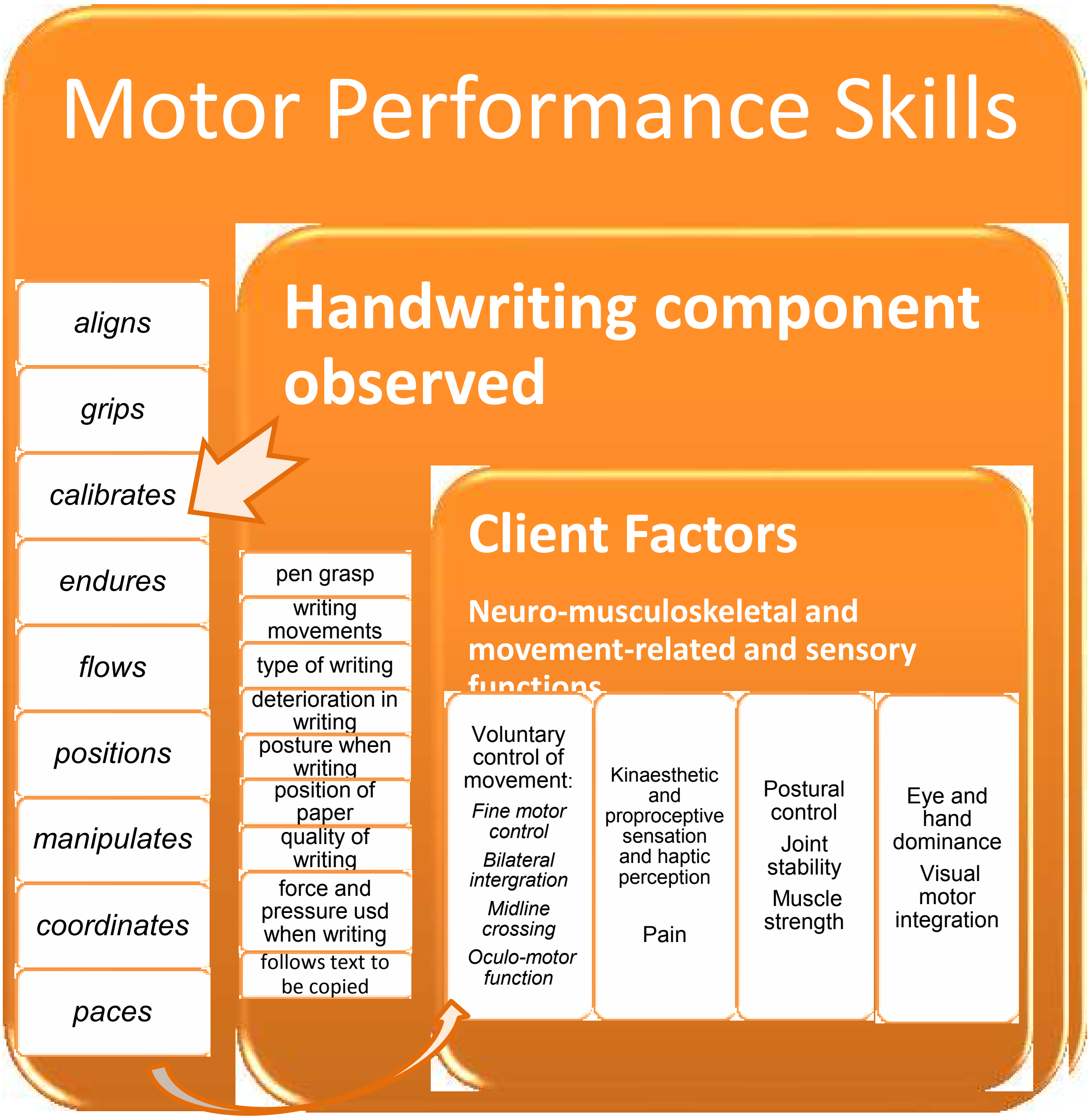

Figure 2.1 Motor performance skills and neuro-musculoskeletal and movement-related and sensory function client factors related to components of handwriting

Figure 2.1 and 2.2 present the framework used to present the observable motor and process performance skills associated with the handwriting components. These performance skills are linked to the client factor which may be responsible for the deficits observed and that would need to be assessed to confirm if deficits were present.

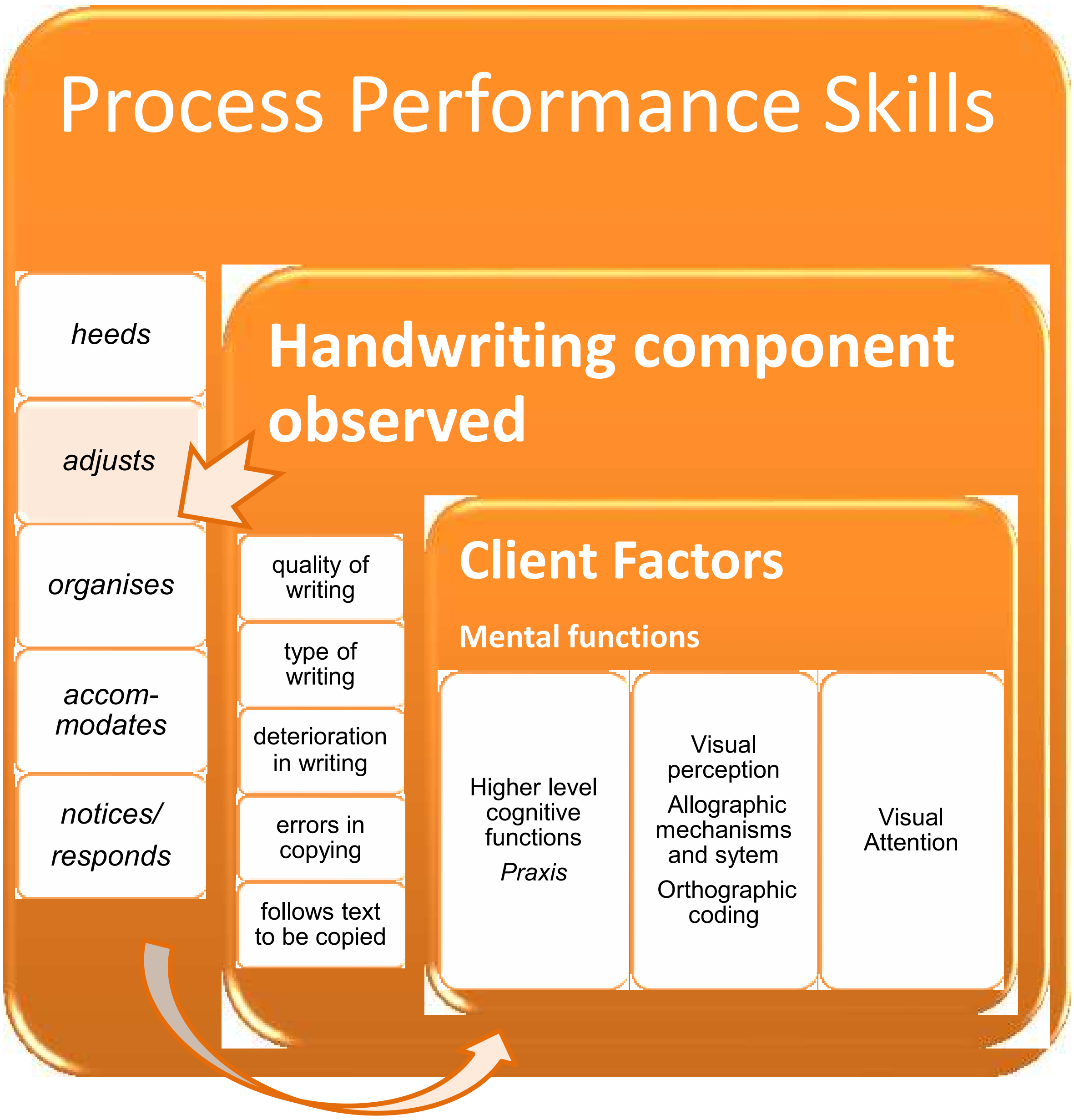

Figure 2.2 Process performance skills and mental function client factors related to components of handwriting

2.7 Performance skills and associated components of Handwriting

The majority of the components considered in this review were based in the motor skills as well as the physical and sensory client factors, as the study focused on the mechanics of handwriting. This review did not consider the cognitive and written language aspects related to handwriting. Literature in various disciplines including occupational therapy, physiotherapy, education, psychology and biokinetics was reviewed. Most studies did not present a high level of evidence as many had small samples of less than 50 participants and had not used blinded assessors when differences between children and students with and without deficits in handwriting were compared. It is difficult to compare studies as a number of standard and informal assessments were used. This literature review forms a comprehensive basis for understanding the components which should be considered in assessing handwriting and identifying which components could be considered in students in higher education. The performance skills are presented in relation to the writer and the presentation of their handwriting as well as the outcomes of handwriting

2.7.1 Performance skills and associated components of handwriting and client factors related to the writer

2.7.1.1 Demographics

Age and gender

When considering demographics, it has been found that both gender and age may affect the speed and legibility of handwriting. It has been shown that girls and women write more legibly and faster than men ($p \leq 0.001$) [van Drempt et al., 2011; Ziviani and Watson-Will, 1998]. These findings are controversial Mergl et al. (1999) found no gender differences in writing speed between men and women in healthy adults [Mergl et al., 1999]. Differences for gender are usually not accommodated in handwriting assessments [Reisman, 2004].

In terms of age, the writing of those over 40 years of age is less legible than that of younger adults. The age range of post-secondary students shows very little variation in writing speed, with slightly older students (23-25 years) writing an average of one to four more words per minute than younger college students (17-18 years) [Barnett et al., 2010; Furr and Bacharach, 2008]. Other factors such as socioeconomic status have been shown to affect handwriting performance however. Significant differences in handwriting speed were found between 1224 primary and high school learners aged between 7 and 19 years from disadvantaged and more advantaged schools, based on socio-economic status, in Ireland. O'Mahony et al. (2008) suggested this placed students from poor socioeconomic backgrounds at a disadvantage when writing examinations [O'Mahony et al., 2008].

Hand preference

Approximately 10% of individuals worldwide are left handed [McManus, 2002] Park (2013) found that muscle activation measured by electromyography signals, in the wrist flexors was greater in 16 left handed adult writers who presented with a greater risk of musculoskeletal disorders in their hand and shoulders than 20 right handed writers [Park, 2013]. A number of authors have reported that right-handed children performed better on in-hand manipulation tasks than left-handed children [Bonoti et al., 2005; Kastner-Koller et al., 2007]. The bias of activities and tools for right-handed people may have affected the results in these studies [Freitas et al., 2014; Park, 2013].

Other studies have found no differences in fine motor ability between left and right-handed children and a number of authors have shown that there is no significant difference in writing speed between right and left-handed children of all ages [Reisman, 2004]. O'Mahony et al. (2008) found substantial variation between the writing speed of left and right handers in their study with right handers having a speed advantage on a nine minute handwriting test [O'Mahony et al., 2008]. Goez and Zelnik (2008) observed that left-handedness occurs more often in conjunction with learning disabilities, developmental coordination disorder (DCD) and dyslexia. An increased prevalence of problems with fine motor skills and handwriting in children who have left-handed preference has also been suggested but this is controversial. They suggest that fine motor dysfunction and dysgraphia may occur in children with these diagnoses [Goez and Zelnik, 2008].

Mixed dominance has also been reported as playing a role in handwriting outcomes. In a study by Denckla et al. (1985) 32% of the students referred for a reading problem had a discrepancy in the dominance of the preferred hand and preferred eye. She felt these children were at risk as they could have “oculomotor activity controlled predominantly by the right hemisphere and the motor control over the pencil used for copying controlled predominantly by the left hemisphere”. p.194 [Denckla et al., 1985].

2.7.2 Motor performance skills and associated components of handwriting and client factors related to the writer

Motor performance skills which can be observed in the writer when writing include picking up the pen, stabilising the paper. judging whether the force applied to the pen and the paper is appropriate, while maintaining an adequate posture and using an efficient amount of physical effort to write [American Occupational Therapy Association, 2014; Pollock et al., 2009]. Prehension or gripping the pen or pencil as well as manipulation when imparting movement to the pen can also be considered. This is dependent of the writer gathering sensory information to ensure the automaticity or flow of the writing and the stability of the pen or pencil in the hand [MacKenzie and Iberall, 1994]. The complex activity in the hand when writing requires the co-ordination of approximately 40 muscles with motor stability provided by the muscles of the upper limbs while the trunk for maintains an upright posture [Selin, 2003].

Aligns

The performance skill Aligns is defined as the alignment of the body without propping or leaning [American Occupational Therapy Association, 2014] and is required when writing to align the eyes and upper limbs with the surface and the paper on which the individual writes (Pollock et al., 2009). Thus, posture and postural control is considered under this performance skill.

Posture and postural control

Posture when writing can be affected by inefficient use of proximal muscles in the upper limb and trunk. In children with low postural tone, it has been shown that there is a need to exert extra effort to maintain an upright posture against gravity [Amundson, 1992; Parham et al., 2001]. These children have difficulty stabilising their trunk and shoulder girdle and often move while writing to achieve more stable or comfortable positions [Gajraj, 1982; Rigby and Schwellnus, 1999; Rosenblum et al., 2004] This can have an effect on their ability to sustain fine motor activities where a rapid deterioration in posture results in their faces being held near the page, affecting the visual feedback of what is being written. Poor trunk posture when writing, associated with poor head position and downward visual alignment as well as ineffective shoulder stabilisation, also results in further dysfunction in aspects of handwriting such as spatial organisation and increased pen pressure (Coulter et al., 1994; Amundson, 1992)

Postural control is therefore seen as an important gross motor skill needed for handwriting. The recommended posture is: good postural alignment of the trunk, supported by a chair, elbows flexed with the forearms supported on the table and the feet supported on the floor with the head aligned for visual scanning, (Erhardt, 1992; Feder and Majnemer, 2007; Pollock et al., 2009). Blöte et al. (1987) noted that young children usually start writing with the forearm and the elbow on the table but move towards just the pronated forearm supported on the table (Blöte et al., 1987). Compensatory postures described in 12 university students ascribed to poor proximal stability in the shoulder and trunk, have also been associated with inefficient pen grasps. This results in poor positioning of the hand on the table when writing (de Almeida et al., 2013).

Grips

The performance skill of grips refers to the finger placement on the task object or pen [American Occupational Therapy Association, 2014]. In handwriting this is related to pen grasp and the way in which the pen is held which is important to allow for the use of the fine movements necessary for writing.

Pen Grasp

Research on handwriting in the occupational therapy literature commonly reports on pen or pencil grasp [Dennis and Swinth, 2001; Pollock et al., 2009; Rosenblum et al., 2003b; Schwellnus et al., 2013b; Selin, 2003; Shah and Gladson, 2015]. The accepted classification of pen grasps in occupational therapy literature is based on the work of Schneck and Henderson (1990) who used development of pencil and crayon grasp in children to describe pencil grasps. Most authors accept the dynamic tripod grip as the most efficient of the pen grasps where the pen is held between the opposed thumb and the radial side of the middle finger with the index finger resting on the pen (Figure 2.3). The wrist is held in extension [Schneck and Henderson, 1990]. This pen grasp permits the degree of finger and thumb flexion and extension needed especially for cursive writing with enhanced efficient letter formation [Elliott and Connolly, 1984].

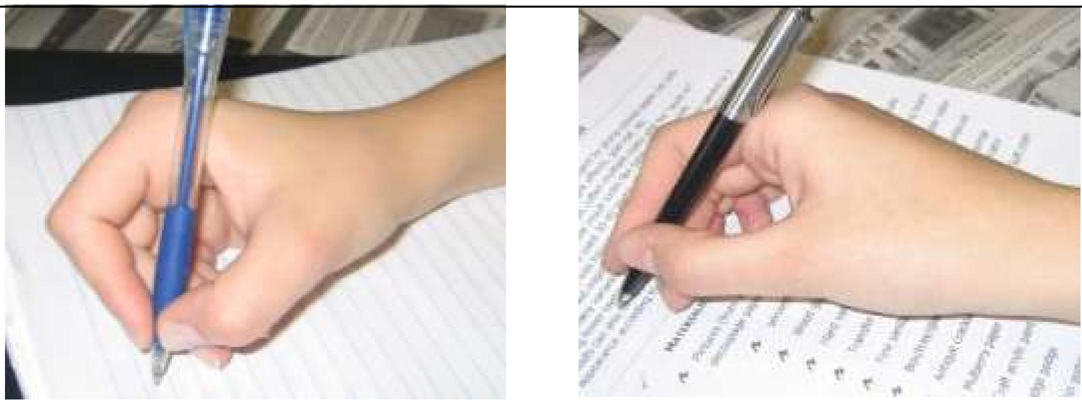

Figure 2.3 The Dynamic tripod grasp and the lateral tripod grasp

The lateral tripod grasp, where the thumb is positioned anywhere along radial side of the index finger, has been demonstrated to achieve the same levels of control, legibility, speed and accuracy as a dynamic tripod grasp [Amundson, 2005]. However some authors feel that the adducted position of the thumb in this grasp restricts finger movement [Benbow, 2006; Summers, 2001]. Stevens (2008) found that children using the lateral pen grasp cannot write for the same period of time and seem to fatigue sooner than those using a tripod gasp [Stevens, 2008].

Studies students in higher education and healthy adult handwriting reported that approximately 5% of adults use pen grasps other than a tripod or lateral grasp (Bergmann, 1990; Gozzard et al., 2012). Summers and Catarro (2003) found however that 67% of the 66 university students in their study used the traditional dynamic tripod grasp. Shah and Gladson (2015) found that was true for only 37% of students the 100 students in their study (Summers and Catarro, 2003, Shah and Gladson, 2015). These differences may well be due to the classification of pen grasps in the studies as Summers and Catarro (2003) only identified four grasps whereas Shah and Gladson (2015) reported seven adapted variations of the dynamic tripod grasp. Research in this field has been affected by lack of consensus about classification of pen grasps as well as the length and types of writing assessments used [Graham and Weintraub, 1996].

Inefficient or other immature pen grasps described by Schneck and Henderson, (1990) include a four finger grasp, a cross thumb grasp and a static tripod grasp where writing movements occurred in the hand and not the fingers [Schneck and Henderson, 1990]. Most research indicated that these grasps may affect the ability to write although four finger grasp or quadrupod grasp, where the pen is held against the ring finger is considered an efficient grasp in children. This grasp reduces the radial–ulnar dissociation in the hand however, affecting the stabilisation normally provided against the palm by the ring and little finger [Ziviani and Wallen, 2006].

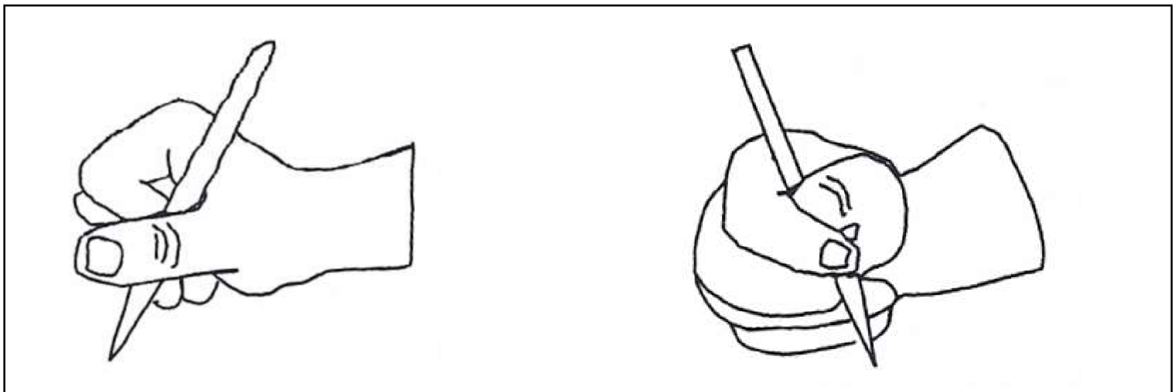

Figure 2.4 The thumb wrap, thumb tuck grasp

Benbow et al. (1992) added to the classification of pen grasps: a cross thumb grasp called a thumb wrap grasp with the thumb over the fingers or a thumb tuck grasp when the thumb is under the fingers [Benbow et al., 1992] (Figure 2.4). These grasps are considered inefficient as the web space may be completely closed which restricts the movement of the pen [Dennis and Swinth, 2001].

Inefficient pen grasps have been associated with poor endurance and a lack of stability in the hand when writing [Benbow, 2006; Stevens, 2008; Ziviani and Wallen, 2006]. It is not clear what role these components play in the quality and outcomes of handwriting, particularly in adults but the general consensus in the literature is that for both children and adults, pen grasp does not affect the quality of handwriting. Research on 46 fourth-grade children confirmed that different pen grasp patterns do not have a significant influence on handwriting outcomes such as legibility and speed in short assessments [Dennis and Swinth, 2001].

Fatigue and pain, the force of the grasp and repositioning the pen in the hand were not considered when evaluating pen grasp in this research however [Rosenblum et al., 2006]. The force with which the pen is held and the stability of the grasp is associated with the performance skill of Calibrates and these components were considered separately in the current study.

Calibrates

Calibration is related to the force with which the task object or pen is held [American Occupational Therapy Association, 2014] as well as how hard the pen is pressed onto the paper. Research in 2010 indicated that children should be able to vary the force with which they hold a pen as this is related to the legibility of their writing. Those who use a consistent static force when grasping their pens often have handwriting difficulties [Falk et al., 2010].

Proprioception and kinaesthesia and haptic perception

The force with which the pen is held is related to both tactile, proprioceptive and kinaesthetic sensation [Feder and Majnemer, 2007]. Studies indicate that children rely on kinaesthetic feedback in learning both how to grasp the pencil and how hard to press on the paper when writing [Benbow, 2006; Feder and Majnemer, 2007]. In early research Schenk found that pencil grasp was associated with kinaesthetic sensation [Schneck, 1991] but Yu et al. in their study in 2012 on 177 children reported this was only true for children learning to write in Grade 1. They found tactile feedback of objects through manipulation or haptic perception rather than kinaesthetic feedback was used to guide writing from second grade when some writing skill has developed [Yu et al., 2012]. This supported research on the effect on handwriting of adults whose fingers were anaesthetised [Ebied et al., 2004]. Schenk noted that these individuals along with others who have impaired sensory feedback from their fingers, rely more on visual monitoring of their writing resulting in poor automaticity and performance as well as fatigue [Schneck, 1991].

Proprioceptive feedback is received from receptors in the muscles, tendons and joints about the position and movement of upper limbs and hand and posture when writing. Benbow (2014) indicated that another effect of grasping the pen with an adducted thumb, where the web space is closed, is reduced proprioceptive input from the intrinsic muscles of the fingers and thumb. This affects the regulation of the pressure of the grasp on the pen as well as the downward pressure of the pen on the paper. This suggestion supports the findings of Schwellnus et al. (2013) who reported that a closed web space results in significantly more force being applied to the pen [Schwellnus et al., 2013b]. This excessive pressure used may lead to pain with the need to stop and change or release the grasp on the pen and shake the hand which may become worse as the child gets older [Benbow 2014].

Joint stability and muscle strength

The lack of stability in the grasp is related to client factors like strength, endurance and laxity of the joints in the hand. Research investigating low pinch strength, particularly in children, has been associated with poor handwriting. Summers (2001) in her study on 55, 7-8 years old children found an association between joint laxity, stability of grasp and pencil grasp. In younger children hyperextension of the distal interphalangeal (DIP) joint and hyperflexion of the proximal interphalangeal (PIP) joint is seen when they learn to write. This position of the finger changes to flexion at both joints as the child matures and the joints become stable. Of greater concern was laxity of the interphalangeal (IP) joint and metacarpal phalangeal joint of the thumb. Laxity in these joints result in some children compensating with a lateral pinch and closed web space when writing as the short thumb flexor and adductor counteract the abduction of the first finger [Long et al., 1970].

Other children use hyperflexion of the IP joint of the thumb to stabilise their grasp [Summers, 2001]. Hyperextension of the DIP joint of the index finger has also been associated with assessing grasp force when holding a pen [Selin, 2003]. No evidence for the effect of lax joints on handwriting in adults could be found.

The force used to hold the pen and press on the paper has been related to the stability of the pen grasp. The consequences of a lack of stability of the pen grasp are compensatory movements of the fingers and the use of inefficient pen grasps. This has proved to be a disadvantage when writing however, as the effort to maintain the grasp which results in onset of fatigue and loss of motor control affecting legibility [Engel-Yeger and Rosenblum, 2010]. If the grasp is not corrected it may persist and become automatic hindering the development of a more effective grasp. Thomas (1997) who researched near point gripping was also concerned that this deficit develops in preschool situations when the child's hand lacks stability and is habituated and difficult to change when the child starts formal schooling at six to seven years. The pen should be held approximately 2 - 2.5cms for right handers and 2.5 – 3cms for left handers from the point if they are to get adequate visual feedback from what they are writing on the paper in front of them [Thomas, 1997].

Endures

The performance skill Endures is related to the ability to complete a tsk without showing obvious evidence of physical fatigue [American Occupational Therapy Association, 2014] and is related in conjunction with pain, to the inability to sustain writing over a period of time reported in children with dysgraphia.

Fatigue and pain in the hand

Endures appears to be associated with force used when writing and to hold the pen as well as stability of grasp. Benbow (2006) postulates that inefficient pen grasps persisting in older children and adults are related to an initial lack of stability in the hand which is not corrected [Benbow, 2006]. This can also result fatigue and potentially harmful pain in the hand when the demands for speed increases in secondary and higher education situations [Peverly, 2006; Sassoon et al., 1986; Summers and Catarro, 2003].

The study by Summers and Catarro (2003) indicated that the majority of 66 students in their study, even without any handwriting problems report fatigue in long examinations. The correlation between pain and fatigue was low but moderately significant. They reported that 74% of students indicated that fatigue affected the legibility of their handwriting, while half the students reported it caused them to slow down and nearly a third indicated they had to change their grasp on the pen or take at least three breaks to rest their hand when writing [Summers and Catarro, 2003].

Research has also reported decreased speed and the use of less pressure on the paper in Grade 3-Grade 5 children with dysgraphia as they fatigue [Parush et al., 1998]. A study by Engel-Yeger and Rosenblum (2010) using a pressure assessment tool, refuted this and indicated that response to fatigue when writing differs in individuals and this is related to many different components in handwriting [Engel-Yeger and Rosenblum, 2010].

Pain

Pain when writing has been associated with lack of stability of grasp and poor posture as well as a lack of practice of handwriting. These factors lead to increased risk of cumulative trauma or repetitive strain injury and an inability to sustain writing for long periods [Lay et al., 2002]. Pain in the hand, forearm and can affect the upper limb and other parts of the body is a common symptom of dysgraphia and is associated with other handwriting problems [Chang et al., 2015; Crouch and Jakubecy, 2007]. It has been reported that this pain can be made worse by stress related to the inability to write adequately and finish timed examinations [Best Resources for Achievement and Intervention re Neurodiversity in Higher Education 2006]

Rosenblum and Gafni-Lachter (2015) found pain to be one of the components identified in the Handwriting Proficiency Screening Questionnaire for children (HPSQ-C) in which children between the ages of 7-14 years reported on aspects that affect their handwriting proficiency [Rosenblum and Gafni-Lachter, 2015]. This was supported by Smeulders et al. (2001) who found that chronic wrist pain influenced the automaticity of writing as individuals with pain adapted their movement patterns to accommodate the pain [Smeulders et al., 2001].

The effect of pain on the speed of handwriting was studied by Summers and Catarro (2003) who asked 66 second year occupational therapy students to rate their pain on a 10 point scale, on a short handwriting assessment and over a long two hour examination. All students reported some discomfort however when pain was classified as low, moderate and extreme on both the short handwriting assessment and for the longer examination there was a significant difference in the number of words written per minute in this study.

This finding was not supported by Chang et al. (2015) in their study, which showed that legibility and not speed of writing was affected by pain in 40 university students, although the intensity of the pain is not considered or reported in the study. They divided the students into a perceived pain when writing group and no perceived pain group, and assessed their writing for 30 minutes, using Chinese characters on a digital tablet. The pain group perceived discomfort within 10 minutes of starting to write which increased over time. This was attributed to the greater proportion of time they had their stylus tips on the tablet without producing faster writing, resulting in over-exertion of the writing muscles. The results of the study may have been biased by the use of a digital table which does present some challenges in terms of the position of the hand and the use of a stylus [Chang et al., 2015].

Since a large number of students report pain when writing examinations and it is not clear what handwriting outcomes are affected by this, it is important that components which are associated with this pain be determined in relation to that reported by typical students [Siegel, 1999b].

Flows

Flows refers to the smoothness and efficiency of movements or praxis when interaction with the pen and paper when writing [American Occupational Therapy

Association, 2014]. Movements used when writing and type of pen used to write were considered under this performance skill.

Praxis

Praxis is the ability to carry out activities using movement actions over a set period of time in an organised and fluid manner. Praxis includes the physical action as well as the idea of movement, the planning, execution and correction of the movement. When writing, praxis is what supports the forming of letters and the complex sequences of letters and words. This is important when children are learning to write and has been linked with kinaesthesia as they develop the sequence of movements required to form letters [Amundson, 1992]. The link between praxis and handwriting was shown by Tseng and Murray (1994) who reported that a test of finger praxis predicted legibility in children with poor handwriting, explaining 10% of the variance [Tseng and Murray, 1994].

Components of praxis, namely proactive control of the movement anticipated beforehand, is used by individuals with dyspraxia and handwriting deficits and they are seen to lack rhythm and automaticity in their writing. They demonstrate inconsistent joining and breaking of letters in a word and often lift the pen from the page at inappropriate times or for longer periods, finding it difficult to produce legible written work in an acceptable time [Rosenblum et al., 2004; Schneck, 1991].

Writing movements

The smooth controlled movement needed for handwriting are also reliant on muscle activity in the finger and thumb which must be supported by fixation of the elbow, shoulder and trunk. This allows for adequate distal control to produce the writing. The mature writing style seen in adults involves the activation of the intrinsic muscles in the hand [Dooijes, 1983]. The vertical strokes rely mostly on finger movement with little involvement of the thumb while finger and wrist movements are used together for oblique strokes [Contreras-Vidal et al., 1998]. The ring and little fingers should provide stabilisation in the hand and support the movement occurring on the radial side of the hand [Ziviani and Wallen, 2006]. The extrinsic muscles at the wrist are used for horizontal strokes and for moving the hand across the paper [Dooijes, 1983; Dounskaia et al., 2000].

The position of the wrist is important and an increased angle of extension of the wrist has been linked to pain when writing as well as writing being more effortful. Wrist flexion has also been associated with the need to stabilise the hand when writing and may result in more pain when writing for an extended period of time [Chang et al., 2015].

Poor distal function and static pen grasp has also been shown to result in recruitment of activity in proximal muscles for stabilisation. The effects of proximal and distal movement in handwriting on energy use and fatigue are complex and appear to have more serious implications for those with handwriting deficits [Lay et al., 2002]. When the biomechanics of writing of children in the second to fourth grade were explored by Van Galen et al. (1993) using electronic recordings, they found that children with writing problems had higher velocity in their movements and a greater number of undesirable movements in their hand and forearm muscles. This was confirmed by Naider-Steinhart and Katz-Leurer (2007) who found that children with less efficient slower writing could not inhibit undesirable movements in their distal upper limb muscles which resulted in assumed greater energy use [Naider-Steinhart and Katz-Leurer, 2007].

de Almeida et al. (2013) found similar results in their study on 12 university students with inefficient static pen grasps. These students recruited and used proximal shoulder and elbow muscle groups when writing. The students had greater electromyography activity in trapezius and biceps, suggesting higher energy expenditure, when compared to 12 students with efficient dynamic pen grasps. The students with inefficient grasps adapted their proximal upper limb movements by using shoulder elevation and active elbow flexion [de Almeida et al., 2013].

Fine motor control

Efficient distal movements in the hand and fine motor control are therefore needed when writing, for the correct size and placement of letters as well as grading and timing of movements necessary for fast legible handwriting. It appears that the temporal aspects of movement and motor control found in finger movement tasks like the "Thursday test" relate directly to motor control in handwriting. Berninger and Richards (2008) found that isolated successive finger movements are linked to automatic legible letter writing when sequencing strokes needed to write letters. This differed in children who had good and poor hand writing [Berninger and Richards, 2008] and was confirmed by their research using functional magnetic brain imaging (fMRI) blood-oxygen-level-dependent (BOLD) contrast for serial and non-serial finger movements. More regions of the brain were activated (bilateral inferior temporal, right precuneus, left superior parietal, right inferior frontal orbital) in good writers with adequate time related integration of written letters and sequential finger movements [Berninger and May, 2011]. Using the same techniques Katanoda et al. (2001) showed the pre-central and post-central gyri and part of the basal ganglia are activated in adults both for writing movements and in a finger tapping task [Katanoda et al., 2001].

Instrument used to write

The type of writing as well as the pen used can affect the speed of writing**.** Kao (1979) researched the effect of various pens and pencils on handwriting and found the fastest but most fatiguing writing was achieved with a ball point pen. Participants found that a fibre tipped pen was the most comfortable and least fatiguing with which to write [Kao, 1979]. In a later study also on Chinese students Chan and Lee (2005) found students preferred a ball point pen in relation to comfort, fatigue and writing ease compared to a pencil [Chan and Lee, 2005]. The diameter of the pen has been shown to affect speed as well as the quality of handwriting and comfort, when assessed by university students [Gnaneswaran et al., 2007]. Goonetilleke et al. (2009) found that pens should be circular for reduction in errors and ease of movement and that although they did not find the type of pen affected university students' writing speed in the short term, they felt the long term effects of different pens should be researched [Goonetilleke et al., 2009].

Positions

Positions relates to positioning of the body in relation to objects as well as objects in relation to the body to allow the activity to be completed efficiently [American Occupational Therapy Association, 2014].

Position of the paper

Very little has been published on the organisation skills needed when writing, to prepare the work area and position the paper appropriately. Authors however indicate that it is important to teach children to write with the paper placed at the angle of the forearm on the table [Graham, 2008; Sassoon, 2003]. Lohman (1993) in a study on 138 university students, considered the effect of the placment of the paper on the table when writing. He found that writing on paper placed vertically rather than at an angle on the table significantly affected the legibility of handwriting in university students irrespective of whether the students were left or right handed [Lohman, 1993]. It has been indicated that the positioning of the paper may be related to control of voluntary movement including bilateral integration and midline crossing [Pollock et al., 2009].

Bilateral integration and midline crossing

The ability to use the two sides of the body in a co-ordinated way simultaneously is referred to as bilateral integration or coordination and is associated with the ability to perform asymmetrical movements. Handwriting requires asymmetrical movements in that the preferred hand holds the pen for writing while the non-preferred hand stabilises the paper [Exner, 1989]. Children with bilateral integration dysfunction may not be able to dissociate the different movement components for the two hands and fail to fixate the paper while writing [Amundson, 1992].

Readiness to write in the young child requires that they can not only coordinate asymmetrical movements but that they have developed a more complex level of bilateral integration - the ability to cross the body midline with either hand during activities. The lack of midline crossing has been associated with problems such as letter reversals in handwriting [Baird et al., 2003; Benbow et al., 1992]. There is little information on the effect of this on handwriting in older children and adults and the use of the preferred hand in contralateral space. The positioning of the paper to the ipsilateral side of the preferred hand may be related to a deficit in midline crossing although there is no evidence for this. This position of the paper may rather be related to less accurate motor control in contralateral space [Smits-Engelsman et al., 2004].

Manipulates

Manipulates is the use of dexterous finger movements [American Occupational Therapy Association, 2014] and relates to the manipulation of the pen in the hand or in-hand movements required to write. It also, refers to the movements within the hand needed to form letters and move across the page as words are written [Erhardt, 1992; Erhardt and Meade, 2005].

In-hand manipulation needed for adjusting the pen in the hand can be observed Exner (1989). This includes translation which involves moving the pen to the correct position in the hand with the tip facing down. Movement of the fingers away from and towards the tip of the pen while adjusting the pen in the hand when writing is considered as shifting [Exner, 1989; Feder and Majnemer, 2007]. Brown and Link (2016) found that in-hand manipulation alone cannot be associated with writing speed and accounted for about only 10% of the variance seen in the number of letters written by primary school children [Brown and Link, 2016]. The effects of in-hand manipulation appears not to have been well researched in adults however [van Drempt et al., 2011].

Coordinates

Coordinates is the performance skill requires the use of two or more body parts to manipulate and control an object like a pen [American Occupational Therapy Association, 2014]. Research indicates that children with motor coordination dysfunction such as DCD are likely to have temporal rather than spatial deficits in their writing. These temporal deficits were reported initially by Rosenblum and Livneh-Zirinski (2008), who found that children with fine motor coordination problems pause frequently with their pens held in the air [Rosenblum and Livneh-

Zirinski, 2008]. Although this phenomenon is not well understood, these children tend to write less than typical children [Prunty et al., 2014]. It has been proposed that the pauses may be related to muscular adjustments between strokes or fatigue but there is little agreement in the literature as to the definition of a pause and what length of pause should be considered.

Visual Function

Both, vision which includes visual acuity and refractive errors, and visual function or efficiency, incorporating accommodation, binocular vision and ocular motility as well as saccades, are required when writing. It is proposed that these aspects play a role in visual tracking of the movement sequence of the hand, when learning to write. As handwriting becomes automatic, vision is still used to monitor the hand movement and the handwriting. Speed is affected. if the child continues to pay visual attention to letter formation and sequencing however [Siebner et al., 2001].

Following text when copying

Deficits in ocular motility or visual function result in excessive backward and forward movements of the head needed to scan what is being copied. The studies on the relationship between visual function including saccades and oculomotor dysfunction and handwriting speed have been done on predominantly Chinese children writing Chinese characters which are written vertically. Cheng-Lai et al. (2013) showed a strong relationship between rapid automatic naming (RAN) assessed using the Developmental Eye Movement (DEM) test which assesses slow vertical saccadic function and handwriting speed in children with dyslexia [Cheng-Lai et al., 2013]. Saccadic efficiency was linked to the length of time children pause to visually process characters and copy them accurately [Lam et al., 2011]. This research may not be applicable when writing horizontally however as faster horizontal saccades associated with oculomotor function may be used. Visual skills must be coordinated with fine motor control when writing as well as other components which are considered under visual motor integration.

Visual Motor Integration

Visual motor integration has been considered essential for academic participation and is considered to play an important role in academic activities such as reading and handwriting [Schenk, 2013]. Research has indicated that in young preschool children the ability to co-ordinate a motor response with visual input or visual–motor integration the best predictor of legibility in handwriting. They found that children, who could copy the first nine forms on the Beery Developmental Test of Visual Motor Integration (VMI) which includes the oblique cross, could copy significantly more letters [Bara and Gentaz, 2011; Weil and Amundson, 1994]. Although the association between the VMI and handwriting was also found in 101 Grade 1 children the VMI scores were not a predictor of handwriting success at this age [Marr and Cermak, 2002]. As children got older and handwriting became automated the association between VMI and handwriting decreased and Bo et al (2016) found no correlation between visual motor integration and handwriting In children with DCD between 8 and 12 years of age however [Bo et al., 2014].

Since handwriting, even when deficits are present is automated in adults it seems that visual motor integration is unlikely to be associated with handwriting and this component will not be addressed in the screening assessment.

2.7.3 Performance skills and associated handwriting components related to the presentation of writing

2.7.3.1 Motor skills and associated handwriting components and client factors related to the presentation of writing

Calibrates

Force and pressure used when writing

The pressure with which the pen presses down on the paper is measured as the axial pressure of the pen. Schwelinus et al. (2013) measured the effect of axial force in the writing of 74 Grade 4 learners, using a digital tablet and electronic pen. They found that while a lateral grasp resulted in significantly more force being used with the pen on the tablet when writing, this had no relationship to the legibility of the writing [Schwellnus et al., 2013a].

Variability in the pressure of the pen on the paper however has been associated with poor legibility [Baur et al., 2006] especially when writing fast [Engel-Yeger and Rosenblum, 2010]. Yu et al.(2012) also confirmed that the handwriting speed is related to an optimal amount of pen pressure on the paper and that both pressing too hard or too lightly may affect handwriting [Khalid et al., 2010; Yu et al., 2012]

Studies indicate that downwards pen pressure for adults when writing is around 1.4–1.5 Newton. This does vary according to the writing task and Kao et al. (1983) found that students press harder when writing cursive and self- generated text [Kao et al., 1983] Their results indicate that less pressure was used when writing single letters than when writing words.

Endures

Deterioration in quality of writing

Deterioration in writing over time is indicative of fatigue and has been associated with an increase of axial pressure on the paper especially in children with dysgraphia and handwriting problems [Parush et al., 1998]. Kushki et al. (2011) however using digital tablets, found an increase in axial pen forces over time in both typical children and those with dysgraphia. They attribute this to both psychological and muscular fatigue in their sample of 105 grade four children, which resulted in a decrease in the quality of the children's writing [Kushki et al., 2011]. Deterioration in writing has not been commented on in research in post-secondary students although this may be reflected as a change in legibility in some studies.

Handwriting is further affected by the fatigue which occurs as result of maintaining a static grip on the pencil when writing. Engel-Yeger and Rosenblum (2010) found a significant difference in the pinch strength of 23 children with and 28 children without handwriting problems or dysgraphia, aged between 8-10 years. After two writing sessions in which they were assessed using a copying task, the children with dysgraphia, had a significant deterioration in the quality of their handwriting compared to those with no handwriting problems [Engel-Yeger and Rosenblum, 2010]. It has been suggested that reduced pinch strength also results in the recruitment of undesirable movements and the use of other muscles resulting in the stressing or overusing of certain muscles leading to pain and cramping in the hand and forearm [Freund and Takala, 2001].

2.7.3.2 Process skills and associated handwriting components and client factors related to the presentation of writing

Heeds

Heeds relates to the monitoring of the task required of the individual as they perform the task [American Occupational Therapy Association, 2014]. Spelling and errors, made while writing were reviewed under Heeds.

Errors in Writing

Spelling

Since the handwriting task in the current study involved copying, the spelling errors made while copying were reviewed, and not spelling ability in general related to dysgraphia. Re and Cornoldi (2015) studied spelling errors when copying in 35 Italian children with attention deficit hyperactivity disorder (ADHD) and dyslexia. They presented with significantly more spelling mistakes than 35 typical peers when copying. Children with ADHD made fewer mistakes when copying than during dictation but stopped to check spelling of words, particularly for double letters in words [Re and Cornoldi, 2015]. A study by Tops et al. (2013) on spelling when summarising a passage in university students found incorrect spelling was indicative of underlying dyslexia with moderate effect size ($d \leq .60$) for summary tasks and a large effect size ($d \leq 1.06$) when comparing the work of dyslexic to non-dyslexic students [Tops et al., 2013]. Therefore, checking spelling of copied work may provide evidence of dyslexic dysgraphia in a screening assessment.

Mistakes and Corrections

Research shows that children with handwriting problems misplace or ignore capital letters and punctuation and misspell words when they present with learning disorders [Graham and Harris, 2009]. A similar result was reported in a study with 200 higher education students by Tops et al. (2013) during summarising and dictation tasks. They found moderate effect size differences for proper punctuation and capitalisation (effect size $d \leq 0.40$) when comparing the work of dyslexic to non-dyslexic students. They found there was no difference between the two groups of students for the quality of their handwriting however [Tops et al., 2013].

The need to make corrections in the text when writing, affects the students train of thought about the content and the fluency of their writing is thus compromised [Fulk and Stormont-Spurgin, 1995; Graham and Harris, 2009]. Therefore, the number of errors made as well as the use of punctuation and capital letters should be assessed when screening for possible dysgraphia or handwriting problems. These problems occur when writing and provide evidence of problems which are not necessarily related to the speed or legibility of handwriting.

Adjusts

The performance skill of adjusts related to making changes during a task in the current situation to overcome problems with task performance [American Occupational Therapy Association, 2014].

Students with dysgraphia and other handwriting problems may have corrections and erasures in their written work. Errors when words or letters are crossed out and then corrected or rewritten appear to be common when adults are writing although in copying tasks these should not occur frequently [van Drempt et al., 2011]. Overwriting, retouching letters, crossing out are all indicative of errors. In individuals with dysgraphia these occur when they realise they have spelt a word incorrectly or letters are in the wrong sequence. This also occurs when words are missed or read incorrectly while copying although Tops et al (2013) did not find significant difference between dyslexic and non-dyslexic students for word order, word omission and added word errors [Tops et al., 2013]. Assessing whether the student is aware of their errors and whether they adjust their performance to correct these errors should be screened to determine if this component differs for students with dysgraphia of handwriting deficits.

Organises

Organises relates to the position or logical spatial arrangement of letters and words in handwriting so as not to be too spread out or too crowded [American Occupational Therapy Association, 2014] . The client factors considered under the organisation of letters and words on a page include visual perception.

Visual Perception

The relationship between visual perception or the ability to organise and interpret what is seen and handwriting is also not clear. Evidence that an association exists is poor and only a non-existent or weak relationship has been shown in research [Tseng and Cermak, 1993; Tseng and Chow, 2000]. Brown and Link (2016) found that visual closure in combination with motor problems accounts for 25.5% of the variance of speed of writing in the speed of writing in 39 typical primary school children.

Most studies in this area have methodological problems as they have included a motoric component in the perceptual assessment when comparing typical children to those with dysfunctional handwriting. Thus although visual perception has been associated with handwriting no causal link has been made [Leung et al., 2014]. Even so texts do link problems with visual spatial perception such as position in space with the spacing between letters and words [Schneck and Amundson, 2010]. Although poor visual memory has also been associated with difficulty in copying tasks and letter sequences it has only been linked to handwriting problems in approximately 28% of children [Feder and Majnemer, 2007].

When children with dysgraphia were compared to those with dyslexia it appeared that the problems seen in writing related to visual perception, are to do with poor sequencing which affects writing letters in the wrong order, reversing letters and leaving them out of words [Best Resources for Achievement and Intervention re Neurodiversity in Higher Education 2006]. There is little evidence for the effect of visual perception on the handwriting of university students and whether this is related to the sequencing of letters and missing letters in words when copying.

Accommodates

Accommodates relates to behaviour used to prevent ineffective performance of a task [American Occupational Therapy Association, 2014] and may be associated with students with SLD and other disabilities compensating for their problems by using strategies that make their performance more effective [Casale, 2009].

When copying or writing students make accommodations to facilitate the process by reading words softly or subvocalizing to themselves while writing [Berninger and Wolf, 2009; Crouch and Jakubecy, 2007; Deiner, 2012; National Center for Learning Disabilities, 2006] This has been noted as a sign of dysgraphia and appears to assist the individual in memorising and recognising the words they are copying which enhances task performance. Research shows that this is also an accommodation used by second language English speakers [Bauer and Gort, 2012].

The other accommodation made in copying is that of following text to be copied with a finger. Oculomotor and saccadic dysfunction result in a frequent loss of place in the text while copying which affects writing automaticity. Compensation by having to follow the text with a finger while copying is then used to prevent the student losing their place. This has been related to the speed with which copying can be completed [Best Resources for Achievement and Intervention re Neurodiversity in Higher Education 2006; Scheiman, 2002].

Type and size of writing

To accommodate the development of fine motor skills children are mostly taught to write in printed letters initially using the Latin alphabet and then change to cursive writing after approximately two years as cursive writing is deemed to be faster.

Although since 2010 the teaching of cursive handwriting is no longer a requirement in American primary schools as dictated by the Common Core education standards, some schools are reintroducing this type of writing. This supports the work of Blazer (2010) who feels learning cursive script benefits the child’s fine motor skills; fluidity of written communication; and writing efficiency so they tend to get better marks [Blazer, 2010]. Niedo et al. (2014) suggested it was beneficial for orthographic representations and motor sequencing, to teach children with SLD to produce text in as many different ways as possible [Niedo et al., 2014].

Most literature shows that adult writers use a mixture of printed and cursive writing which supports speed as well as legibility [Gozzard et al., 2012; van Drempt et al., 2011]. While Summers and Catarro (2003) found that writing style did not affect the output during a two hour examination [Summers and Catarro, 2003], Graham et al. (1998) found this mixed style of writing to be the fastest in short writing tasks [Graham et al., 1998].

A variation in the size of letters has been linked to legibility of handwriting. Ziviani and Elkins (1984) showed that the size of writing is one of the factors which predict legibility in handwriting in children in their study on 575 Grade 3-Grade 7 children [Ziviani and Elkins, 1984] .

The size of writing decreases as fine motor control improves as children develop automaticity in their writing which decreases to an accepted 3 mm after Grade 2. Very small writing can affect the readability of handwriting but no evidence for research into the size of handwriting for typical adults was found in the literature search [Charles et al., 2004].

Notices and responds

Notice and responds is defined as the ability to act on cues from the environment which affect task performance. When copying, it is important to respond to the lines of text being copied. Omission of letters, the beginning and the end of words and whole words or lines of text as well as confusion of similar words, are seen [Best Resources for Achievement and Intervention re Neurodiversity in Higher Education 2006; Scheiman, 2002]. These symptoms of oculomotor dysfunction may be related to visual attention.

Visual Attention

Binocular deficiencies cause an individual to use excess effort when focusing for reading and writing and reduce the ability to sustain visual attention [Scheiman, 2002]. Johnson and Zaba showed that 25% of academic deficiencies can be related to visual tracking and convergence deficits [Johnson and Zaba, 1999]. Visual attention deficits were some of those described in the literature along with poor comprehension when reading, omitting words and swopping letters in words and skipping or rereading lines included by Tassinari and DeLand (2005) in their symptomatology questionnaire for oculomotor dysfunction [Farrar et al., 2001; Tassinari and DeLand, 2005].

Research on visual attention indicates that children with deficits need to look at what they are copying more often. This is because they have deficits in fixation or visual attention span which affects how many letters they can copy accurately in one visual fixation [Bosse et al., 2014]. In adults, visual attention span should allow them to visually process the next word while the previous word they read is being written [Lambert et al., 2011].

2.7.4 Performance skills associated with components related to the outcomes of handwriting

The outcomes by which handwriting is judged in terms of flows and organisation is legibility, and in terms of paces is the speed and the fluency of handwriting These outcomes can be assessed by the performance skills described above and may be affected by any of the client factors reviewed in relation to handwriting.

Paces

Paces is the ability to maintain an effective rate of work throughout a task [American Occupational Therapy Association, 2014] and in handwriting is related to speed of writing.

Speed

From the research on different types of dysgraphia not all those with dysgraphia and hand writing difficulties have illegible handwriting, depending on the remediation received. Most will have some timing problems in relation to their speed of writing [Best Resources for Achievement and Intervention re Neurodiversity in Higher Education 2006].

Graham et al. (1998) found that handwriting speed on a copying task improves relatively constantly from one grade to the next as children progress through school, but remains one of the deficits seen in children with dysgraphia. The speed measured in letters per minute appears to level off in Grade 9, by increasing from 20 LPM to 110 LPM which is close to the speed attained by adults [Graham et al., 1998].

Speed norms for adult handwriting were established in the USA and Australia in the 1960’s and 1980’s and in the most recent study on a copying task for 16 typical 20-24 year old Australians was found to be 18.66 words per minute (WPM) [Gozzard et al., 2012]. This was based on filling in a survey and a sentence writing task. This handwriting speed was much slower than the norms reported in the DASH 17+, where the average speed for 10 minutes of free writing was between 24-28 wpm. It appears that students write more quickly than the typical young adult who is not studying and writing examinations [Barnett et al., 2010].

However, when observing university students’ handwriting in examinations Summers and Catarro (2003) found they wrote an average of 16.2 to 19.26 WPM over a two hour examination, indicating this faster writing speed described above may not be sustained over a long period where there is a high cognitive load.

Those students who wrote more words however, were identified as having demonstrated better academic ability in terms of the examinations [Summers and Catarro, 2003]. Handwriting speed was also found to be related to the quality of note taking in university students who still wrote notes. Therefore, maintaining an adequate writing speed over a period of two three hours is important and students who present with slow writing in a short five to ten minute assessment task must be considered at risk for their handwriting impacting on their academic achievement.

Flows

Legibility

The legibility of handwriting has been related to handwriting problems or dysgraphia in both children and adults. When assessing handwriting difficulties and dysgraphia, poor legibility may be the one of the main concerns and is often the reason for referral and assessment of handwriting [Danna et al., 2013b]. In many individuals with dysgraphia, irrespective of remediation, the legibility of handwriting does not improve during the school years and letter formation, the variability in letter, word spacing and alignment remain at an unacceptable level [Graham, 2006].

The legibility of writing has been shown to decrease when typical children write in longer tasks but in university students no relationship was found between legibility the length of time students wrote for in examinations. Summers and Catarro (2003) reported that even through the writing of some students deteriorated by the sixth page when writing between 14 and 16 pages in examinations, writing legibility was not substantially affected. A limitation of this study is that legibility was not analysed on the last page of writing in the examination which may have reflected a difference in legibility when students may have increased their speed if they had not completed the final questions in time [Summers and Catarro, 2003].

There is also little correlation between legibility and writing speed in both long and short writing tasks with 46 typical Grade 4 students [Dennis and Swinth, 2001]. They found that endurance did affect legibility in typical children but the small sample and use of different writing tasks in the groups they compared may have affected the results of the study. Shah and Gladson (2015) in their study on 100 college students, who copied a long passage, did find a significant correlation between legibility and speed although the study was flawed. Only 34 letters of the 382-word copied were analysed in terms of legibility and this was done inconsistently by a number of different researchers [Shah and Gladson, 2015]. Therefore, there is little clarity on the role of speed of writing and fatigue on legibility in students in higher education.

Automaticity of handwriting

The assessment of automaticity of handwriting is associated with the performance skills of Flows and Paces. The fluency or automaticity of handwriting has been assessed using digital writing tablets it has been found that this is not affected by slow pen movements but is rather due to pausing with the pen either resting on the page or when the pen is held in the air.

Writing out the alphabet in lower case letters has been related to automatic long term memory letter retrieval without other higher order processing [Alstad et al., 2015]. By timing the task, it can be assumed that a good performance represents better representation of the letters in memory as well as a more automatic retrieval routine. The scoring of the WSAM has been used to identify children at risk of handwriting dysfunction by assessing the number of letters written correctly in a given time period [Berninger and Fuller, 1993].

Rosenblum in 2005 used the WSAM Alphabet task on a digital system to differentiate primary school children with and without hand writing dysfunction. She found signification differences between the two groups in terms of speed and spatial organisation supporting the use of the Alphabet task in screening for handwriting automaticity [Rosenblum, 2005]. This WSAM Alphabet task has been incorporated into other standardised tests like the DASH and the DASH 17+ as a test of automaticity or writing fluency [Barnett et al., 2007, 2010]. This has added to the evidence that the WSAM Alphabet task is valid for the assessment for adult students.

The assessment of handwriting outcomes is important as deficits in the outcomes have been shown to impact on students' ability to be productive in academic activities such as note taking, studying and writing examinations [Chang et al., 2015]. Standards provided in the DASH 17+ are available for speed and automaticity of writing for students in higher education but not legibility, although these standards may not apply to students in South Africa [Barnett et al., 2010].

2.8 Summary

Presently essay and short question examinations at universities are mostly still handwritten and students with dysgraphia or writing dysfunction are compromised by timed examinations. The awarding of accommodations for dysgraphia is affected by the lack of clarity and acknowledgement that this is related to a separate SLD as well as other conditions that affects the ability to write legibly and with adequate speed. Research indicates that students with learning disabilities and writing problems benefit from academic concessions, at a postsecondary or university level. There is little clarity on what concessions should be awarded, how they are to be assessed, at what level a student could be considered as dysgraphic and what assessments should be used. This literature review supports the development of an assessment for students in higher education to screen for handwriting deficits.

In spite of the move to technology, research indicates that learning to write is still important and can affect the ability to read and spell. Handwriting assessments with the exception of the DASH 17+ have been developed to assess children and adolescents. Some of these assessments lack adequate psychomotor properties but are used and reported research and due to the need for evaluator training and complex scoring, their clinical usability seems limited. The same is true for assessments using digital tables. It appears that only two screening assessments related to handwriting for young children are available. These did not meet all the criteria for screening assessments presented in the review. Most assessments only score handwriting outcomes in relation to legibility and speed and do not consider client factors and components of handwriting affecting the ability to write.

Although handwriting outcomes have been shown to correlate with posture and consistency of grasp in children with writing deficits and dysgraphia it is unknown if this is true for students in higher education. Speed and legibility of writing has however been linked to pain and fatigue [Shah and Gladson, 2015; Summers and Catarro, 2003] as well as the position of the paper on the table in post-secondary students [Lohman, 1993]. Therefore, in occupational therapy, it has been recognised that observing the end product and not the process and performance required to achieve the end product does not always provide evidence of handwriting problems. It has been suggested that by assessing the performance of the writing task, deficits which can guide further assessments and appropriate concessions, can be identified. Therefore, research on components affecting handwriting was reviewed. Most studies reviewed were descriptive and many considered components and client factors which differ when typical children and students in higher education are compared to those with dysgraphia and handwriting difficulties.

Evidence for the relationship between handwriting outcomes and the other performance skills, components of handwriting and client factors reviewed above, has not been confirmed. The review of the motor and process skills related to the writer and the presentation of handwriting provided a basis for item and subtest development for the screening assessment in this study.

CHAPTER 3: OVERVIEW OF THE STUDY AND METHODOLOGY PHASE 1.

3.1 OVERVIEW OF THE STUDY

The overall study design was sequential based on the development and evaluation of a screening assessment or instrument. The steps for instrument development described by McCoach et al. (2013) and Laver Fawcett (2013) were followed in sequence and were intergrated with the criteria to be considered when developing and evaluating a screening assessment according to American Educational Research Association (AERA) [American Educational Research Association, 2014; Glover and Albers, 2007; Laver Fawcett, 2013; McCoach et al., 2013]. This resulted in the study being completed in three phases [Glover and Albers, 2007; Laver Fawcett, 2013; McCoach et al., 2013]. The purpose of the current study was to develop and dertermine the usability of the Handwriting Screening Assessment as a diagnostic assessment. This type of assessment is usually designed to be administered to an individual as opposed to a group, by an evaluator with specific qualifications, in this case an occupational therapist. The Handwriting Screening Assessment was designed to identify the presence of risk for dysgraphia and handwriting deficits and to guide recommendations for further assessment in order to determine the need for academic concessions [Fuchs and Fuchs, 1998]. For a screening assessment of handwriting to be appropriate and useful for the students in higher education it needs to accurately and reliably predict the risk for dysgraphia or handwriting problems. The standardisation of the assessment should be supported by validity and reliability studies. The usability or benefit of the assessment to the target population for students requesting concessions should be shown. An overview of the three phases of the study is presented in Figure 3.1, with the steps of instrument development and the associated criteria for the development and evaluation of screening assessments [American Educational Research Association, 2014] addressed in each phase. A summary of the methods used for each phase is also included in Figure 3.1.

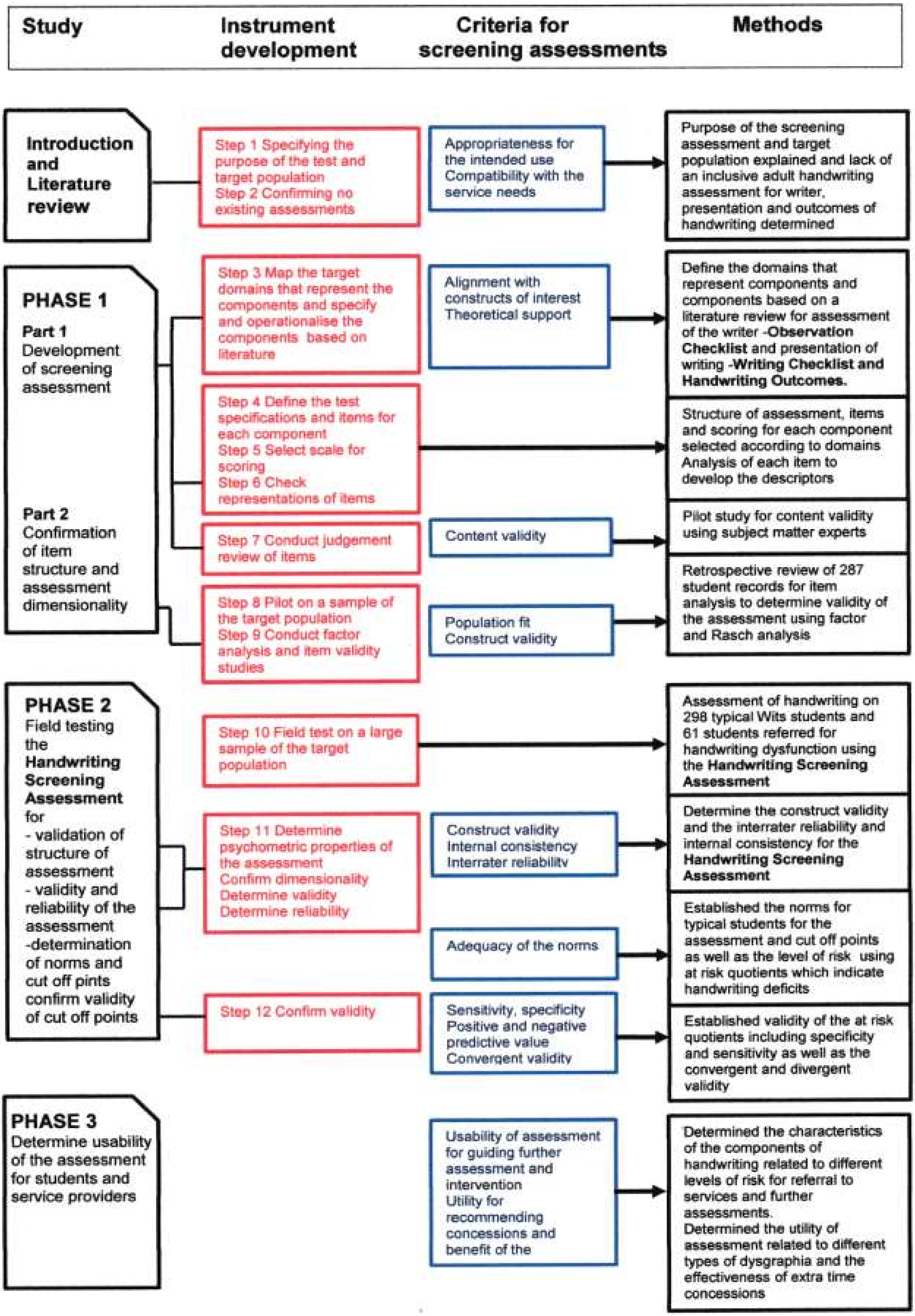

Figure 3.1 Overview of the methodology of the study

The steps for instrument development based on those suggested by McCoach et al. (2013) and Laver Fawcett (2013) (marked in red in Figure 3.1) were followed in the development of the Handwriting Screening Assessment

- Step 1 which specified the purpose of the instrument and Step 2 which ensured that there is no existing instrument that will adequately serve the purpose of the assessment to be developed were covered in Chapter 1 and Chapter 2.

The following steps were completed in Phase 1 of the study:-

- *development of the instrument* - this included Step 3 in which target domains were specified and mapped and the components were operationalise based on the literature. This step was initiated in the literatrue review and domains, components and associated client factors were finalised in Phase 1 of the study. In Step 4 test specifications as well as the type of assessment and format for the items were defined. The scoring based on ordinal and interval scales was finalised in Step 5. In Step 6 the analysis of each component, was completed to develop descriptors for each item. Items were matched back to the domains to ensure adequate content presentation. A judgement review of items using content analysis with subject matter experts was completed in Step 7.
- *pilot study* – In Step 8 the screening assessment was piloted on a sample of the target population using a retrospective record review. A demographic questionnaire to determine the population fit or profile of the sample was developed. Factor analysis and Rasch analysis were used to determine item validity and the dimensionality of the screening assessment in Step 9. Guidelines for the administration of the screening assessment were developed.

In Phase 2 of the study the following steps were completed:-

- *validity and reliability studies* – In Step 10 the screening assessment developed in Phase 1 was field tested on a sample of typical students and students referred for handwriting assessment using a descriptive cross sectional study design. The psychometric properties of the screening assessment were confirmed based on the results in Step 9. The construct validity, convergent and divergent validity, internal consistency and inter-rater reliability for the screening assessment were determined in Step 11. After norms for typical students had been determined the clinical accuracy in terms of specificity and sensitivity were also established.

The criteria for the development and evaluation of screening assessments (marked in blue in Figure 3.1) were matched and combined with the steps of instrument development. These criteria were based on those published by the AERA [American Educational Research Association, 2014; Glover and Albers, 2007].

The criteria include:

- *intended use of the screening assessment* - the purpose of the Handwriting Screening Assessment including the context for use, compatibility with the service needs and the constructs of interests. These criteria were addressed in Chapter 1 and 2 -the introduction and literature review.
- *technical adequacy* – Phase 1 and Phase 2 of the study considered the criteria for technical adequacy in the development of the Handwriting Screening Assessment. In these phases criteria for the population fit as well as the adequate content validity, construct validity, convergent and divergent validity, internal consistency and inter-rater reliability were covered. The criteria for clinical accuracy and adequate norms based on a recent normative sample representative of the population were also addressed.
- *usability* - in phase 3 further analyses of the characteristics of the components of the Handwriting Screening Assessment for the target population of students referred for handwriting assessment were completed. This provided evidence of the presence of deficits in the target population for establishing the need for further assessment. The utility of the screening assessment for the stakeholders in guiding intervention or recommendations for concessions by determining if different types of dysgraphia could be identified the sample of students identified with

dysgraphia or handwriting deficits was explored. The benefit of the screening assessment in terms of the students' academic outcomes was also considered.

The methods (marked in blue in Figure 3.1) are presented below and include Steps 3-12 of instrument development as well as the research designs used to determine the technical adequacy and the usability in the development of the Handwriting Screening Assessment.

3.2 Ethical considerations

Ethical clearance was obtained from the Wits Human Research Ethics Committee (HREC) for the review of the records of students assessed for extra time because of handwriting problems. Ethical clearance was also obtained for the assessment of the handwriting of typical students and students referred for assessment of handwriting at Wits (Appendix A).

Permission for the use of records of students assessed for extra time because of handwriting problems in the Occupational Therapy Department was obtained from the Head of Department for the record review (Appendix B) as this was the department in which the records were kept. Permission was obtained from the Deputy Registrar of Student Affairs at the Wits for recruitment of students on the university campuses. Since students in the Health Sciences Faculty and the Department of Occupational Therapy and Physiotherapy were recruited specifically for reliability studies. The permission of the Dean of this Faculty (Appendix C) as well as the Heads of the Occupational Therapy and Physiotherapy Departments was also obtained (Appendix D).

In order to protect the interests of the students and ensure no coercion was used when approaching typical students to participate in the study the students were approached by a research assistant who was a student and occasionally by the researchers or a second research assistant who was an occupational therapist, if the student research assistant was not available. The students they approached were invited to take part in the study and the study was explained to them. The requirements for their participation in the study were explained to those who showed interest and if the students then agreed to participate they were provided an information sheet approved by the HREC (Appendix E) and asked to sign informed consent (Appendix F).

Students referred for handwriting assessment were asked for permission to allow the results of their assessment (that was completed as routine assessment for concessions), to be included in this study once they had been informed of the outcome of the assessment. This was done to ensure that the assessment was not affected by the request for the results to be used in the study. It was clearly explained that refusal to allow for the results of their assessment to be used would have no effect on the outcome and recommendations for extra time and concessions. The students were also asked to give permission for their academic results to be accessed at the end of the year and the following year. They were provided an information sheet approved by the HREC (Appendix G) and asked to sign informed consent (Appendix H).

The HREC which applies high international ethical standards required that all checks and balances were adhered to, to ensure that the students were protected. All students were informed that participation in the study was voluntary and students were free to refuse to participate or withdraw at any stage without any consequence.

All data sheets were coded and no names or student numbers were used so confidentiality was ensured. No identifying data were required on the data sheets of the typical students and the person information of the students referred for assessment was available only to the researcher and was locked away in a secure location. Feedback on the research findings were made available to students on request. After the screening assessment was completed, typical students were informed if the researcher if she was concerned about their performance in relation to their handwriting. The students were offered assistance and they were provided with CHWC details if they wished to have further assessment.

3.3 Methodology Phase 1 - Development of the screening assessment

This phase of the study addressed Steps 3 to 9 of the instrument development outlined in Figure 3.1 and was divided into two parts. The aim for this phase of the study was to develop the Handwriting Screening Assessment and to complete a pilot study on the validity of the items and the dimensionality of the assessment.

3.3.1 Objectives:

Part 1: Construct validity and reliability of the Handwriting Screening Assessment

- To establish the construct validity of the Handwriting Screening Assessment by determining: -
  - the statistical properties of the subtests in the Observation Checklist, the Writing Checklist and the Handwriting Outcomes to establish and confirm their dimensionality and structure.
  - the differences in the three sections of the Handwriting Screening Assessment for known group factors - age, gender and school attended.
  - the differences in the three sections of the Handwriting Screening Assessment between typical students and those referred for handwriting assessment.
- To establish the reliability of the Handwriting Screening Assessment by determining the internal consistency and interrater reliability for the three sections of the Handwriting Screening Assessment.

Part 2: Cut off points and at-risk quotients for the Handwriting Screening Assessment

- To establish the norms and cut off points related to at risk quotients (ARQs) to identify students at risk for handwriting deficits on the Observation Checklist, the Writing Checklist and the Handwriting Outcomes.

3.3.2 Part 1: Development of the screening assessment

3.3.2.1 Research design

The research design used in this part of the study was descriptive as no variables were manipulated and no intension included [Pett et al., 2003]. The screening assessment was developed to measure the key components of handwriting based on Steps 3-7 of instrument development (Figure 3.1) [Laver Fawcett, 2013; McCoach et al., 2013]. These steps were followed to identify domains from the motor and process performance skill framework for each on the handwriting constructs identified in the literature review. These domains and constructs formed the basis for the development of items for the **Handwriting Screening Assessment**. The alignment of the constructs of interest were integrated with the criteria for the development of screening assessments [Glover and Albers, 2007].

3.3.2.2 Research procedure

The assessment was divided into sections and each section considered a different construct of handwriting to provide an inclusive overview of all components of handwriting. The constructs of handwriting included were those in which components could be observed in the writer (**Observation Checklist**) and the presentation of their writing (**Writing Checklist**). **Handwriting Outcomes** in terms of speed, legibility and automaticity of writing made up the third section of the assessment**.**

Each component was then analysed based on the literature review, to determine descriptors of what was considered ideal or good practice when writing and the indicators of deficits. The descriptors for each item were generated and assigned a score. Once the items for the Observation Checklist and the Writing Checklist had been completed they were piloted for content validity. The Handwriting Outcomes section was based on standard measures of speed, legibility and automaticity and was not included in the content validity pilot study.

Pilot study for content validity

The content validity of the Observation Checklist and Writing Checklist items was established by using subject matter expert (SME) opinion. Inclusion criteria were set for SMEs for the content validity study according to professional development and expertise in the field of paediatrics and handwriting [Schell and Schell, 2007] as no occupational therapy experts in adult handwriting could be identified to assist with the study.

Inclusion criteria

- Occupational therapists with experience in handwriting remediation
- Either having completed or completing a PhD
- Ten years of experience

Three SMEs who met these criteria and who were working or who had worked with handwriting problems in younger children were asked to review each checklist item for relevance and clarity. The checklists were emailing to the SMEs. The SMEs were asked to critically evaluate the checklists and the individual items and return them with comments to the researcher.

After the suggested changes were made, the revised checklists were emailed to the SMEs for final checking. The checklists with the changes approved by the SMEs were used in Part 2 of this phase of the study.

3.3.3 Part 2: Pilot study to confirm item and subtest validity and checklist dimensionality

3.3.3.1 Research design

In part 2 of Phase 1, Steps 8 and 9 of instrument development were combined with the population fit or population profile as required for criteria for screening assesments, by piloting the asessment on a sample of students from the target population which was students refrred for handwriting assessment.

The construct validity for the items and the subtests as well as the dimentionality of the Observation Checklist and the Writing Checklist was determined. The items developed for each domain and component in Part 1 were piloted by using a retrospective review of records of students referred for handwriting assessment and who had been assessed in the Wits Occupational Therapy Department. The Observation Checklist and the Writing Checklist were assessed for item validity and unidimensionality using factor analysis and Rasch analysis.

A retrospective record review was used as it was low cost and since the information was all recorded on a set format, the data were relatively easy to retrieve. Records which included a sample of the students' actual handwriting were also available for analysis [Kielhofner, 2006]. This research design was appropriate because by using the existing records a large sample could be included in the pilot study which was a pre-requisite for both factor and Rasch analysis.

3.3.3.2 Record selection

All records of students who were assessed for handwriting problems between 2008 and 2012 by the Occupational Therapy Department at Wits that were available were used.

Sample size

The number of complete records of students who had been assessed for problems related to handwriting was 287. This provided a sample size of approximately 10 participants per item on the 31 items on the Observation Checklist. This checklist was used to determine the sample size as it had the greatest number of items of the three sections in the Handwriting Screening Assessment [Gorsuch, 1983]. For exploratory factor analysis factor loadings between 0.80 and 0.60 are considered stable if the sample is greater than 150 and therefore for the current study the sample size was deemed adequate [Guadagnoli and Velicer, 1988].

3.3.3.3 Measurement instruments

Demographic questionnaire

A demographic questionnaire was developed by the researcher and included aspects such as gender, age, course being completed, academic history and previous history of learning disabilities. Previously awarded extra time and other concessions the student had been given were recorded. Any other relevant history of medical conditions which may affect handwriting was also included (Appendix I).

Handwriting Screening Assessment

The Handwriting Screening Assessment that was developed in Part 1 and corrected after it was piloted for content validity was used to collect the data for this pilot study (Appendix J). This screening assessment consisted of three sections: - the Observation Checklist, the Writing Checklist and Handwriting Outcomes. The outcomes including the speed of copying and legibility were determined for each student.

- The speed of the hand writing was calculated from the number of words copied from the 115 word passage (Appendix K) in three minutes. The number of words was adjusted to accommodate both added words, words crossed out and mistakes as well as words and lines of text repeated or left out, and then divided by three to provide a WPM score. The acceptable level for words copied was based on that provided on the DASH 17+ by Barnett (2010) for best copying at a mean of 24-28 WPM [Barnett et al., 2010]. By using the best copying scores from the DASH 17+ which are slower than the fast copy speed, r the longer passage copied in the current study at the students normal handwriting speed. Was accommodated
- The legibility score used was based on the percentage of illegible letters and a global 7 point scale with a cut off set a 3 (Table 3.1)..

Table 3.1 Legibility Score criteria

1 very legible writing	every letter clear and - read 100% -95% of letters
2 legible writing	not every letter clear - can read less than 95% of letters (31-60 out of 601 letters illegible)
3 partially legible writing	some letters not clear--can read less than 90% of letters (61-119 out of 601 letters illegible)
4 mixed legible and illegible writing	some letters not clear -can read less than 80% of letters (120-179 out of 601 letters illegible)
5 partially illegible writing	some letters not clear -can read less than 70% of letters (180- 239 out of 601 letters illegible)
6 illegible writing	some letters not clear —can read less than 60% of letters (240-293 out of 601 letters illegible)
7 very illegible writing	few letters clear – can read less than 50% of letters (294+ out of 601 letters illegible)

These criteria for legibility in adult handwriting suggested by Gozzard (2012) were used as adult handwriting may have some words that are not legible. The cut off used equated to at least 90% of words being legible based on Gozzard's criteria of the meaning of the text is clear [Gozzard et al., 2012]

3.3.3.4 Research procedure

Once ethical clearance (Appendix A) and permission to use the records (Appendix B) had been obtained the records were sourced from the Wits Occupational Therapy Department. The demographic questionnaire, the Observation Checklist, the Writing Checklist and the Handwriting Outcomes (Appendix I and J) were used to record the data from the 287 records. Each report was read by the researcher and the demographic questionnaires as well as the Observation Checklist were completed.

Each students' written record contained informal observations of the students' behaviour when writing and this was used to complete the data for Observation Checklist. The Writing Checklist was completed using the sample of the students' handwriting. The writing was checked for spelling mistakes, missing text, punctuation, capital letters and unreadable letters by a third research assistant who had a BSc degree. The researcher then scored the organisation and slant of the letters, size and type of writing and the legibility for each student's handwriting sample. The speed of writing for the Handwriting Outcomes was obtained from the records which included samples of handwriting on the same 115 word passage used in Handwriting Screening Assessment. The legibility of writing was scored on a 7 point scale using the same sample of handwriting. No writing automaticity score could be obtained from the records as this had not been assessed for these students.

The data were entered into an Excel spreadsheet for analysis using Statistica v12 and SPSS v 12.

3.3.3.5. Data Analysis

Descriptive statistics were used to analyse the data of the students' demographic factors to establish the demographic profile of the students referred for handwriting assessment.

Exploratory factor analysis was used to determine the validity of the items on the Observation and Writing Checklists as they were scored on a Likert scale. Initially correlations between the scores for each item were determined using Spearman's correlation coefficient to accommodate the ordinal nature of the data. The five steps suggested by Williams et al. (2012) for exploratory factor analysis were used to determine the adequacy of the data and factor extraction [Williams et al., 2012].

Item response theory or Rasch analysis was used to determine the dimensionality of the Observation and Writing Checklists. The threshold for each item was analysed to determine if the level of dysfunction (score) ascribed to each descriptor reflected the difficulty of that descriptor in relation to the difficulty of the other descriptors in that item. Disorganised thresholds where difficulty was not appropriately assigned were adjusted to form an ordered set of responses. Once the threshold for each item was set correctly in terms of the level of dysfunction the items in each checklist were analysed to determine if the items formed a unidimensional assessment [Tennant and Pallant, 2006].

Since the assessment was constructed from a number of components related to handwriting it was found that the item fit was not unidimensional for the either the **Observation** or the **Writing Checklists.** Therefore, a Rasch subtest analysis was completed. A non-significant p value greater than 0.05, after the application of a Bonferroni correction was used to determine the fit of the subtests in the two checklists [Cheng et al., 2008].

Subtests were then analysed for the difficulty level and log residuals were used to establish over or under discrimination. The lack of local dependency of the subtests was confirmed using correlations between the subtests and equating t-tests. This ensured that each subtest measured a difference component and there was no redundancy in terms of the subtests and items [Andrich, 2005]. The criteria for an adequate fit for each of these analyses are included in the results chapter.

Exploratory factor analysis and Rasch analysis were not used with the results of the Handwriting Outcomes as these were already recorded using interval scales. These results were descriptively analysed using frequencies to indicate the percentage of students that performed poorly in terms of speed and legibility of handwriting. Adequate performance was based on criteria from the literature [Barnett et al., 2010].

CHAPTER 4: RESULTS PHASE 1

4.1 Introduction

The development of a screening assessment to determine handwriting deficits for students in higher education was based on the steps of instrument development and the criteria for screening assessments described in the literature review and methodology chapters. This chapter reports on the results of the first phase of the study which aimed to develop a handwriting screening assessment.

4.2 Part 1: Development of the screening assessment

This part of phase addressed the results for the first nine steps in the instrument development process outlined in Figure 3.1.

4.2.1 Step 1: Specifying the purpose of the test and target population

The purpose for and target population for which the Handwriting Screening Assessment was developed were covered in the introductory chapter 1. The assessment was developed as a screening tool to be administered in a short time to determine if students in higher education present with handwriting deficits.

Components related to the risk for dysgraphia needed to be identified so that appropriate further assessments, concessions and adaptations could be recommended when students are expected to produce written work, particularly for examination and grading purposes [Feder and Majnemer, 2007; Graham et al., 2006;]. The purpose of the screening assessment was to determine the effects of components related to the writers themselves such as body posture [Graham and Weintraub, 1996; Parush et al., 2010], and the presentation of the writing in terms of errors, spelling, grammar and erasures [Graham et al., 2011].

This assessment may in future be administered by occupational therapists to students requesting concessions for handwriting in higher education in South Africa and only students who identified with deficits on screening will be referred for a longer and in depth assessment. Thus, the limited funds available to support students with disabilities could be used judiciously to provide comprehensive assessment for the students who have been shown to need it.

4.2.2 Step 2: Confirming no existing assessments

A review of the literature confirmed that no holistic screening assessment which considers the writer, presentation of writing and handwriting outcomes exists for the target population, which is university students that require concessions for handwriting. No screening assessment for dysgraphia in university students has previously been described.

The handwriting assessments used in studies in the last seven years were those designed for use in school children with the exception of one study on students with DCD which used the DASH 17+ [Barnett et al., 2011].

4.2.3 Step 3 Map the target domains that represent the components and specify and operationalise the components based on literature.

The target domains in this study were the motor and process performance skills. The domains for each of the three sections of the Handwriting Screening Assessment the Observation Checklist, the Writing Checklist and the Handwriting Outcomes were based on the motor and process performance skills which can be observed in handwriting. The operational definition for each skill was based on that provided in the OTPF III [American Occupational Therapy Association, 2014]. The components of handwriting associated with each skill were determined so that the components of handwriting could be organised into groups according to observable performance skills (Table 4.1, 4.2 and 4.3).

The components to be evaluated were then defined in terms of observable actions or behaviours and a task to elicit that performance was determined [Stiggins, 1987]. Therefore, a bottom up approach to the assessment of hand writing which considers the components required to develop the skill of handwriting is warranted when screening for handwriting deficits in older children and adults [Carlson and Cunningham, 1990]. A review of the outcomes of handwriting does not provide adequate evidence for referral for further assessment of specific client factors that can be made to recommend concessions.

Each component was operationalised by linking the construct with a number of specific, concrete indicators or descriptors that can be observed and measured based on the literature [McCoach et al., 2013]. Items which could be used to measure each component were therefore based on the observable actions related to handwriting that could be scored by an occupational therapist while watching students complete handwriting tasks for a short period. The association of client factors with each measurable aspect of the components of handwriting were also considered.

A framework which represented the domains in terms of the motor and process performance skills and the associated components of handwriting was developed specifically for the current study as handwriting had not been classified according to performance skills previously. The development of this framework was peer reviewed by an expert occupational therapy colleague with 10 years of experience as an occupational therapist. She had experience with motor and process performance skills and their use in observation of activities from previous exposure to the Assessment of Motor and Process Skills (AMPS) [Fisher and Griswold, 2014] and was also experience in the remediation of handwriting in children. Agreement between the researcher and this expert colleague on the operational definitions for the motor and process performance skills was obtained, as well as the associated components of handwriting, the operationalisation of the components and the associated client factors.

Observation Checklist

Table 4.1 indicates the domains for the **Observation Checklist** which allowed for observation of the students' actions and behaviour related to motor and process performance skills associated with handwriting while copying. The performance skill of Positions was represented by the positioning of the paper in relation to the student and the table [Pollock et al., 2009]. These aspects can be associated with the client factors of writing movements, posture and crossing the midline where the paper is positioned to the side of the writing hand. Placing the paper being copied from above the one being written on or to the side of the non-writing hand may be associated with visual function deficits and eye dominance.

Table 4.1 Domains and components of handwriting with associated client factors –Observation Checklist

Domains Performance skill	Components of handwriting	Operationalisation of the components	Associated client factors
Positions (positions self and tasks objects effectively - OTPFIII) **Accommodates** (prevents ineffective task performance- OTPFIII)	Position of paper	Orientation of paper on the table	Posture Crossing the midline Visual function Eye dominance
		Paper in relation to student	
		Position of paper in relation to paper being copied from	
Flows (uses smooth and fluid upper limb movements when interacting with task objects- OTPFIII)	Preferred hand Writing movements - wrist position	Hand used to write	Dominance Flexion or extension of the wrist
		Position of wrist when writing	
Manipulates (uses dexterous finger movements- OTPFIII)	Movements when writing	Hand and digits used to write	Praxis, Writing movements In-hand manipulation Fine motor control Muscle strength
		Movements in writing hand	
		Pausing	
Coordinates (uses two or more body parts together to manipulate and stabilize task objects- OTPFIII)		Fixates the paper	Bilateral integration Midline crossing
Grips (effectively pinches or grasps task objects- OTPFIII)	Pen grasp	Position of fingers on pen	In-hand manipulation Fine motor control Visual function Muscle strength
		Type of pen grasp	
		Position of thumb	
		Joint pen is held against	
		Pen slant	
Calibrates (uses movements of appropriate force, speed, or extent when interacting with task objects- OTPFIII)	Force and pressure used in hands when writing	Firmness of pen grasp	Proprioception, kinaesthesia and haptic sensation
		Firmness of non-writing hand on paper	
		Web space	
		Position of finger and thumb joints	
Aligns (interacts with task objects without persistent propping or leaning- OTPFIII)	Posture when writing	Trunk posture	Posture Postural control Visual function
		Support on table with arms	
		Position of head in relation to paper	
Notice/ responds (responds appropriately task-related cues- OTPFIII) **Accommodates** (prevents ineffective task performance- OTPFIII)	Reads text when copying	Follows text being copied	Visual function Attention
		Head movement	
		Mouthing words	

The performance skill of Flows was associated with the preferred hand as it more difficult to write from left to right on a page with the left hand with greater activation of muscle activity in the left upper limb when writing. The use of this hand is often associated with wrist flexion when writing [Park, 2013].

The movements in the hand and of the digits could be observed as Manipulates, Coordinates and Calibrates. These components [Selin, 2003] which include the correct positioning of the joints of the wrist and fingers for writing are associated with the muscle strength, in hand manipulation, fine motor control as well as proprioception, kinaesthesia and haptic perception [Yu et al., 2012]. The assessment of pen grasp has previously included all these components but for the current study was divided into Calibrates (stability of grasp related to the force of the grasp), Grips (the actual grasp used to hold the pen) and Manipulates and Coordinates (the movement in the hand used to write). These components represented different motor performance skills and therefore were considered separately. Repositioning of the pen in the hand or shaking of the hand while writing may indicate the client factors of pain or discomfort was included as part of the assessment of movements in the hand when writing [Feder and Majnemer, 2007].

Aligns was associated with posture and supporting the forearms of the writing and non-writing hand on the desk. This included whether the student sat symmetrically while writing as poor sitting posture has been associated with dysgraphia and handwriting deficits [Crouch and Jakubecy, 2007] . Following the text to be copied with a finger or excessive head movement to check every word being read may be indicative of oculomotor and saccades problems or visual attention difficulties. These fall under the performance skills of Notice and responds and Accommodates as using a finger to follow the text is a form of accommodation to improve performance [Chan and Lee, 2005].

Writing Checklist

Since dysgraphia and handwriting difficulties may result in inconsistencies in type and slant of letters, spacing of letters and words on the paper, unfinished and omitted lines of text, words and letters, random punctuation and poor spelling as well as unreadable words the presentation of the writing was assessed for these components [Pollock et al., 2009] (Table 4.2). The planning and sequencing of letters observed as Flows and Organises provide information about the client factors of writing movements, fine motor control, visual perception and praxis [Tseng and Murray, 1994].

Table 4.2 Components of handwriting with associated performance skills and client factors –writing checklist

Domains Performance skill	Components of handwriting	Operationalisation of the components	Associated client factors
Flows (uses smooth and fluid upper limb movements when interacting with task objects- OTPFIII) **Organises** (logically spatially arranges in an orderly fashion such that the space is not too spread out or too crowded- OTPFIII)	Quality of writing	Writing in relation to lines Organisation of letters and words Slant of letters Percentage unreadable words	Writing movements Fine motor control Visual perception
Adjusts (effectively overcomes problems with ongoing task performance- OTPFIII) **Accommodates** (prevents ineffective task performance- OTPFIII)	Type of writing	Size of writing Print or cursive	Writing movements Fine motor control Visual perception
Calibrates (uses movements of appropriate force, speed, or extent when interacting with task objects- OTPFIII)	Pressure used to write	Pressure used on the paper to write	Proprioception, kinaesthesia and haptic sensation
Endures (persists and completes the task without showing obvious evidence of physical fatigue- OTPFIII)	Deterioration in writing	Change in writing over time	Muscle power Muscle endurance Pain
Heeds (carries out and completes the task as specified- OTPFIII) **Adjusts** (effectively overcomes problems with ongoing task performance- OTPFIII) **Attends** (does not look away from what he or she is doing, interrupting task progression- OTPFIII)	Errors in copying	Corrections Spelling Punctuation, capital letters Missing or added words or letters	Attention Dyslexia Orthographic coding Allographic mechanism Visual function

The pressure used when writing on the page or Calibrates relates to proprioception, kinaesthesia and haptic sensation [Yu et al., 2012]. Deterioration in the writing over a duration of approximately five minute was associated with Endures and Flows [Kushki et al., 2011]. Type and size of writing was aligned with Accommodates and Adjusts as student adapt their type of writing for speed and increase the size to improve legibility.

Errors in writing specifically punctuation, spelling and incorrect use of capital letters as well as added or missing words and letters are associated with the performance skill of Heeds and Attends which may be related to visual attention and oculomotor function or may be signs of orthographic coding and allographic mechanics related to dyslexia [International Dyslexia Association, 2012]. Corrections made were aligned with the process performance skill of Adjusts as students improved their performance by correcting errors.

Handwriting outcomes

Handwriting outcomes are assessed using the measures of speed and legibility. The performance skill of Paces is related to the word per minute assessment of speed reported in most assessments, while legibility which is aligned to Flows and Organises can be assessed by rating the readability of the handwriting using a Likert scale (Table 4.3).

Table 4.3 Components of handwriting with associated performance skills and client factors –Handwriting outcomes

Domains Performance skill	Components of handwriting	Operationalisation of the components	Associated client factors
Paces (maintains a consistent and effective rate or tempo of performance throughout the entire task -OTPF III)	Speed	Number of words written in a minute	Writing movements Fine motor control Visual perception
Flows (uses smooth and fluid upper limb movements when interacting with task objects- OTPFIII) **Organises** (logically spatially arranges in an orderly fashion such that the space is not too spread out or too crowded- OTPFIII)	Legibility	Readability of letters and words	Writing movements Fine motor control Visual perception
Paces (maintains a consistent and effective rate or tempo of performance throughout the entire task -OTPF III) **Flows** (uses smooth and fluid upper limb movements when interacting with task objects- OTPFIII)	Automaticity	Pausing while writing Writing sequenced letters of the alphabet	Fine motor control Muscle power Muscle endurance Orthographic coding Allographic mechanism

The recognition, reproduction and sequencing of letters in the alphabet is related to the automaticity of writing and the performance skills of Flows and Paces [Sumner et al., 2014].

4.2.4 Step 4 Define the test specifications and items for each component the Observation Checklist, Writing Checklist and Handwriting Outcomes

4.2.4 1 Define the test specifications

The assessment used in the development of the Handwriting Screening Assessment was a formal, evaluator scored screening assessment of handwriting skill. A norm reference format was used as the test needed to classify students so that achievement in handwriting between typical students and those with deficits could be differentiated. Norm reference tests allow students to be ranked across a continuum of ability and those with handwriting deficits falling into the lowest ranks so these can then be identified as having problems with efficiently producing handwriting as required at a higher education level. The assessment was therefore standardised on a number of students so that scores could be interpreted against a normal distribution [Furr and Bacharach, 2008].

A handwriting assessment should contain a number of different modes which test different skills. Modes of assessment can include letter formation fluency [Beminger et al., 1991] free writing on a given topic, writing something from memory, near point copying, far point copying, dictation and composition. It is suggested that the assessment should reflect the context in which the student will be expected to perform [Pollock et al., 2009]. As the purpose of the current study was to develop a Handwriting Screening Assessment to determine the performance in examinations for university students, only letter formation automaticity and near point copying were assessed, as exams do not usually require far point copying and dictation. Near point copying requires the transfer of visual information and allowed observation of visual function and attention while reading the text that needed to be copied. Reading and transferring information and data from the question paper in the examination is frequently required in a number of different courses such as accountancy. The spatial organisation and the assessment of the proper formation of letters and the organisation of written output is also possible using this copying mode. Free writing was not included as the screening was for the assessment of the writing process only and not the cognitive aspects of composition.

Students' ability to maintain adequate hand writing over an extended period was not the concern of this screening assessment and therefore the **Handwriting Screening Assessment** consisted of a "copying" and an alphabet assessment.

- Copying a paragraph of 115 words (Appendix K). A paragraph from a university level text book was used, printed in 10 Times Roman font which did not contain words which are considered jargon. The size of the font is in line with some examination papers. Copying allowed not only for the observation of writing but also the ability to visually follow text and pay attention as the text to be copied as the word "observable" is repeated in two consecutive lines to determine if students could track the text efficiently and not miss a line of copied text.
- Writing the alphabet in lower case letters repeatedly for one minute as indicated in section 3.4.3.2 for the WSAM Alphabet task.

While it is possible to identify problems with components and outcomes of handwriting in three minutes longer assessments allow for fatigue, speed and other components to be evaluated against norms [O'Mahony et al., 2008]. Sawyer et al. (1996) found when assessing motor skills in high school learners that a five minute copying task was an adequate time to observe a writer in terms of motor skills and speed in handwriting [Sawyer et al., 1996]. A trial use of the 115 word paragraph (Appendix K) indicated that students took between four to six minutes to copy the paragraph with one minute added for the WSAM Alphabet task, making it suitable to include in the Handwriting Screening Assessment as it is unrealistic to screen the handwriting of students for a long period.

4.2.4.2 Items for each component the Observation Checklist, Writing Checklist and Handwriting Outcomes

In order for a clear indication of the behaviours and writing to be observed, items for the components of handwriting listed above were developed based on a format suggested by Selin (2003) in her study on the assessment of pencil grasp in children. Descriptors or detailed statements outlining each action or behaviour to be observed or component of writing to be evaluated were developed [Selin, 2003]. These descriptors were originally based on the work of Blöte and Dijkstra (1989) who used observations to assist in data collection when researching the effect of manipulation of the pencil grasp in children [Blöte and Dijkstra, 1989; Lyytinen-Lund, 1998]. This method was chosen as it allowed the therapist assessing the handwriting to do so quickly and provided options which increase accuracy [Laver Fawcett, 2013].

The items for each component were developed for both the Observation Checklist (31 items) with descriptors to assess student actions and behaviour and the Writing Checklist (16 items) to assess the students' handwriting (Appendix L). All components were analysed so descriptors represented the functional and different levels of deficits identified from the literature and the researcher's experience in assessing students with handwriting problems over 10 years. Each descriptor was related to an associated motor or process performance skill related to handwriting problems or dysgraphia. A similar analysis process was followed for all other performance skills and components of handwriting that were included in the Observation Checklist and Writing Checklist.

The criteria for the Handwriting Outcomes section of the Handwriting Screening Assessment included the speed of the handwriting based on number of words written per minute, legibility scored on a 7 point scale and automaticity of handwriting based on the WSAM Alphabet task.

4.2.5 Step 5 Select scale for scoring

For each item under the components Observation Checklist and the Writing Checklist, three descriptors were listed one under the other [Selin, 2003]. Functional actions and behaviour as well as handwriting were indicated by 01, while descriptors of partial dysfunction were indicated by 02. The more severe dysfunction was placed third and indicated with 03. On the advice of the statistician all items were scored using the same format of three descriptors so that factor analysis and item analysis testing could be completed on the Handwriting Screening Assessment.

An example of the item format was therefore as follows: -

The web space of the writing hand was
01 open
02 narrowed
03 completely closed

Scoring for some observations such as whether the writing was on the lines or not and the size of the writing were facilitated by the use of transparent overlays. The distance between feint ruled lines used on the paper in the current study was 8mm and writing size of letters that did not extend upwards of between 3-6mm was considered adequate. Letters less than 3mm in height were considered small writing and bigger than 6mm were considered large writing. An overlay with these dimensions was used to judge the size of the students writing.

Writing needed to be less than 2mm above or below the lines to be considered as functional in terms of writing on the lines as very few students write exactly on the lines. An overlay with these dimensions was used to judge writing above or below the lines.

The Handwriting Outcomes section of the Handwriting Screening Assessment included the speed, legibility and automaticity of handwriting as reported in Step 3. The speed of the handwriting was established by determining number of words the student could write of the 115 word paragraph in three minutes. Added and crossed out words as well as omissions were considered in the WPM score. Legibility was assessed on a 7 point scale by counting the number of unreadable letters (Table 3.1). The number of unreadable letters was counted for each student in the paragraph and a percentage of unreadable letters out of the total of 601 letters in the passage was calculated. Results were adjusted to accommodate added and missing letters, words and lines of text.

For automaticity of handwriting using the WSAM Alphabet task, all the correctly sequenced legible letters of the alphabet written in one minute were counted. Letters written in upper case were counted even though students were asked to write in lower case.

4.2.6 Step 6 Check representations of items and Step 7 Conduct judgement review of items

These two steps were completed simultaneously by using the pilot study to determine the content validity of the items on the Observation Checklist and Writing Checklist described in section 3.3.1.2. Since the measures for the Handwriting Outcomes were standardised these were not included in the content validity pilot study.

All comments from the SMEs were collated for each item on the Observation Checklist and Writing Checklist. The following changes were made to the items in view of the comments. Concerns addressed by the SMEs were in relation to the formatting and content of some items on the checklists.

Changes made to the Observation Checklist

Four of the 31 items on this checklist were removed and four new items replaced them. A sheet of possible pencil grasps for guidance was added. Three items were reworded.

The removed items from the initial checklist (Appendix L) included: -

Item 6: It was felt that the deviation of the wrist had not been shown to affect writing so item was removed [Yu and Chang, 2011].

Item 9: In writing the pen point – is lifted between words, during words or after each letter was removed as it was too difficult to assess this accurately when watching the students write.

Item 16: The pressure with which the student held the paper with the non-writing hand was removed as this was not considered an important component in handwriting.

Item 23: Do you consider the student's pen grasp functional? - This was considered to be the opinion of the assessor and was removed as it was felt this was too subjective. Drawings of various pen grasps based on a suggestion by Selin (2003) were added [Selin, 2003]. Deficits in pen grasp were categorised according to an open or closed web space which Benbow et al. (1992) felt differentiated functional from dysfunctional pen grasp [Benbow et al., 1992].

Items that were reworded in the corrected assessment (Appendix J) included: -

Item 14: the first descriptor under Movement in writing hand was changed to “maintains same grasp throughout“ instead of “no extra movement” which was considered too vague. The length of time the students wrote before shaking their hand was included in the descriptor under this item.

Item 11: Students grasp on the pen is – the term “firm” was changed to “not tight” or “loose” as it was difficult to observe “firm”.

Item 15: The rotation of the thumb to 90^0 was a concern as it has been pointed out by Ziviani (1983) that very few children rotate their thumb to oppose the index finger in a dynamic tripod grasp and this descriptor was considered misleading in terms of the tripod grasp [Ziviani, 1983] . It was adjusted to the thumb is aligned with the tip of the index finger and rotation was removed.

Items that were added in the corrected assessment (Appendix J) included: -

Item 21 An item was added to observe which fingers rested on the pen

Item 28 It was suggested that an item about movement of the trunk and limbs be added to evaluate the students’ inability to maintain a stable posture.

Item 16 and Item 17 Two further items on the writing movements were also added for the observation of fine motor control and manipulation as these were considered to be lacking. This included where writing movements occurred and dissociation of the ulnar fingers for stabilisation of the hand on the page as movement for efficient handwriting should take place in the radial fingers and the thumb.

Changes made to the Writing Checklist

This checklist contained 16 items and the constructs in two items were more clearly defined in the corrected checklist (Appendix J): -

Item 10: Concerns with the difference between missing letters in words and spelling mistakes were raised. The item was retained and marked if one letter was left off the end of a word – for example plant instead of plants. This was considered as indicating dysfunction in visual function or attention rather than a spelling problem.

Item 13: Spelling was to be considered a problem when incorrect letters or reversed letters or missing or added letters were found in a word for example environment was written envrioment.

The Handwriting Screening Assessment was altered according to the changes listed above and other items were accepted as they were. The corrected Handwriting Screening Assessment was used for piloting the items to confirm construct validity in terms of the item validity and dimensionality of the sections in part 2 of this phase of the study.

4.3 Part 2 Confirmation of item and subtest validity and assessment dimensionality of the Handwriting Screening Assessment

This part of Phase 1 covers the results for Steps 8 to 9 in instrument development (Figure 3.1). A retrospective record review of 287 students referred for handwriting assessment between 2008 and 2012 was used to obtain data for this phase of the study. The demographic, medical and educational history of the sample of students was reviewed to establish the demographic profile of the students referred for handwriting assessment at Wits. An item analysis of the Observation Checklist, Writing Checklists and Handwriting Outcomes using data from the records reviewed, was completed and the validity and dimensionality of the two checklists confirmed.

4.3.1 Step 8 Pilot on a sample of the target population

4.3.2 Demographic questionnaire

Descriptive results in terms of the students' demographics and educational history presented a profile of the students referred for handwriting assessment at Wits (Table 4.4).

Table 4.4 Demographics of the sample (n=287)

	n	Percentage
Age		
18-21 years	152	53.0
22-24 years	97	33.8
<24 years	38	13.2
Gender		
Male	177	61.7
Female	110	38.3
Hand Dominance		
Right hand	256	89.2
Left hand	28	9.8

All the students whose records were reviewed were 18 years or older with the age range being 18-29 years. The majority of students were below the age of 24 years with those who started university later than 18 years or repeating years making up the group who were older than 24 years. Just under two thirds of the students were male and nearly 10% of them were left handed.

4.3.3 Medical History

Nearly 60% of the students had a diagnosed medical condition. The most commonly diagnosed condition was SLD with ADHD and dyslexia (Table 4.5).

Table 4.5 Medical and diagnosed disorders (n=287)

Medical	**n**	**Percentage**
Previously diagnosed		
Specific learning disability	96	33.4
Psychiatric disorder	22	7.66
Hand or upper limb injury	18	6.27
Neurological disorder	24	8.36
Visual disorders	3	1.04
Other	8	2.79
TOTAL	171	59.6
Visual correction		
Wore glasses/contact lenses	136	47.4

Most of the conditions diagnosed were chronic and included psychiatric disorders such as anxiety with panic attacks. Those students with neurological disorders had diagnoses such as epilepsy, tremors and head injuries. The small number of students who presented with visual disorders were not partially sighted but had conditions like Keratoconus. Just under half the sample required glasses to correct their vision and the only acute conditions seen were hand and upper limb injuries. Other diagnoses included medical conditions like kidney failure and Reynaud's disease.

Approximately a quarter students reported taking medication on a regular basis. Those who took medication for concentration often only took it when they were writing examinations. Other medication students reported taking included anticonvulsants for epilepsy, anti-psychotic and mood stabilising medication and beta-blockers for anxiety (Table 4.6).

Table 4.6 Medication (n=287)

Medication for	**Concentration**	**Pain**	**Other**
	Percentage (n)		
Medication students reported taking	10.8(31)	2.4(7)	12.2(35)

4.3.4 Education History

The type of school the students attended were divided into categories reflective of the South African context. Public schools were divided into previously advantaged schools and previously disadvantaged schools. The historically disadvantaged schools were those that were under resourced during apartheid and which remain so after democracy [Bhorat, 2004]. Private schools were considered separately (Table 4.7). Nearly equal numbers of students whose records were reviewed attended the three types of schools.

Table 4.7 Type of School and Previous Extra time (n=287)

Type of School attended		Previously had extra time/ writing concessions
	Percentage (n)	
Private	35.5(102)	39.2(40)
Public – previously advantaged	31.7(91)	29.6(27)
Public – previous disadvantaged	32.8(94)	4.2(4)
	100(287)	24.7(71)

The students were registered in all five faculties at Wits offering undergraduate courses (Table 4.8). The majority of students applying for concessions for examinations and extra time were registered in the Faculty of Commerce, Law and Management which includes the Department of Accounting. Those who applied after failing for two or more years often reported that they had been unaware that concessions like extra time were available (Table 4.9).

Table 4.8 Faculty registered with (n=287)

Faculty	n	Percentage
Commerce, Law & Management	129	44.9
Engineering & the Built Environment	61	21.25
Health Sciences	51	17.7
Humanities	24	8.36
Science	22	7.66

Less than half the students had failed a course before applying for academic concessions and extra time (Table 4.9).

Table 4.9 Number of years repeated

Number of years repeated	n	Percentage
0	158	55.1
1	81	28.2
2	38	13.2
3	9	3.1
4	1	.3

The majority of students requesting extra time for handwriting problems were in their 1st year of study in their course.

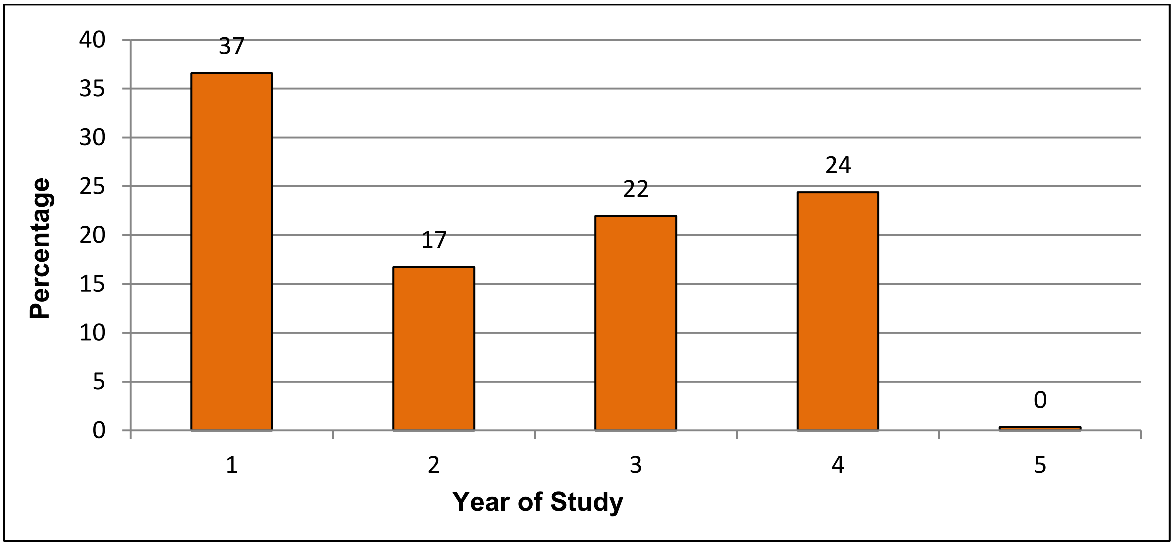

Figure 4.1 Year of study in which concessions were requested (n=287)

4.3.5 Step 9 Conduct factor analysis and item validity studies

To determine if the components of handwriting constitute a single construct in each checklist making them unidimensional, an analysis of the items on the Observation Checklist and Writing Checklist was completed to determine item discrimination and dimensionality**.** The two checklists were considered separately as the constructs assessed in each were different. The items for the Handwriting Outcomes were not included in this analysis as they were already interval scales. Literature has confirmed the lack of association between speed and legibility of handwriting [Dennis and Swinth, 2001].

The relationship between the items in the Observation Checklist and Writing Checklist and their structure as well as the dimensionality of the theoretical constructs was examined in an exploratory factor analysis using Varimax rotations.

4.3.5.1 Exploratory Factor Analysis

Although the components of handwriting were organised according to the motor and performance skills framework this had never been tested. Therefore, all the components of handwriting were subjected to analysis to determine the fit into this framework. Correlations between all the items on the Observation Checklist and Writing Checklist were calculated.

The results in Appendix M indicate that although a number of significant correlations were found, the majority of these were weak with some were above the ± 0.30 suggested as acceptable for exploratory factor analysis (EFA) [Costello and Osborne, 2005; Davis and Morrow, 2004].

The five steps suggested by Williams and Brown in exploratory factor analysis were used [Williams et al., 2012]. First the adequacy of the data for factor analysis was established. The Kaiser-Mayer-Olkin (KMO) test of sampling adequacy values for both the Observation Checklist and the Writing Checklist scored 0.60 and 0.65 respectively which is at acceptable levels. Bartlett's test of sphericity also reached significance of $p \leq 0.01$ which indicates the data were suitable for structure detection and should reveal distinct loadings into factors [Costello and Osborne, 2005; Linacre, 1995].

Factor extraction was achieved using the Kaiser–Guttman rule with eigenvalues, which represent the amount of variance accounted for by each factor [Kaiser, 1960] (Table 4.10).

Table 4.10 Eigenvalues for Observation Checklist

	Eigenvalues	% Total variance	Cumulative Eigenvalue	Cumulative %
Factor 1	3.61	11.65	3.61	11.65
Factor 2	2.10	6.76	5.71	18.41
Factor 3	1.92	6.19	7.63	24.60
Factor 4	1.71	5.51	9.33	30.11
Factor 5	1.54	4.96	10.87	35.07
Factor 6	1.43	4.60	12.30	39.67
Factor 7	1.38	4.45	13.68	44.12
Factor 8	1.33	4.28	15.00	48.40
Factor 9	1.30	4.20	16.30	52.59
Factor 10	1.17	3.78	17.48	56.37
Factor 11	1.14	3.67	18.61	60.04
Factor 12	1.04	3.35	19.65	63.39
Factor 13	1.02	3.28	20.67	66.67

Eigenvalues greater than 1 for the factor were retained [Gorsuch, 1997]. The 31 items on the **Observation Checklist** were reduced to 13 factors with eigenvalues over 1. Eigenvalues only accounted for 18.4% of the variability in the factors indicating that the **Observation Checklist** could not be considered to have a strong underlying structure accounted for by one or two factors and therefore the test was not considered unidimensional. This is confirmed by the scree plot in Figure 4.2.

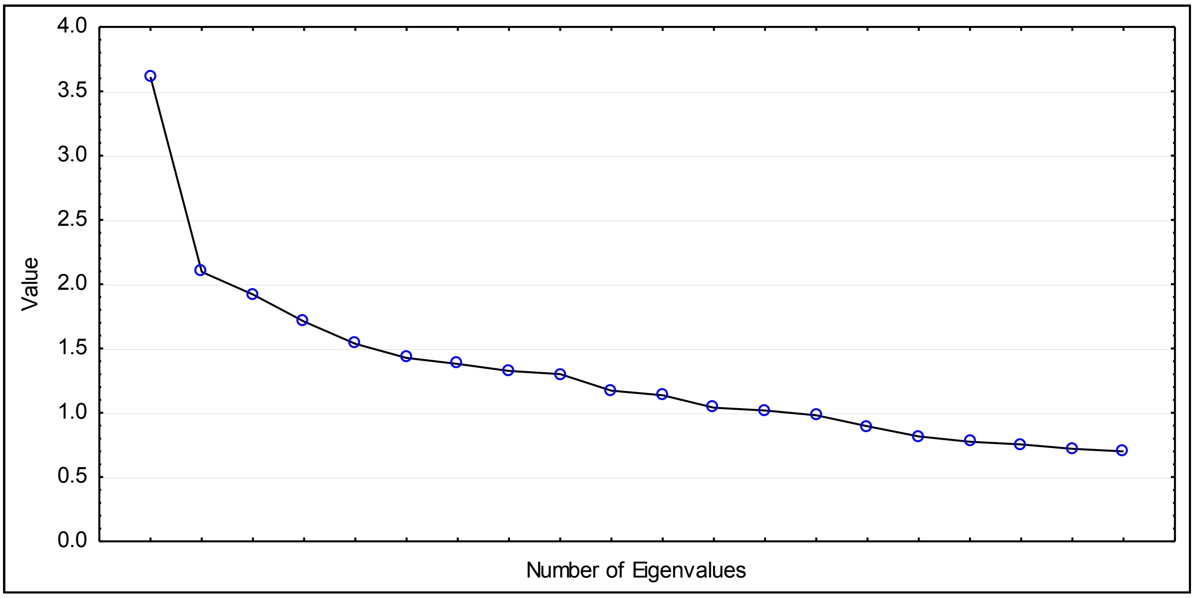

Figure 4.2 Scree plot of principal component analysis for Observation Checklist items on the Handwriting Screening Assessment

The **Writing Checklist** had 7 factors with eigenvalues over 1 (Table 4.11).

Table 4.11 Eigenvalues for Writing Checklist

	Eigenvalue	% Total variance	Cumulative Eigenvalue	Cumulative %
Factor 1	5.54	26.41	5.54	26.41
Factor 2	2.42	11.53	7.96	37.95
Factor 3	1.71	8.18	9.68	46.13
Factor 4	1.30	6.23	10.99	52.37
Factor 5	1.15	5.48	12.14	57.85
Factor 6	1.12	5.36	13.27	63.22
Factor 7	1.03	4.94	14.31	68.16

Although the first two factors accounted for 37.9% of the variability in the data, this assessment could also not be considered to have a strong underlying structure accounted for by one or two factors. This is confirmed by the scree plot in Figure 4.3

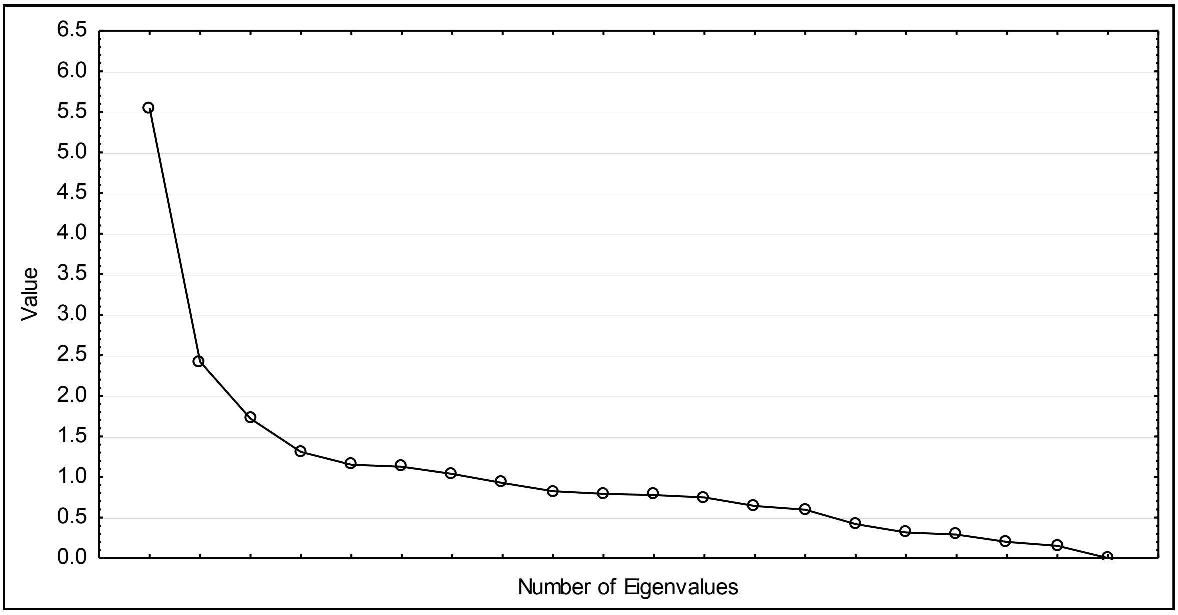

Figure 4.3 Scree plot of principal component analysis for Writing Checklist items on the Handwriting Screening Assessment

Neither the **Observation Checklist** or the **Writing Checklist** could thus be considered as has having one or two constructs which accounted for the variance found and had to be analysed further [Furr and Bacharach, 2008]. Since the EFA indicated little correlation between factors, further analysis using varimax rotation was used to differentiate groups of items on the Observation Checklist and the Writing Checklist [Brown, 2009]. The factor loadings for both the Observation Checklist and the Writing Checklist showed groupings of factors that could be considered as subtests rather than considering all components and items as one construct in the checklists (Appendix N).

Therefore, further analysis was continued using item response theory (IRT) or Rasch analysis to determine if the assessment could be analysed in subtests. This helped address the correlation or dependency between variables and assisted with construct validity of the assessment tool [McCoach et al., 2013].

4.3.6 Rasch Analysis

The lack of a single construct for all the components in each of the checklists was further confirmed using Rasch model analysis using RUMM 2030. The analysis for both the **Observation Checklist** and the **Writing Checklist** is reported in terms of item response, individual item fit and summary statistics. Before the Observation Checklist and Writing Checklist could be analysed using Rasch analysis, the difficulty level in each item need to be checked to confirm the scoring.

4.3.6.1 Item response: - level of difficulty

The Rasch model organises responses on an assessment, by the difficulty of the items in terms of the number of students scoring as most able to least able. Thus, when applied to the structure the difficulty of the items is compared to the ability of the students scoring on a continuum of most able to least able. The data can then be analysed to determine if items on the assessment fit the model and are correctly scored in terms of difficulty using log-transformed item scores generated from the responses of the students whose records were reviewed. Each item on the **Handwriting Screening Assessment** was analysed separately to determine if the scores represented the correct level of difficulty (Figure 4.4).

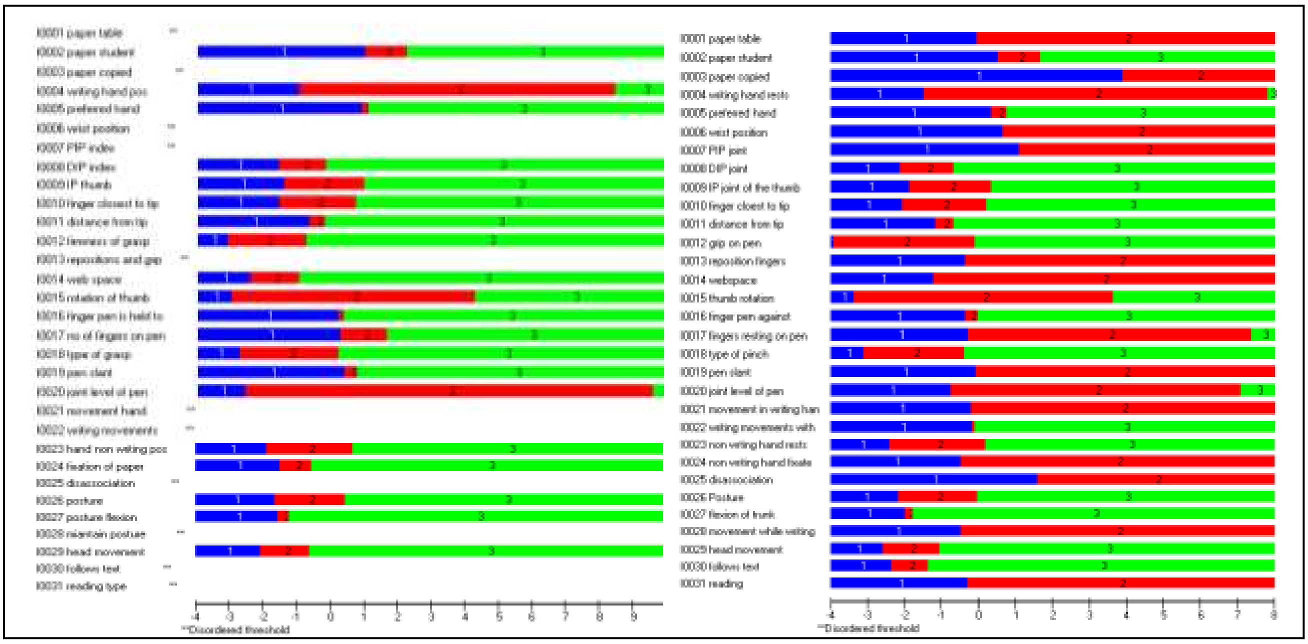

Figure 4.4 Disordered and ordered thresholds for the Observation Checklist

The order of these descriptors and the scoring on these items was disordered in terms of response options. In the **Observation Checklist** 12 of the items were disordered (Figure 4.4) and seven items in the **Writing Checklist** (Figure 4.5) [Andrich et al., 2010]

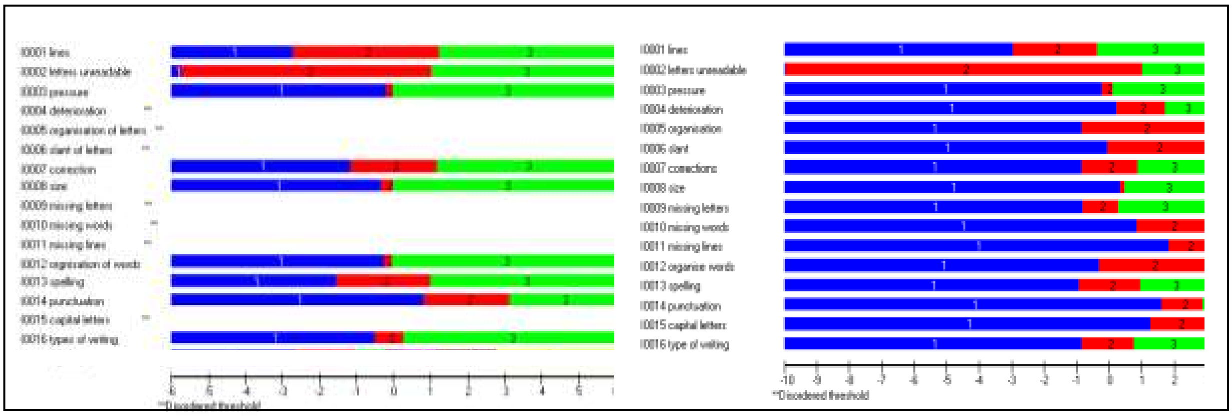

Figure 4.5 Disordered and ordered thresholds for the Writing Checklist

It was necessary to review and rescore all the items that were disordered or that did not fit in to the individual item fit residuals. In some items the order of the scoring was changed. The other disordered thresholds were evaluated and changed in terms of scoring. In some cases, one option was removed to order the threshold. Four revisions of the **Observation Checklist** and **Writing Checklist** were necessary to achieve ordered thresholds (Figure 4.4 and Figure 4.5) A revised version of the **Handwriting Screening Assessment** was completed with the changes to the items incorporated (Appendix N).

4.3.6.2 Summary statistics for the Observation Checklist and the Writing Checklist

Once the thresholds for the items on the Observation Checklist and Writing Checklist were corrected and revised the fit of the checklists to the Rasch model was determined. Bonferroni adjustments were included in the chi-square (X^2) significance tests on all components and items in the Observation Checklist and Writing Checklist to determine if there were significant differences between their observed and expected values of abilities (Table 4.12).

The significant differences (p=0.00) between the expected and observed values on the chi squared tests indicated that for all the components on the Observation Checklist and the Writing Checklist, the scores of the students did not fit the Rasch model. This confirmed that the items needed to be adapted into subtests for each component to fit the Rasch model [Linacre and Wright, 1994].

Table 4.12 Summary statistics for revised Observation Checklist and Writing Checklists

	Observation Checklist		Writing Checklist	
	Items n=31	**Persons n=287**	**Items n=16**	**Persons n=287**
Item–trait interaction Total item chi-square = 188.11 Total df = 124 Total chi-square probability = 0.00			**Item–trait interaction** Total item chi-square = 196.89 Total df = 64 Total chi-square probability = 0.00	

To determine if a simple structure could be developed on the revised items were clustered to form subtests. These subtests were based on the operationalised domains according to motor and process performance skills.

4.3.6.3 Identifying subtests in the Handwriting Screening Assessment

The 20 factors on the EFA identified in the Observation Checklist and Writing Checklists were reviewed. Subtests based on these factors were tested for fit in the Rach model but did not fit the Rasch analysis or reflect the domains of the performance skills and handwriting components (Appendix N).

Components were therefore clustered according to the motor and process performance skills and handwriting components (Appendix O) into seven subtests for the Observation Checklist and five subtests for the Writing Checklist based on the initial analysis into the framework (Table 4.1, 4.2 and 4.3). Where an item assessed more than one performance skill the item was fitted in consultation with the SME expert into the most appropriate subtest (Appendix O). The twelve subtests were assessed in the RUMM 2030 programme.

IN Table 4.13 the lack of significant differences between the expected and observed values (p=0.29 and p= 0.27) and the overall performance did fit the Rasch model for both the Observation Checklist and the Writing Checklist. The subtests were therefore accepted as valid and further analysis of the subtests was completed to check the fit of each subtest in the Rasch model [Cheng et al., 2008]. This indicated that the based on the subtests each checklist could be considered unidimensional based on the subtest analysis but that each subtest should be scored separately although the checklist scores could be totalled.

Table 4.13 Summary statistics for Subtest on Observation Checklist and Writing Checklists

	Observation Checklist				Writing Checklist			
	Items n=31		Persons n=287		Items n=16		Persons n=287	
	Location	Fit residual	Location	Fit residual	Location	Fit residual	Location	Fit residual
Mean	0.0	0.16	-2.06	-0.26	0.0	0.34	-0.43	-0.22
SD	1.37	0.95	0.42	0.86	0.90	1. 05	0.53	0.87
Person separation index 0.31					Person separation index 0.42			
Item–trait interaction Total item chi-square = 31.64 Total df = 28 Total chi-square probability = 0.29					**Item–trait interaction** Total item chi-square = 23.35 Total df = 20 Total chi-square probability = 0.27			

The overall mean (X) log residual test of fit for the subtests on the Rasch model across all subtest should be as close to 0 as possible with a standard deviation (SD) close to 1. The values found were accepted for the Observation Checklist and the Writing Checklist [Wright, 1996]. The person separation index was not at an acceptable level of 0.7 however [Andrich, 1982].

Unidimensionality was confirmed by equating t–tests and assessing the PC loadings for the subtests in a binomial distribution. For both the Observation Checklist and the Writing Checklist the equating t-tests had values below 5% for the subtests and the proportion of significant tests on the binomial distribution was below 0.05 indicating that the unidimensionality in both checklists was acceptable [Tennant and Pallant, 2006]. However, to determine if any of the subtests identified were over or under discriminating abilities or were redundant and assessed the same components, further analysis of the individual subtest fit was required.

Individual Subtest Fit

The log residual test of fit statistics was used to establish whether the subtests were over or under discriminating [Guttersrud et al., 2014]. In Table 4.14 no log residuals fell outside of the range -2.5 to 2.5. indicating none of the items were too easy or too difficult [Andrich, 2005].

Table 4.14 Residuals and Chi squared values for the revised Observation Checklist and the Writing Checklist subtests

	Location Value	SE	Log Residual	Chi Squared X^2	df	p
Observation Checklist subtests						
Subtest 1 ***Position of paper- positions and organises***	0.39	0.09	0.17	4.58	4	0.33
Subtest 2 ***Maintenance of posture- aligns and stabilises***	-0.8	0.04	0.70	3.62	4	0.45
Subtest 3 ***Stability of grasp- calibrates and grips***	-1.40	0.04	-1.59	3.68	4	0.45
Subtest 4 ***Pen Grasp grips***	0.25	0.04	-0.52	3.96	4	0.41
Subtest 5 ***Movement in fingers and hand manipulates and coordinates***	1.81	0.07	0.30	3.70	4	0.44
Subtest 6 ***Visual Function notice/responds and accommodates***	-1.72	0.04	0.97	1.34	4	0.85
Subtest 7 ***Preferred hand and wrist position flows***	1.48	0.12	1.09	10.75	4	0.02*
Writing Checklist Subtests						
Subtest 1 ***Writing flows***	-0.84	0.03	-1.2	2.36	4	0.66
Subtest 2 ***Endurance and fatigue flows, endures and calibrates***	-0.03	0.05	1.55	2.27	4	0.68
Subtest 3 ***Punctuation heeds***	-0.41	0.06	-0.18	12.93	4	0.01*
Subtest 4 ***Corrections and spelling heeds and adjusts***	1.52	0.09	0.74	3.13	4	0.53
Subtest 5 ***Missing letters and words heeds and attends***	-0.23	0.05	0.80	2.62	4	0.62

*Significance – $p \leq 0.05$

Based on the number of items in the scale Bonferroni adjustments are included in the Chi-square significance tests on each subtest to determine if there are significant differences between their observed and expected values of abilities within each subtest. Only Subtest 4: *Preferred hand* on the **Observation Checklist** and Subtest 3: *Punctuation* on the **Writing Checklist** had Chi-squared values that were significant.

Local dependency of each subtest

The subtests were checked for local dependency to ensure items in one subtest did not overlap with or influence the scoring on other subtests (Table 4 15).

Table 4.15 Correlations for the Observation Checklist and the Writing Checklist subtests on the Handwriting Screening Assessment

Observation Checklist subtests							
	Subtest 1 ***Position and fixation of paper***	**Subtest 2 Maintenance of posture**	**Subtest 3** ***Stability of grasp***	**Subtest 4** ***Pen Grasp***	**Subtest 5** ***Movement in hand and fingers***	**Subtest 6** ***Visual function***	**Subtest 7** ***Preferred hand and wrist position***
Subtest 1 ***Position and fixation of paper***	1						
Subtest 2 ***Maintenance of posture***	-0.09	1					
Subtest 3 ***Stability of grasp***	-0.19	-0.29	1				
Subtest 4 ***Pen Grasp***	-0.08	-0.39	-0.09	1			
Subtest 5 ***Movement in hand and fingers***	-0.04	-0.16	-0.11	-0.14	1		
Subtest 6 ***Visual function***	-0.08	-0.20	-0.29	-0.36	-0.11	1	
Subtest 7 ***Preferred hand and wrist position***	-0.01	-0.05	-0.15	-0.02	-0.02	-0.04	1

Writing Checklist Subtests					
	Subtest 1 Writing analysis	**Subtest 2 Endurance and fatigue**	**Subtest 3 Punctuation**	**Subtest 4 Corrections and Spelling**	**Subtest 5 Missing letters and words**
Subtest 1 ***Writing analysis***	1				
Subtest 2 ***Endurance and fatigue***	-0.29	1			
Subtest 3 ***Punctuation***	-0.27	-0.29	1		
Subtest 4 ***Corrections and Spelling***	-0.35	-0.03	-0.10	1	
Subtest 5 ***Missing letters and words***	-0.44	-0.42	-0.04	-0.00	1

There were no positive correlations above 0.02, the suggested cut off point, on either checklist [Wright, 1996]. This indicates that the subtests measure different theoretical components, and scores in the one should not affect scores in the others. Therefore, none of the subtests were redundant.

4.3.7 Handwriting outcomes

The description of the scores for Handwriting Outcomes which were speed and legibility were considered separately from the checklists.

4.3.7.1 Copying Speed

In Figure 4.6 the mean number of words copied per minute for this sample was 19.41 (SD 4.23) with a median of 15 words per minute which was below the of 24-28 WPM reported for best copying for students in higher education [Barnett et al., 2010]. Therefore 12% of students assessed did copy at an acceptable speed.

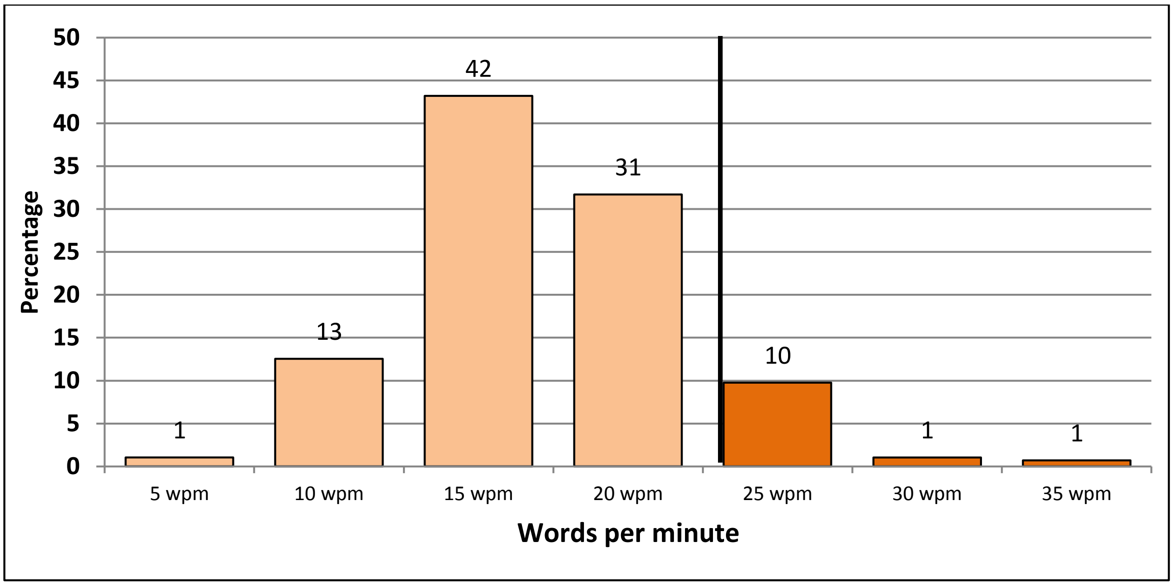

Figure 4.6 Frequency of writing speed – words per minute (n=287)

4.3.7.2 Legibility

Two thirds of the students (66%) had writing that fell into the acceptable category in terms of legibility with a score between 1 and 3 (Figure 4.7) .While only 3% of students had very illegible writing, with a score of 7.

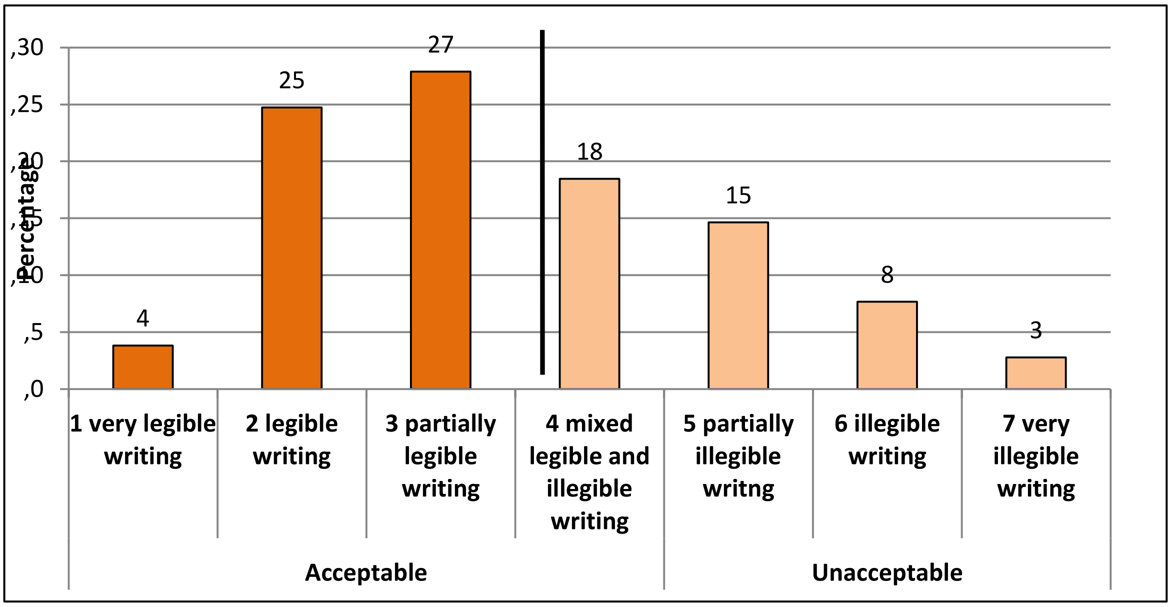

Figure 4.7 Percentage frequency of legibility scores for handwriting

In this phase, the development of the **Handwriting Screening Assessment** in three subtests was completed. This was based on the Steps 1-9 of instruments development as well as the AERA criteria for the development and evaluation of screening assessments. The structure of the assessment based on performance skills, components of handwriting was developed and item development and scoring as well as other aspects such as the length of the test defined. Since the framework used to operationalise the domains for the assessment had not been used with components of handwriting and the associated client factors previously the validity of the structure of the items and checklists developed need to be established.

The item validity and dimensionality of the assessment was piloted using 287 records for students referred for handwriting assessment. The items of the Observation Checklist and Writing Checklist were initially analysed using factor analysis and then Rasch subtest analysis to confirm the unidimensionality of the checklists and the lack of local dependency of the separate subtests. The subtests based on the motor and process performance skills did fit the Rasch model. Handwriting Outcomes including speed and legibility were analysed to obtain an indication of the deficits which occurred in these aspects of handwriting.

CHAPTER 5
DISCUSSION PHASE 1

5.1 Introduction

This phase of the study was completed in two parts. The aim of part 1 of the phase was to analyse handwriting constructs based on the motor and process performance skill framework [American Occupational Therapy Association, 2014] to identify domains and develop the Handwriting Screening Assessment. Part 2 of the phase used a pilot study to confirm item and subtest validity and the dimensionality of the Handwriting Screening Assessment.

In this phase of the study the development of the Handwriting Screening Assessment as a diagnostic assessment for administration by occupational therapists was achieved based on the performance skill framework. Deficits in handwriting were identified in the literature.. The domains for the assessments were operationalised according to the motor and process performance skill framework across three sections: - the Observation Checklist, the Writing Checklist and Handwriting Outcomes. Items were developed by analysing each component into descriptors indicating functional ability and deficits in handwriting based on the literature and clinical experience of the researcher.

A retrospective record review was used to confirm the item validity and dimensionality of the three sections of the Handwriting Screening Assessment. Factor analysis and Rasch analysis were used which indicated the assessment had satisfactory validity with multidimensional checklists. Therefore, further validity studies on typical students and those referred for handwriting assessments were completed in Phase 2.

5.2 Part 1 Development of the screening assessment

There were two objectives for part 1 of the study with the first objective being the identification of domains based on a framework of motor and process performance skills and the associated and components of handwriting and client factors for the Observation Checklist, the Writing Checklist and Writing Outcomes.

The need for a systematic assessment of handwriting or dysgraphia in higher education was supported by Siegel (1998) in her research over seven years. She felt that at a university level IQ tests should not be used to determine deficits in one or more skills not related to intelligence. Since IQ tests are used to predict academic performance, students who achieve a university entrance can probably be assumed to have an adequate IQ and any discrepancies in their performance due to handwriting should be assessed using a handwriting assessment. The development of standardised tests by professionals with appropriate training with sound psychometric properties was identified as a priority for use in HLI [Siegel, 1999b].

The Handwriting Screening Assessment was designed to comply with her suggestions that achievement tests target specific skills to determine whether or not the person meets the criteria for and presents with significant difficulties in that specific skill [Siegel, 1998]. This allows the assessment to be used to make recommendations about concessions. The assessment was also designed to fulfil the screening assessment criteria described by Glover and Albers (2007) based on those published by AERA [American Educational Research Association, 2014; Glover and Albers, 2007].

This included responding to a recognized need of a defined target population and fitting with services already available to them. The Handwriting Screening Assessment was based on a paper and pen task to make the situation as authentic as possible and a “real world” task rather than using a digital tablet assessment that may have been more objective. This also meant the assessment was low cost, could be carried out in various locations and requires no expensive equipment. The set up for the Handwriting Screening Assessment used the same furniture provided in examinations venues for students at the university so that posture and positioning of the paper on a relatively small table. The student could therefore be observed in the environment similar to that used in examinations [Glover and Albers, 2007].

The assessment was based on the observation of the relevant performance skills, and items were developed by analysing components of handwriting. Scoring was based on an ordinal scale reliant on the assessor's judgement for all items on the Observation Checklist. Where possible more objective means of assessment were provided and transparent overlays for size of writing and writing on lines were used for the Writing Checklist. Numbers were used for missing letters or words, and lines of text as well as errors and spelling mistakes making assessment of the items more objective [Arter and McTighe, 2001].

The Handwriting Screening assessment therefore was placed to fulfil a need identified in the assessment of students in higher education in relation to determining specific deficits in handwriting. The test complied with criteria for the development of screening assessments and the domains and components of handwriting were operationalised according to a framework of performance skills used for the observation of individuals in a prescribed task. This provided a unique structure on which the screening assessment could be complied to consider a comprehensive view of the performance and outcomes of handwriting to identify students at risk for dysgraphia and handwriting deficits.

5.2.2. Representation of the items

The corrected Handwriting Screening Assessment was checked to determine if required motor and process performance skills, client factors and signs of dysgraphia associated with handwriting had been included (Appendix J). The percentage of items reflecting motor performance skills and physical client factors was 71% which was appropriate for the motor emphasis of this assessment of handwriting. Process performance skills and mental client factors were assessed in 21% of items. The remaining 7% of items assessed a demographic factor in hand preference and specific symptoms of dysgraphia.

The observation of praxis which is associated with higher cognitive function was not observed overtly as other client factors and performance skills contribute to this component. Visual motor integration was also not observed overtly as it appears to play a less important role in adult handwriting but fine motor control, visual perception and visual function were observed (Appendix O).

The development of the descriptors and items for the Observation Checklist and the Writing Checklist required a detailed analysis of each component of handwriting, following the steps of instrument design as well the criteria for the development of screening assessments, detailed in Figure 3.1.

5.2.1 Defining the Items

The second objective for this part of Phase 1 of the study was to compile a Handwriting Screening Assessment. The items on the Observation Checklist and Writing Checklist were formatted on descriptors of actions and behaviour and writing first used to assess handwriting by Jacobson and Sperling (1976) who described the position of the fingers and joints in pen grasp [Jacobson and Sperling, 1976]. This was extended for use in other occupational therapy studies to include other aspects of actions and behaviour that can be observed such as arm position and posture [Blöte and Dijkstra, 1989].

As suggested by Tierney and Simon (2004) clearly worded writing and action and behaviour specific descriptors were developed, that allowed for the variability between students to be more objectively assessed, even by different raters. Using two or three descriptors for each item allowed for easier analysis, quick assessment and evaluation of the student [Tierney and Simon, 2004]. The analysis for each descriptor was based on components of handwriting associated motor and process performance skills and included defining the criteria that could be observed and scored.

A detailed description of the analysis of the performance skill Positions and the associated component of handwriting for (Table 4.1) is presented as an example of the analysis completed for each subtest of the Handwriting Screening Assessment.

The first three items on the Observation Checklist were

1. Position of paper on the table
   01 in front of student with top point in the midline slanting upwards towards non -preferred hand
   02 vertical
   03 parallel to edge of table

2. Position of paper in relation to the student is
   01 in front of student
   02 to side of preferred hand
   03 to side of non-preferred hand

3. Position of paper being copied from
   01 to the side of the non-preferred hand
   02 above paper being written on directly in front of student
   03 side of the preferred hand

It from the literature it was determined for the position of the paper on the table, the position of the paper in relation to the student as well as the position of the paper being written on to the paper being copied from, should be observed. For item 1 the position of the paper on the table should be in line with the position of the forearm resting on the table [Lohman, 1993]. This allows the pen to move across the lines on the paper without increased extension or flexion at the wrist [Pollock et al., 2009]. If the paper is placed vertically (straight) or horizontally (parallel with the edge of the table) either the wrist position is affected or the student used postural deviation of the trunk and shoulder and elbow positioning to compensate. The item for the position of the paper on the table therefore included descriptors which indicated whether the paper was tilted or vertical or horizontal on the table.

For item 2 the placement of the paper in front of the student is considered correct if the paper can be stabilised by the non-preferred hand and reached in front of the student by the preferred hand, while maintaining an upright symmetrical posture. Deficits can be observed when the places the e paper to the side of the preferred hand. This allows for the observation of client factors such as reluctance to cross the midline. Problems associated with the stabilisation of the paper by the non-writing hand as well as the student's posture can be observed [Amundson, 1992]. This placement of the paper may indicate fine motor problems in contra lateral or midline space [Smits-Engelsman et al., 2004]. The non-preferred hand can also be observed in actions such as propping up the head which may indicate the necessity for assessing postural control or postural tone.

In item 3 the position of the paper the student is copying from should be correctly placed to the side of the non-preferred hand in relation to the paper they are writing on for the use of horizontal saccades used to read [Richman and Garzia, 2009]. Students who place the paper being copied from, above the one they are writing on must be observed for visual function as this may be an accommodation used when horizontal saccades are affected and vertical saccades are used. Placing the paper being copied from, on the side of the preferred hand may also be associated with eye dominance.

All other components for the Observation Checklist and Writing Checklist were analysed and descriptors created for each item in the same way.

5.3 Part 2 Pilot study to confirm item and subtest validity and checklist dimensionality

The first objective for this part of the study was to establish a demographic profile of students referred for handwriting assessment between 2008 and 2012. The demographics of the students indicated that approximately 60% were male. This was not unexpected as research indicates that the ratio of learning disabilities amongst males to females is 2:1.4 [Cortiella and Horowitz, 2014]. Of all the students assessed nearly 60% had diagnosed illness with, not surprisingly more than half of these having a diagnosed SLD (Table 4.5). The most commonly reported diagnosis related to learning disability was ADHD and dyslexia, both of which have been associated with handwriting problems [Adi-Japha et al., 2007].

Forty percent of the student did not have a medical history in relation to their handwriting deficits although most of these students reported handwriting difficulties at school. They had coped without intervention until requesting academic concessions at the time of assessment [Casale, 2009]. This accounted for the students applying for concessions in the later years of study.

Almost equal number of students requesting assessments attended the three different types of schools in South Africa as defined in the results chapter. However, very few students who attended previously disadvantaged schools had received concessions. Just over a quarter who attended previously advantaged schools and more than a third who attended private schools had been assessed and had been awarded extra time, spelling concessions or amanuensis at high school. Thus, many students had been disadvantaged further by the schools they attended where concessions were not provided. Their ability to reach their potential at university may also have been affected as these students were often unaware of the problems which affected their performance in examinations until they failed. They were often unaware that they could apply for concessions.

The two factors students reported most interfered with their handwriting were pain and visual problems. Over 50% of the students reported pain in their writing arm or hand when writing for a short period of time irrespective of their diagnosis. This was identified as the component affecting their handwriting negatively particularly when having to write for prolonged periods. Although pain had a low correlation to the number of words written, students reported that they were slowed down by having to stop writing and rest their hands due to pain [Summers and Catarro, 2003].

Just fewer than half the students wore glasses to correct their vision with only 1% having other visual disorders. The role of visual function including oculomotor function on reading is controversial but has been shown to affect academic performance in children [Goldstand et al., 2005]. However, it appears to be important in the students referred for handwriting assessment and the inclusion of items to assess visual function in the Handwriting Screening Assessment is therefore justified.

During the period when the records for the review took place the faculty of Commence, Law and Management had the highest number of students applying for extra time. This seemed to be related to the five hour examinations in the accountancy degrees the students wrote to prepare them for similar board examinations. The extra length of these examinations further compromised those with handwriting problems. It is apparent that different faculties and courses present different challenges for students with dysgraphia and handwriting problems which accounts for the variation in applications from the different faculties. Some courses mark and expect correct spelling, whereas others have examinations which require mostly mathematical calculations and very few words, although reading in these papers often requires great accuracy. This meant that it was important to include the presentation of the writing in the Handwriting

Screening Assessment so that concessions for spelling and extra time for editing or checking the accuracy of transcribed numbers could be provided if necessary.

The demographic and educational factors identified in this phase of the study supported the development of the History of Handwriting Problems used in Phase 2 and 3 of the study with students referred for handwriting assessment. It was important that problems related to finishing examinations as well as pain and vision were recorded as these may be related to dysgraphia and handwriting deficits. A history of previous diagnosis of SLD or other illness, previous extra time and other concessions as well as therapy for handwriting also supported the risk for dysgraphia. The history in terms of the school attended, the course being followed at university and the support received was needed to provide evidence that the students may have unrecognised handwriting problems. This supported the need for a detailed history before screening of the students' handwriting.

In order to develop a screening assessment handwriting one of the objectives set was to evaluate the validity of the items on the assessment and determine the dimensionality. The data to fulfil this objective was gathered from the records of students who were assessed for handwriting deficits and dysgraphia.

5.3.2 The Observation Checklist and Writing Checklist

The Observation Checklist and Writing Checklist were evaluated using factor analysis. The EFA used to investigate the validity of the items on these checklists, indicated that the checklists could not be considered to represent one or two constructs. The items loaded into a large number of factors and the variance in factors with eigenvalues above 1 being low [Pett et al., 2003]. Varimax normalized factor loadings did indicate that all items loaded with at least one other item except for PIP flexion of the index finger, size of writing and corrections when copying. The initial EFA factor loadings therefore indicated a multidimensional assessment with items that could be clustered.

Therefore, the Observation Checklist and Writing Checklist were analysed further using the preferred evaluation of assessment instruments and outcome measures, IRT or Rasch analysis [Schaaf et al., 2010]. Rasch analysis is based on the ability of the students in relation to the difficulty of the items on the assessment. Since handwriting ability differs amongst students, even those without a problem, this approach to analysing and scoring the Handwriting Assessment Checklist was appropriate. A further advantage was that if the data did meet the criteria of the Rasch model the scores can be equated to interval scales [Osteen, 2010] which facilitates the interpretation of the data.

The items on the Observation Checklist and Writing Checklist did not fit the Rasch model confirming the factor analysis findings that these checklists do not measure one construct. Therefore, the items on the Observation Checklist and Handwriting Checklist were clustered into subtests or "testlets" according to motor and process performance skills identified when analysing the handwriting components (Table 4.1, 4.2 and 4.3). These subtests were based on these domains and those items that loaded together on the EFA that were related to one performance skill. This was not true for all the factors as some factors which loaded together were unrelated according the theoretical framework on which the test was based and the literature. This included items such as pen slant (performance skill Grips) and the position of the non-writing hand (performance skill Aligns) which loaded together on the factor analysis but were split into different subtests as they appear clinically unrelated.

The division of pen grasp or how the pen was held into three subtests was confirmed. This addresses some of the controversy about the importance of pen grasp when assessing handwriting outcomes as these components were often considered together in previous studies [Cheng-Lai et al., 2013; Dennis and Swinth, 2001; Feder and Majnemer, 2007].

In the Writing Checklist, the subtests were based on factors on the EFA which loaded more closely to the domains operationalised according to the performance skills. The items for errors for punctuation, capital letters and spelling when copying did not fit into one subtest as indicated by the factor loadings. Corrections and spelling errors formed one subtest separate from errors related to punctuation and capital letters. This indicated that orthographic coding related to spelling could not be grouped with the allographic mechanism in which capital letters are distinguished and these should be considered as separate constructs in these students.

The PSI was low for both checklists as this represented the separation between students on the entire Observation Checklist and Writing Checklist. Since handwriting deficits vary and students were unlikely to have deficits in all the subtests in a checklist this was not unexpected. This indicated that the subtest scores should be considered separately when determining handwriting deficits if the subtests with deficits are to be differentiated from those without deficits.

However, since these results represented the target population of students referred for handwriting assessment it was decided to accept the fit of ten of the twelve subtests on the Observation Checklist and the Writing Checklist to the Rasch model as well as the low PSI acceptable. No further revision was made to the Handwriting Screening Assessment at this stage. It was accepted that the items in this format were valid for the observation of the writer in the Observation Checklist and the presentation of handwriting in the Writing Checklist. Therefore, this version of the Handwriting Screening Assessment was used in Phase 2 of the study.

5.3.3 Handwriting Outcomes

On the Handwriting Outcomes, the average speed for copying the 115 word passage was 19.41 WPM (Figure 4.7). This was slower than the speed reported by Barnett et al. (2010) of 24-28 WPM for best copying on the DASH 17+ [Barnett et al., 2010]. The best copying score was used to make the comparison to the copying task in the DASH 17+ which is a simple one line sentence. This sentence is written repeatedly for two minutes and can be memorised by the student once they have written it once or twice. Therefore, they do not have to read the sentence while copying throughout the task whereas in the current study the entire paragraph must be read while copying. Therefore, the best copying speed on the DASH 17+ where students try to write neatly was felt to provide a suitable level against which to base the speed of copying in this Phase as no values for typical students were available.

The percentage of students who fell into the categories below 4 of the global rating scale indicated that just less than half of students requesting assessment for handwriting have a problem with handwriting legibility (Figure 4.8). Not unexpectedly this percentage was higher than that reported by Gozzard et al. (2012) for typical adults between 20- 24 years, as the students in the current study all presented with handwriting deficits. Gozzard et al. (2012) also used a less sensitive four-point scale to assess legibility

CHAPTER 6 METHODOLOGY PHASE 2:

6.1 Introduction- Psychometric properties of the Handwriting Screening Assessment

This phase of the study addressed Steps 10 to 12 of instrument development outlined in Figure 3.1. The aim of this phase of the study was to establish the construct validity and reliability of the **Handwriting Screening Assessment** as well as determining the cut off scores which could be used with ARQs to identify students at risk for dysgraphia and handwriting problems. The validity of the screening assessment based on the ARQs was also determined. Field testing of the Handwriting Screening Assessment was completed on typical students and students referred for handwriting assessment at Wits. The objectives for this phase of the study were divided and addressed in three parts.

6.2 Objectives for Phase 2:

Part 1: Construct validity and reliability of the Handwriting Screening Assessment

- To establish the construct validity of the Handwriting Screening Assessment by determining: -
    - the statistical properties of the subtests in the Observation Checklist, the Writing Checklist and the Handwriting Outcomes to establish and confirm their dimensionality and structure.
    - the differences in the three sections of the Handwriting Screening Assessment for known group factors - age, gender and school attended.
    - the differences in the three sections of the Handwriting Screening Assessment between typical students and those referred for handwriting assessment.
- To establish the reliability of the Handwriting Screening Assessment by determining the internal consistency and interrater reliability for the three sections of the Handwriting Screening Assessment.

Part 2: Cut off points and at risk quotients for the Handwriting Screening Assessment

- To establish the norms and cut off points related to at risk quotients (ARQs) to identify students at risk for handwriting deficits on the Observation Checklist, the Writing Checklist and the Handwriting Outcomes.

Part 3: The validity of the Handwriting Screening Assessment based on at risk quotients

- To establish the validity of the Handwriting Screening Assessment based on the ARQs by determining: -
  - the difference in the ARQs between typical students and those referred for handwriting assessment.
  - the clinical accuracy of the ARQs on the three sections of the Handwriting Screening Assessment. by determining the sensitivity, specificity and predictive values as well as the receiver operating characteristic (ROC) curves of each.
  - the convergent and divergent validity of ARQs on the three sections of the Handwriting Screening Assessment in relation to scores on other standardised tests - the DASH 17+ and the Developmental Eye Movement test (DEM) for students referred for handwriting assessment.

6.2.1 Null hypotheses

Known group factors

- There will be no difference for the subtest scores on the three sections of the Handwriting Screening Assessment based on the known group factors of age, gender and school attended.

Typical students and those referred for handwriting assessment

- There will be no difference in the subtest scores and ARQs of typical students and those referred for handwriting assessment on the three sections of the Handwriting Screening Assessment.

6.3 Research Design

The research design used for Phase 2 of the study was a descriptive cross sectional, prospective, quantitative design. This design was appropriate as it allowed numerical data to be collected so conclusions could be drawn from the sample of students, representative of a larger population at one point in time. The design was descriptive as no manipulation of variables was required [Kielhofner, 2006]. The Handwriting Screening Assessment was administered individually and students were observed while writing. Actions and behaviour related to motor and process performance skills were recorded once, while the participants were writing and their handwriting was analysed subsequent to this.

The results of the study were presented in three parts. In part 1 the data were further analysed using Rasch analysis to confirm the item and subtest validity and checklist dimensionality determined in the pilot study in Phase 1 of the study. The construct validity of the three sections of the Handwriting Screening Assessment was investigated by comparing differences between the typical students and those referred for handwriting assessment as well as for differences for known group variables. The reliability of the subtests and items in the subtests was also established.

In part 2 cut off scores and ARQs were determined for all three sections of the Handwriting Screening Assessment based on the norms for typical students.

In part 3 further psychometric analysis of the construct validity, based on the ARQs including the clinical accuracy of the assessment and convergent and divergent validity was evaluated.

6.3.1 Participant Selection

Both typical students with no history of handwriting problems as well as students referred for handwriting assessment by CHWC were included in the study. All students were to be registered for an undergraduate course at Wits.

6.3.1.1 Selection of Typical Students

Since the Handwriting Screening Assessment needed to be administered on an individual basis for this phase of the study, students were conveniently selected from the five faculties that have undergraduate programmes at Wits. Students were approached by research assistants, one of whom was a qualified occupational therapist and one who was an occupational therapy student, and invited to participate. Those who agreed to participate were then recruited into the study.

Inclusion criteria

- Wits undergraduate students from any school or department who gave informed consent to participate.
- Had never had concessions for extra time related to handwriting or learning problems.

Exclusion criteria

- Students with hand and upper limb abnormalities and injuries.
- Students with severe visual problems.
- Students with a history of learning disabilities.

Sample size

The analysis of items on the Handwriting Screening Assessment requires a sample size of between 5 to 10 subjects for each item on the Observation Checklist as it was the longer of the three sections of the Handwriting Screening Assessment and had 31 items [Costello and Osborne, 2005]. Therefore, a sample of 300 typical students was recruited.

To determine the sample size for the students referred for handwriting assessment a power calculation based on differences in a study by Chang et al. (2015) using a digital assessment of handwriting was used. The current study indicated a sample size of a minimum of 234 participants per group was needed based on a clinical difference of 0.21 between the groups with a standard deviation of 0.70 for the legibility or handwriting quality scores on a 7 point legibility scale. The significant difference or α was set at $p \leq 0.05$ and β at 90% power to determine the difference between typical students and those identified with handwriting problems needing assessment. Student dropout rate was not considered as this was a cross sectional study. A sample size of 49 participants per group was required however when speed of writing was considered based on a clinical difference of 0.59 WPM with a standard deviation of 0.85 [Chang et al., 2015].

6.3.1.2 Selection of students referred for handwriting assessments.

Total population sampling was used to recruit students referred for assessment of handwriting deficits [Kielhofner, 2006]. All Wits students referred by CHWC to the Occupational Therapy Department, for assessment for academic concessions due to problems such as not finishing exams or handwriting problems in 2013 and 2014 were invited to participate in the study.

Sample size

Seventy six students were referred to the Wits Occupational Therapy Department for assessment in the period January to May when requests for accommodations are allowed each year. Sixty one of these students who met the inclusion criteria agreed to participate and were recruited into the study. Copying the 115 word paragraph used in the Handwriting Screening Assessment was routinely used as part of their assessment to recommend further assessments.

6.4. Measurement Tools

6.4.1 Demographic Questionnaires for typical students and those referred for handwriting assessment

Two questionnaires designed by the researcher to establish the demographics of the two groups of participants.

For the typical students (Appendix P) the questionnaire included questions on: - age, school attended, courses repeated at university and any known history of learning disabilities and handwriting problems experienced. Questions about handwriting problems such as the presence of pain when writing, endurance and fatigue experienced when writing, problems with posture and visual strain in long examinations were included. The students were asked to indicate if they preferred to use a specific type of pen when writing.

The history of handwriting problems questionnaire (Appendix Q) was developed for the students referred for handwriting assessment. This was a longer questionnaire which included the same information obtained from the typical students but also included information on the students' academic and medical history pertinent to their handwriting problems. This questionnaire was administered in an interview format.

6.4.1.1 Pain Assessment

The typical students were asked to rate their pain when writing long examinations on a 10 point visual analogue scale (VAS).

The students referred for handwriting assessment, because their pain varied during the course of the assessment were asked to rate their pain verbally during the assessment on a numeric verbal rating scale (NVRS). They were asked to report the severity of the pain on a scale of 1 to 10 as it changed as well as the site of their pain. This allowed for interrogation of the type and site of the pain.

The two pain scales correlate highly and can be used interchangeably [Holdgate et al., 2003]. No students in the current study had a problem with rating their pain on these scales.

6.4.1.2 Handwriting Screening Assessment

The Handwriting Screening Assessment (Appendix R) included the Observation Checklist with seven subtests and a Writing Checklist with five subtests and Handwriting Outcomes section. The Handwriting Screening Assessment was piloted for inter-rater reliability between the researcher and the second research assistant who was the qualified occupational therapist, and who assisted with administration of the assessment (section 4.2.3.6).

> ***Observation Checklist***
>
> The Observation Checklist developed in Phase 1 of the study was used while observing the students individually throughout the time they copied the 115 word paragraph so as to monitor their writing behaviour over the entire assessment period.

Writing Checklist

The subtests for the Writing Checklist were scored from the student's handwriting sample according to the criteria established in Phase 1 of the study.

Handwriting Outcomes

The outcomes including the speed of copying, legibility and a writing automaticity scored on the WSAM Alphabet Task were determined for each student.

- The speed of the hand writing was calculated from the number of words copied from the 115 word passage in three minutes. The number of words was adjusted to accommodate both added words, words crossed out and mistakes as well as words and lines of text repeated or left out, and then divided by three to provide a WPM score. The acceptable level for words copied was based on the mean number of words written by typical students in this phase of the study
- The WSAM Alphabet writing task consists of writing out the alphabet in lower case as fast as possible in a set time [Berninger et al., 1991]. In the current study the format used was that where the legible, correctly sequenced lower case letters written in 60 seconds were counted and scored [Barnett et al., 2010]. The acceptable level was set according to the mean score for typical students. The interrater reliability of the WSAM Alphabet task was shown to be 0.79 for the 60 second scoring for two raters in research on school children of all ages [Barnett et al., 2011; Berninger et al., 2008b].
- The legibility score used was based on the percentage of illegible words (Table 6.1) rather than letters as counting letters (Table 3.1) proved to be too time consuming The percentage of illegible words was determined based on a legibility 7-point scale based on the percentage of unreadable words with 1 being *very legible writing* and 7 being *very illegible writing* [Weintraub et al., 2007]. The legibility cut off was based on the mean score for typical students in this phase of the study.

Table 6.1 Legibility scores according to unreadable words

1 very legible writing	every word clear and - read 100% -96 of words
2 legible writing	not every word clear - can read at least 95% of words (1-11 out of 115 words illegible)
3 partially legible writing	some words not clear--can read at least 90% of words (11-22 out of 115 words illegible)
4 mixed legible and illegible writing	some words not clear -can read at least 80% of words (23-33 out of 115 words illegible)
5 partially illegible writing	some words not clear -can read at least 70% of words (34 -45 out of 115 words illegible)
6 illegible writing	some words not clear —can read at least 60% of words (46-56 out of 115 words illegible)
7 very illegible writing	few words clear – can read at least 50% of words (57+ out of 115 words illegible)

6.4.1.3 Detailed Assessment of Handwriting Speed 17+ (DASH 17+)

The DASH 17+ (Appendix S) consists of four tasks: - best copying, fast copying, an alphabet task and free writing. The scores for each are included in a total percentile score. The assessment evaluates the speed of writing but also takes legibility into account by excluding illegible letters and words in the score. There is an optional graphic speed task which assess fine motor control but which is scored separately and is not included in the percentile score calculated for the assessment. This aspect of the DASH 17+ was not scored as part of this study.

Scaled scores for various age groupings from 17- 25 years are provided which are converted to a standard score and then a percentile score [Barnett et al., 2010]. The tasks in the assessment are:

Best and Fast Copying tasks

The copying task is done for two minutes for best and fast copying and WPM is calculated for each. The copying tasks require copying of a simple short sentence which contains all the letters of the alphabet and the students' ability to produce their best handwriting is compared to their ability to write fast. A difference of five words or less per minute indicates the student is not able to change the speed of their writing when asked to do so.

Alphabet task

This task is the same as that used in the Handwriting Screening Assessment and lower case letters of the alphabet are written for one minute. Only legible and correctly sequenced letters are counted.

Free Writing

This 10 minute task is based on the student writing on the topic of "My Life". A diagram of suggested ideas is available to cue the student and the students are observed and timed in two minute intervals to determine if they write a consistent number of words over the duration of the 10 minutes. The number of illegible words is counted and a percentage for legibility can be calculated although this is not included as a score. No guidance is given as to what should be considered illegible. The free writing task requires the generation and organisation of ideas [Torrance and Galbraith, 2006] but no guidance is given for use of punctuation or spelling.

The reliability and validity of the DASH 17+ was tested on a sample of 393 students at various institutions in the UK and reliability was excellent as reported in the literature review. Discriminate and content validity as well as reliability are reported. Validity was ensured by using principal component factor analysis which justified the subtests and the adding of the subtest scores to obtain a total score. Discriminate analysis on 33 students with reported dyslexia showed that they had a significantly lower score than typical students [Barnett et al., 2010].

6.4.1.4 Bernell's Developmental Eye Movement Test (DEM) -2.0

The DEM 2.0 can be used for screening eye-movements or as a diagnostic examination for children with vision problems related to SLD (Appendix T). The DEM 2.0 is a norm based assessment which assesses fast and slow saccades and provides an objective measure of eye movements and oculomotor function [Richman and Garzia, 2009]. Although it was designed and standardised on children up to the age of 13 years, norms for adults have been published. These norms reported by Powell (2006) were used in the data analysis in the current study [Powell et al., 2006].

The DEM 2.0 can be administered in five minutes. The assessment consists of three sub-tests which include timing the reading aloud of numbers in a vertical alignment in two sub tests and numbers in a horizontal alignment in the third subtest. The lists of numbers are presented and students are asked to read them aloud as quickly as possible. They may not use their finger to track the numbers. Four scores are generated:- vertical time, horizontal (adjusted) time, ratio, and errors [Richman and Garzia, 2009].

Vertical scores

Scoring for the vertical time score was determined by adding the seconds taken to read both vertical lists of numbers. This test determines rapid automatised naming (RAN) which is a visual-verbal skill that requires naming numbers or pictures and a deficient score on this test can be related to inefficient slow saccades [Tassinari and DeLand, 2005].

Horizontal scores

Scoring for the horizontal time was the time in seconds taken to complete the reading of the horizontal numbers. This score was adjusted for any errors made which may be either omissions and/or additional numbers. A deficient score on this test can be related to inefficient fast saccades [Tassinari and DeLand, 2005].

Error scores

Errors in all subtests are noted and scored separately as an error score. Adults are expected to make no errors on the test and omission, addition, substitution and transposition errors are all noted [Richman and Garzia, 2009]. Very few students made errors and thus these scores were not included in the analysis of this study.

Ratio score

The ratio score was calculated by dividing the horizontal time by the vertical time allowing for different types of eye movement dysfunction to be determined. Students with a dysfunctional horizontal time present with an oculomotor deficit (Type II Behaviour) while students with both vertical and horizontal dysfunction and a high ratio score present with a mixed automaticity and oculomotor deficit (Type IV Behaviour). Students with vertical and horizontal dysfunction and a normal ratio score can be considered as having difficulty in automaticity (Type III Behaviour).

Test-retest reliability of the DEM 2.0 for vertical scores is r = 0.89 and for horizontal scores is r = 0.86 but only r = 0.57 for ratio scores. Interrater reliability is reported at r = 0.81 for vertical time scores, r = 0.91 for horizontal scores with a lower r = 0.57 for the ratio scores [Richman and Garzia, 2009].

6.5 Research Procedure

Once permission from the relevant authorities (Appendix C) and ethical clearance for this phase of the project had been obtained (Appendix A) a research assistant, an occupational therapist with 20 years' experience in assessing and treating handwriting difficulties, was recruited.

6.5.1 Training of Research Assistant

The second research assistant who was the qualified occupational therapist assisted with the data collection of the typical students in this phase of the study. Prior to starting this phase of the study, she was trained in the use of the Handwriting Screening Assessment. Training in an assessment tool is needed to minimise the effects of differences between raters and to improve inter-rater reliability [Moon and Hughes, 2002]. The training therefore involved providing her with criteria for each item and confirming that she understood the scoring for each item (Appendix Q). The test was practiced on two students with both assessors rating the students at the same time. The first student was assessed by both assessors together discussing aspects as they scored and the second student was scored separately and then scores compared and discussed.

6.5.2 Pilot Study to determine interrater reliability

Permission was obtained from the Head of the Occupational Therapy and Physiotherapy Departments (Appendix D) to assess students to establish the inter-rater reliability of the Observation Checklist**.** Arrangements were made to assess students at their convenience when they were not in lectures. The researcher and the trained second research assistant assessed 20 students to determine inter-rater reliability on the Observation Checklist.

Once the students had given signed informed consent, the students were assessed individually by both the researcher and second research assistant observing them at the same time, as they completed the assessment.

6.6 Data Collection

6.6.1 Students

6.6.1.1 Typical students

The Dean of Student Affairs at the University of the Witwatersrand as well as the Dean of the Health Sciences Faculty were approached and gave permission to carry out the research (Appendix C).

A research assistant who was an occupational therapy student was enlisted in the study to assist with recruitment of typical students into the project. Students were approached by this research assistant and occasionally by the second research assistant at convenient times when they were not in lectures and asked to participate. A place to assess the students was organised.

The study was explained to those students who showed interest in participating and they were provided with an information sheet (Appendix E) which they had an opportunity to read. If they still wished to participate they were asked to sign informed consent (Appendix F). If the students agreed to participate and signed informed consent they were first asked to complete the demographic questionnaire for typical students (Appendix P)

They were then asked to complete the Handwriting Screening Assessment following this. Assessments took place in designated venues which were quiet. Chairs and tables of a standard size were sourced for the assessments. The students sat at a table that was approximately at the level of their forearms with their elbows were flexed to 90^0. It was not possible to adjust the furniture which was of a standard height so there was some variation in terms of the ergonomic fit for the students and some students did not achieve the ideal ergonomic position required for writing. The furniture used represented the height of the desks provided by the university in most examination venues.

Each assessor sat directly opposite the students at the table/desk and assessed students individually. Students were provided with an examination pad with feint rule lines, a copy of the passage they were to write out which was printed on an A4 sheet of paper and a standard BIC ball point pen. Students were permitted to write with their own pens if they preferred and this was noted on their demographic questionnaire.

The assessment was explained to each student and they were told that they should copy the passage at their usual handwriting speed. It was confirmed with the students that they understood the instructions. The assessors instructed the students when to start copying. Students were timed separately using timers on iPads and the word they wrote at three minutes was noted so the WPM could be calculated. Each student then wrote the alphabet for one minute on the same sheet of paper.

The students' writing sheets were attached to their questionnaire and data collection sheet on completion of the assessment and sheets for each student were coded.

6.6.1.2 Students referred for handwriting assessment

Participants applying for concessions including extra time due to possible handwriting problems were tested using the Handwriting Screening Assessment (Appendix R). They were assessed in a quiet room with appropriate furniture, similar to that used in the university examination venues. The research procedure was the same as that used for the typical students. All assessments were completed by the researcher. The History of handwriting problems was completed with each participant in an interview format (Appendix Q).

Depending on the results of the Handwriting Screening Assessment other assessments including the DASH 17+ and the DEM 2.0 were administered to confirm deficits in components related to handwriting. These students were provided with the standard instructions for both assessments. All the components of the DASH 17+ and DEM 2.0 were timed by the researcher according to the instructions in the manual [Barnett et al., 2007; Richman and Garzia, 2009].

Students were asked to provide permission for their results to be used in the research project on completion of the assessments. Once the assessments had been administered and it was determined what concessions would be recommended for the students, the research study was explained to them. They were provided with an information sheet (Appendix G) which they kept. They were asked to sign informed consent and also give permission for their end of year results to be accessed (Appendix H).

6.6.2 Reliability studies

In order to establish inter-rater reliability five final year occupational therapy students who were involved in research related to handwriting completed the Handwriting Screening Assessment on five typical students to determine the interrater reliability.

The raters were all trained in the use of the Handwriting Screening Assessment and provided with the guide (Appendix U) on how to administer the assessment. All five raters observed the same student while they were writing and scored all five students on the Observation Checklist**.** The number of words written in three minutes was noted. The Observation Checklist was scored by all five raters who then scored the handwriting sample on the Writing Checklist and Handwriting Outcomes.

6.7 Data Analysis

Demographic data for the students were analysed using descriptive statistics including frequencies. The demographics of the students and pain when writing were compared for the typical students and those referred for handwriting assessments using Chi-squared tests. Descriptive statistics including the mean and standard deviation were determined for the subtests of the Observation Checklist, the Writing Checklist and Handwriting Outcomes.

The psychometric analysis for this phase of the study was divided into three parts

- Part 1: Construct validity and reliability of the Handwriting Screening Assessment
- Part 2: Cut off points and at risk quotients for the Handwriting Screening Assessment
- Part 3: The validity of the Handwriting Screening Assessment based on the at risk quotients

6.7.1 Part 1: Construct validity and reliability of the Handwriting Screening Assessment

In order to establish the construct validity of the Handwriting Screening Assessment a number of psychometric analyses were used. This included confirmation of the subtest validity and determining any local dependency between subtests, analysis of differences between the typical students and those referred for handwriting assessment as well as differences between known group factors for this sample. Reliability studies for the Handwriting Screening Assessment were also completed for this part of the study.

Confirmation of subtest validity and assessment dimensionality

Rasch analysis of the Observation Checklist and the Writing Checklist

Rasch subtest analysis was used to analyse both the Observation Checklist and Writing Checklist for all the students, typical and those referred for assessment. This analysis was used to confirm the subtest structure established in Phase 1. Rasch summary statistics were completed for both checklists to determine their dimensionality. The location and residual fit of each checklist was also recorded to determine the variation in the item-person traits. The person separation index was calculated to determine the ability of the test to differentiate those with deficits. Log residuals were used to establish whether the subtests were over or under discriminating [Andrich, 1982]. Correlations and equating t tests were used to determine local dependency of the subtests [Andrich, 2005].

Subtest analysis of Handwriting Outcomes

The data for Handwriting Outcomes were analysed using descriptive statistics. Frequencies for each subtest for both groups of students were presented in histograms. The acceptable range for these outcomes for students were indicated based on those reported by Barnett et al. (2010) [Barnett et al., 2010; Weintraub et al., 2007].

Local dependency of Observation Checklist, Writing Checklist and Handwriting Outcomes

Correlations on the mean scores of the Handwriting Outcomes using Pearson's correlation coefficients were determined to establish if any local dependency existed between the subtests on the Observation Checklist and Writing Checklist. The interpretation used for correlations is presented in Table 6.2 [Kielhofner, 2006].

Table 6.2 Interpretation level for correlation values

Correlations between 0.00 and 0.19	Negligible relationship
Correlations between 0.20 and 0.39	A weak relationship
Correlations between 0.40 and 0.59	A moderate relationship
Correlations between 0.60 and 0.70	A strong relationship
Correlations between 0.80 and 1.00	An excellent relationship

Analysis for differences

Differences according to known group factors

A Differential Item Functioning (DIF) analysis was also used to confirm whether the subtests in the Observation Checklist and the Writing Checklist were unbiased for age, gender and type of school attended.

The Handwriting Outcomes mean scores for both groups of students were compared to determine if there was a significant difference between the groups for any known group factors related to age, gender and school attended, using Chi-squared test or a Fisher's exact test if there were less than five participants in a group [Kielhofner, 2006].

Differences between typical students and students referred for handwriting assessment

All data for the three sections of the Handwriting Screening Assessments could be considered as interval scales once the data fits the Rasch model [Linacre, 1995], so parametric tests were used, set at significance of 0.05 for comparison of the two groups of students.

Student t-tests and Cohen d effect sizes were used to determine the difference on the subtests of the Observation Checklist, the Writing Checklist and Handwriting Outcomes between the typical students and those referred for handwriting assessment. This allowed both statistical and clinical significance to be established. Effect size was used to determine clinically relevant changes based on the scale described by Cohen. A large effect size is above 0.8, while a moderate effect size falls at 0.5 and a small effect size is 0.2 and below [Cohen, 1992].

Reliability

Reliability for internal consistency of the Observation Checklist, Writing Checklist and the Handwriting Outcomes in the form of Cronbach's alpha were determined. A level of 0.7 was set as acceptable internal consistency [Tavakol and Dennick, 2011].

The interrater reliability for the Observation Checklist and Writing Checklist was established with five raters using a two way, single measure inter-class coefficients. Absolute agreement between raters was assessed for these subtests [Hallgren, 2012]. The inter class coefficients (ICC) for each item and subtest on the Observation Checklist, Writing Checklist and Handwriting Outcomes were determined, with the exception of the copying speed which was a time read from a stopwatch. Since there was no random selection of the raters single measure ICCs for five raters were calculated using absolute scores [Hallgren, 2012] with a score above 0.7 set as good agreement [Cicchetti, 1994].

6.7.2 Part 2: Cut off points and at risk quotients for the Handwriting Screening Assessment

Norms for typical students for each subtest on the Observation Checklist and Writing Checklist and the Handwriting Outcomes, were determined by converting the total raw score for each subtest into z scores. This allowed the level for cut off points for risk of dysgraphia to be set. Raw scores were recoded against a normal distribution curve and were plotted according to the mean range and - 1SD, -2SD and -3 SD.

The z scores were used to determine at ARQs to identify at risk students for the Observation Checklist, Writing Checklist and the Handwriting Outcomes [Spaulding et al., 2006]. The guideline for deciding on the appropriate cut off score below which one identifies a deficit in handwriting was set at the 22nd percentile. There is evidence that this score identifies individuals at low risk for dysfunction compared to typical population [Fawcett and Nicolson, 1998] .

A cut off at the 10th percentile which identifies those having a high risk of dysfunction related to handwriting and 4th percentile which identifies those with a very high risk were based on criteria using Stanine scores described by Fawcett and Nicolson (1998) [Fawcett and Nicolson, 1998; Shaywitz et al., 1990].

6.7.3 Part 3: The validity of the Handwriting Screening Assessment based on the at risk quotients

The validity of the **Handwriting Screening Assessment** based on the ARQs was determined by establishing differences between the typical students and those who were referred for handwriting assessment. The clinical accuracy of the ARQs and the convergence and divergence with two standardised reference assessments were also established.

Differences between typical students and students referred for handwriting assessment

Student t-tests and Cohen d effect sizes were used to determine the difference on the subtests of the Observation Checklist, the Writing Checklist and Handwriting Outcomes for the ARQs for the typical students and those referred for handwriting assessment [Kielhofner, 2006]. The Frequency of the typical students and those referred for handwriting assessment were determined for the differ levels of risk.

Clinical Accuracy of the Handwriting Screening Assessment

Based on the ARQs the sensitivity and specificity as well as the predictive values for the Observation Checklist, the Writing Checklist and the Handwriting Outcomes were determined. Receiver operating characteristic (ROC) curves set at the cut off points were used to indicate the accuracy of the Handwriting Screening Assessment in determining risk for dysgraphia or handwriting deficits [Parikh et al., 2008].

Convergent and divergent validity

Hypotheses for convergent and divergent validity

- The ARQs for the Handwriting Outcomes will be convergent with the DASH 17+ percentile scores as both assess speed and automaticity of handwriting.
- the Handwriting Outcomes Subtest 3: *WSAM alphabet task* score would be convergent with the DEM vertical scores as both assess automaticity.
- the Subtest 6: *visual function* score on the Observation Checklist and Subtest 5: *missing letters and words* score on the Writing Checklist would be convergent with the DEM vertical and horizontal time scores as they measure visual function.
- The ARQs for all other subtests, except the two mentioned above, on the Observation Checklist and Writing Checklist would be divergent from and would not correlate with the DASH 17+ percentile scores and the DEM vertical and horizontal time scores as each assessment measures different components of handwriting.

This analysis was completed on the scores of the students referred for handwriting assessment. Due to the small sample size the data were not normally distributed (Lilliefors ≤ 0.10);[Razali and Wah, 2011]. The median and lower and upper quartile ranges for the ARQs for the Observation Checklist, the Writing Checklist and the Handwriting Outcomes as well as the percentile and raw scores for DASH 17+ and the DEM 2.0 were determined. Non-parametric Spearman's correlation coefficients were used to correlate the ARQs of the three sections of the Handwriting Screening Assessment with the percentile scores on the DASH 17+ and the DEM 2.0 to determine convergent and divergent validity for the assessments. The interpretation used for correlations are the same as those in Table 3.3.

CHAPTER 7: RESULTS PHASE 2

7.1 Introduction

The results of Phase 2 of the study report the findings for typical students and students who were referred for handwriting assessment on the **Handwriting Screening Assessment**.

Two of the 300 typical students recruited for the study failed to complete the demographic questionnaire and their data were not included in the results. Therefore, the sample of typical students was 298. A total of 61 students referred for handwriting assessment agreed to participate in the study. Thus, the sample size for this phase of the study was 359 students, 298 typical students and 61 students referred to the Occupational Therapy Department for assessment of their handwriting.

7.2 Demographics

7.2.1 Personal information

The typical students' age ranged from 18 years to 25 years (Table 7.1). The majority of students were below the age of 20 years. No students doing a second degree or postgraduate studies were assessed. The students referred for handwriting assessments were significantly older and their ages increased up to 29 years ($p=0.001$)

Just under two thirds of the typical students were female while significantly more of those referred for handwriting assessments were male ($p=0.001$). Although there were more left handed students in the group referred for handwriting assessment, this number was not significantly different from the typical student group in which approximately 10% were left handed.

The significant differences between the typical students and those referred for handwriting assessment for demographic factors indicated that the students referred for handwriting assessment did have a different demographic profile to that of typical university students. Table 7.1 supports the profile described in

Phase 1 as there were more male students, who were older and more likely to have attended a private school. A disproportionate percentage was registered in the Faculty of Commerce, Law and Management and a higher percentage had repeated a year.

Table 7.1 Demographics of the sample (n=359)

	Typical Students (n=298)		Students referred for handwriting assessment (n=61)		Chi squared (df)	p value
	n	**Percentage**	**n**	**Percentage**		
Age						
17-19 years	135	45.3%	29	47.5%		
20-21 years	123	41.3%	9	14.8%	18.00 (2)	0.01**
22-25 years	40	13.4%	18	29.5%		
26-29 years	0		5	8.2%		
Gender						
Male	116	38.6%	37	62.2%	10.58 (1)	0.01**
Female	182	61.4%	22	37.8%%		
Hand Dominance						
Right hand	268	89.9%	50	82.0%	2.56 (1)	0.10
Left hand	30	10.1%	11	18.0%		

Significance * p≤0.05
** p≤0.01

7.2.2 Education History

7.2.2.1 School

The type of schools the students attended was divided into categories reflective of the South African context. This consisted of three categories: private schools and two types of public schools which were historically advantaged and disadvantaged as described in section 4.3.3 (Table 7.2).

The majority of typical students assessed had attended public schools, with slightly more attending historically disadvantaged schools. Of these students, 38 reported that they had problems with handwriting in examinations. These problems included difficulties with speed, pain and legibility of handwriting but none of them had had extra time or other concessions.

Table 7.2 Type of School and Previous Extra time (n=359)

	Typical Students (n=298)		Students referred for handwriting assessment (n=61)			
Type of School attended	n (%)	Previously had extra time/ writing concessions n (%)	n (%)	Previously had extra time/ concessions n (%)	Chi square (df)	p value
Private	52 (17.4%)	0	30 (49.2%)	24 (39.4%)	22.76 (1)	0.01**
Public – historically advantaged	105 (35.2%)	0	13 (21.3%)	6 (9.8%)		
Public – historically disadvantaged	141 (47.4%)	0	18 (29.5%)	3 (4.9%)		

Significance * p≤0.05
** p≤0.01

Of the students requesting extra time and other concessions, who had been referred for handwriting assessment, significantly more had attended private schools (p=0.001) and 40% of these students had had extra time and other concessions including spelling and typing concessions or scribes at school. Very few students who attended historically disadvantaged schools were aware of, or had received concessions, while nearly 10% who attended historically advantaged schools had been assessed and had been awarded extra time concessions while at high school. All these concessions applied to matriculation examinations while some were in place from Grade 9. These findings reflect those found in Phase 1.

7.2.2.2. University

Faculty registration

The faculties the students were registered in differed with highest percentage of students from the typical sample being registered within the Health Sciences Faculty while nearly a third of the students referred for handwriting assessment were from the Faculty of Commerce and Law and Management (Table 7.3).

This was due to the researcher being based in the Health Sciences Faculty and the convenient sampling of the typical students. This led to a significant difference in the faculty distribution of the typical students and percentage of students registered in each faculty in 2013 [The Strategic Planning Division, 2013] (Chi squared 23.51, df=4. p= 0.001)

Table 7.3 Faculty with which the students registered (n=359)

	Percentage students in each Faculty in 2013/4 at Wits	**Typical Students (n=298)**		**Students referred for handwriting assessment (n=61)**			
Faculty		**n**	**%**	**n**	**%**	**Chi Squared (df)**	**p value**
Commerce, Law and Management	25.5%	34	11.4%	19	31.1%	15.06 (4)	0.01**
Engineering and the Built Environment	19.5%	86	28.8%	6	9.8%		
Health Sciences	16.4%	97	32.5%	12	19.7%		
Humanities	25.4%	35	11.6%	17	27.9%		
Science	13.24%	46	15.7%	7	11.5%		

There was also a significant difference between the percentage of students registered in each faculty in 2013 [The Strategic Planning Division, 2013] and the percentage of students referred for handwriting assessment from that faculty. This indicates that the percentage of students referred for handwriting assessment, from certain faculties such as Commerce, Law and Management was high while in other faculties like Engineering and the Built Environment very few students apply for concessions.

Year of study

The majority of students requesting extra time for handwriting problems were in their 1st year of study in their course as were the majority of typical students assessed (Figure7.1).

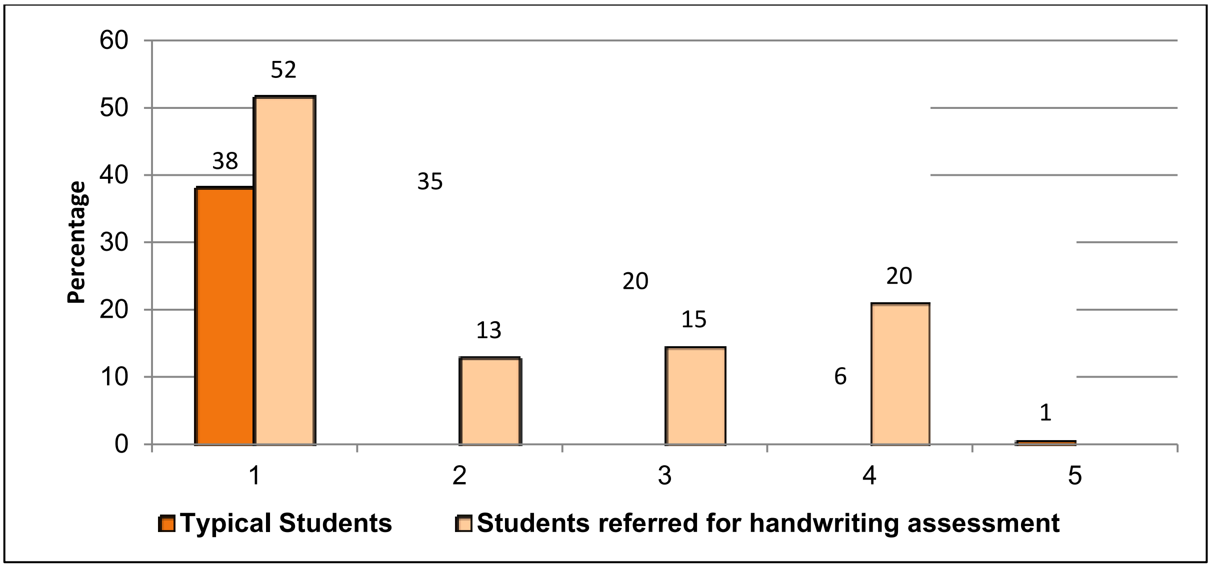

Figure 7.1 Year of study for typical students (n= 298) and students referred for handwriting assessment (n=61)

While student numbers drop over the years as fewer typical students in 3rd, 4th and 5th year were assessed there was an increase in 4th year students being referred for handwriting assessment. The difference in the years of study between the two groups was significant, with more students in later years of study being referred for handwriting assessment (Chi squared=21.62, df=4, p=0.001).

7.2.2.3 Years repeated

While just over 20% of the typical students had repeated at least one year in the course, 38% of the students referred for handwriting assessment had repeated at least one year of their course. In Figure 7.2 it can be seen that significantly more students referred for handwriting assessment had also repeated two or more years of their course and often reported that they had been unaware of the extra time concession and were only advised to apply for concessions once they had failed (Chi squared=11.5, df=4, p=0.013).

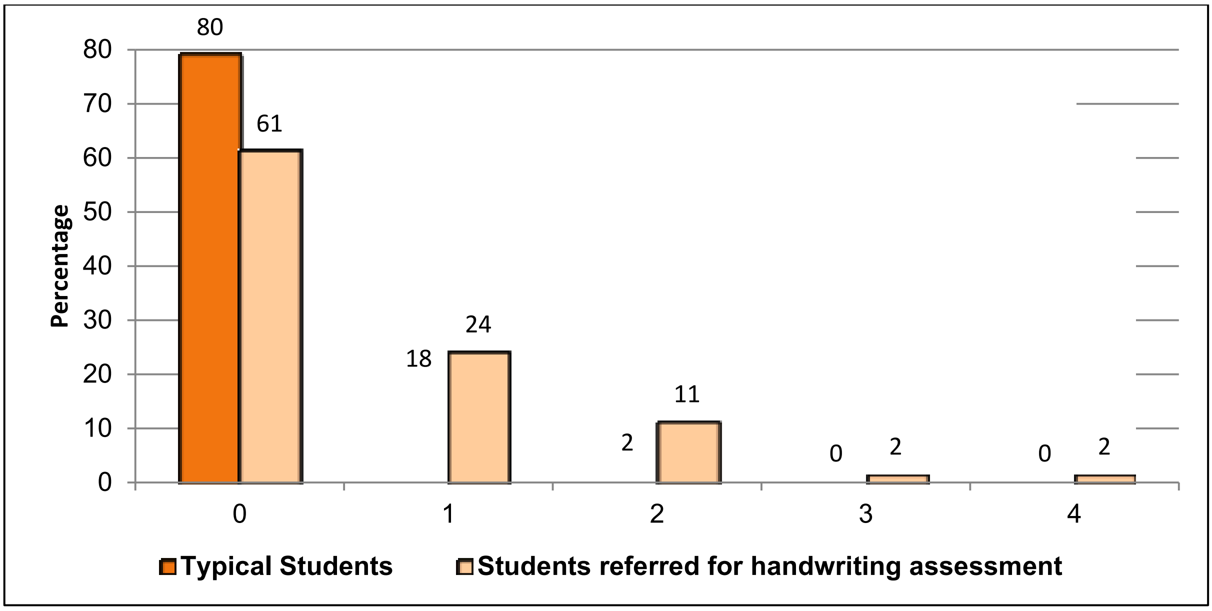

Figure 7.2 Number of years repeated by typical students (n= 298) and students referred for handwriting assessment (n=61)

7.2.3 Other problems identified in relation to handwriting.

Both pain and the choice of a writing instrument differed when the typical students and students referred for handwriting assessment were compared.

7.2.3.1 Pain

Pain was a problem reported by both groups. Students were asked to indicate if they experienced pain or discomfort when writing examinations and this was recorded on a Visual Analogue scale. A score of 1-4 was assessed as severe discomfort, while a score of above 5 was assessed as pain.

While 75% of typical students did report shaking their hands when writing examinations less than 1% reported high pain levels.

The results for the typical students indicated that 50% (149) reported they had discomfort when writing long examinations for two to three hours, while 32% (95) of students responded that they never experience these symptoms. Of the typical students that had pain or discomfort when writing examinations 27.5% (41) reported low discomfort, 33% (49) moderate discomfort and 28 % (42) high discomfort which was equated with a low level of pain below a 4 on the VAS pain scale. Sixteen students (5.4%) reported discomfort or pain in the hand and upper limb within five minutes of starting to write. In the group of students referred for handwriting assessments 45.9% experienced pain or discomfort within five minutes of starting to write (Table 7.4).

Table 7.4 Pain and discomfort reported within five minutes of starting to write (n=359)

	Typical Students (n=298)		**Students referred for handwriting assessment (n=61)**		**Chi squared X^2**	**df**	**p value**
	n	**Percentage**	**n**	**Percentage**			
Pain	16	5.4%	33	45.9%	61.11	1	0.01**
No pain	282	94.6%	26	54.1%			

Significance * p≤0.05
** p≤0.01

7.2.4 Choice of pen

The other factor that differed between typical students and those referred for handwriting assessment was the choice of a preferred pen. Only 19% (57) of the typical students reported preferring to write with a specific pen. Nearly 50% of the students referred for handwriting assessment reported using a specific pen or writing with a pencil was important for either legibility or the speed of writing. In some cases use of a specific pen reduced the amount of pain they experienced when writing examinations. Unlike typical students, seven students preferred to write with a pencil [Chan and Lee, 2005] and reported that writing with a pencil increased both the speed and legibility of their writing (Figure 7.3). The students referred for handwriting assessment often reported that they were unable to use a clutch pencil due to the continuous breakage of the lead because of the pressure they used when writing.

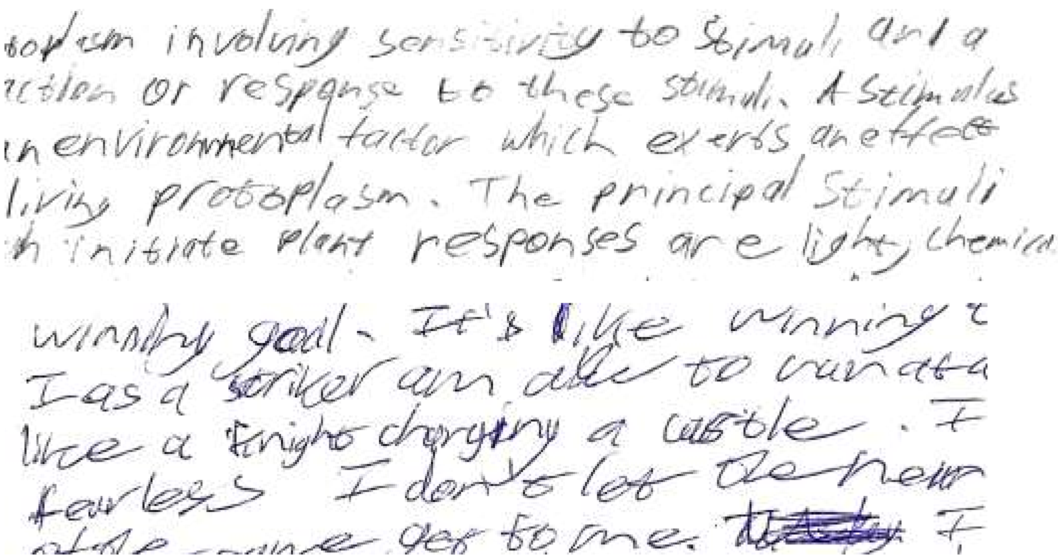

Figure 7.3 Difference in legibility for a student writing with a pencil and a ball point pen

In summary, the group of typical students and those referred for handwriting assessment differed significantly for all the demographic and educational factors except dominance. This indicates that students referred for handwriting assessment present with characteristics which are different from typical students. More male students were referred for handwriting assessment and they were older, in later years of study and had repeated more years of study. The highest percentage of students referred for handwriting assessment, were registered in two faculties at the university: Commerce, Law and Management and the Humanities.

No students in the typical group had had concessions previously while students referred for handwriting assessment attending private schools had had the most concessions at school. Students attending public schools had rarely had concessions previously, particularly those at previously disadvantaged schools. Other factors that differed between the two groups of students were the number of students that reported experiencing pain when writing and the choice of the instrument with which they wrote.

7.3 Psychometric properties of the Handwriting Screening Assessment

This phase of the study was divided into three parts to determine the validity and reliability of the **Handwriting Screening Assessment** as well as to determine cut-off points indicating students at risk for dysgraphia or handwriting problems.

7.3.1 Part 1: Construct validity and reliability of the Handwriting Screening Assessment

Based on Step 11 of instrument development (Figure 3.1) the psychometric properties of the **Observation Checklist, Writing Checklist and Handwriting Outcomes** were analysed to determine the construct validity and reliability of the **Handwriting Screening Assessment.**

To determine the validity of the **Observation Checklist** and the **Writing Checklist** they were analysed with the Rasch method to confirm the subtest fit and dimensionality for the entire sample of typical students and those referred for handwriting assessment. The validity of the interval scales on the **Handwriting Outcomes** section was also established.

Evidence for construct validity was further presented using differentiation studies to determine if differences were present on the three sections of the **Handwriting Screening Assessment** for known group factors: age, gender and school attended.

7.3.1.1 Subtest Analysis of Handwriting Screening Assessment Observation Checklist and the Writing Checklist

Relationship and fit of subtests

The results of the typical students and those referred for handwriting analysis were combined and analysed according to the subtests determined in Phase 1 for the **Handwriting Screening Assessment,** using the RUMM 2030 software.

Fit of subtests to the Rasch model

The data fitted the Rasch model for both the **Observation Checklist** and the **Writing Checklist** with non-significant chi squared scores. A mean of 0 and a standard deviation of 1 for the fit residuals and locations indicate the best fit to the Rasch model (Table 7.5).

Table 7.5 Summary statistics for observation and Writing Checklists

	Observation Checklist				**Writing Checklist**			
	Subtests =7		**Persons n=359**		**Subtest =5**		**Persons n=359**	
	Location	**Fit residual**	**Location**	**Fit residual**	**Location**	**Fit residual**	**Location**	**Fit residual**
Mean	0.00	-0.00	-1.51	-0.22	0.00	0.13	-0.62	-0.21
SD	1.08	0.98	0.37	0.85	0.82	1.12	0.55	0.81
Person separation index 0.3					Person separation index 0.4			
Item–trait interaction Total item chi-square = 38.46 Total df = 35 Total chi-square probability = 0.32					**Item–trait interaction** Total item chi-square = 35.74 Total df = 25 Total chi-square probability = 0.08			

The values for the fit residuals for the subtests and location for the subtests for both the Observation Checklist and Writing Checklist were therefore acceptable [Wright, 1996].The mean and standard deviation of the person location did not fit these criteria due to the nature of the assessment in which it was not expected that students would have the ability to meet the top score for each subtest. All students had some deficits when writing and this was reflected in the negative means were found for person location.

A lack of separation was also seen between the persons in this analysis as the person separation index (PSI) of 0.03 was found for the Observation Checklist and 0.4 Writing Checklist fell below the suggested 0.7. Thus, there was limited variation in the person abilities and the opportunity for the ordering of the students according to their level of ability was reduced for total combined scores for all the subtests on the checklists. The students could be divided into two groups in terms of their ability on both checklists [Andrich, 1982].This was further analysed by considering the person–item distribution.

The person–item distribution

The scores of typical students and those referred for handwriting assessment were analysed to obtain both item difficulty and person difficulty levels along interval logarithmic scales converting scores to interval scales (Figure 7.4).

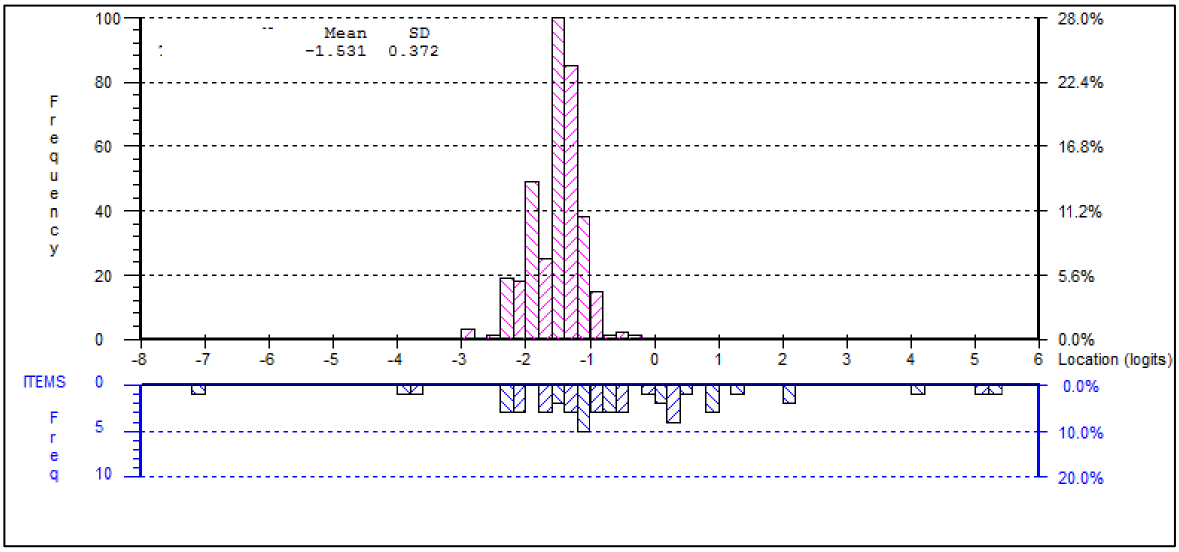

Figure 7.4 Person Item Threshold Distribution for Observation Checklist (n=359)

The clustering of the person abilities confirms the smaller PSI with the person abilities along the interval scale showing a distribution to the negative side with a mean of -1.5. This confirms that students did not achieve the ideal for all items as most students scored poorly on some items in the subtests.

The items showed a greater variation in scores with the majority of items showing they targeted the ability of the students, across a range of difficulty. The easy item on the item axis is related to Observation Checklist item 20: *the finger the pen is held against* where the majority of the students obtained a high score. In Figure 7.5 the person abilities for the **Writing Checklist** along the same interval scale also showed a distribution to the negative side as very few students have perfect writing without some deficits although for this checklist the mean score was closer to 0 at -0.6 indicating the students achieved higher scores on the **Writing Checklist** than on the **Observation Checklist**. Students scoring below –1 may present with deficits that indicate they need further assessment. The students scoring at -4 showed deficits in all items. The results for both checklists indicated a lack of variation in the ability of the students, particularly the Observation Checklist. This indicated a lack of sensitivity in the items but both had an adequate fit to the Rasch model and unidimensionality and were considered to have satisfactory validity.

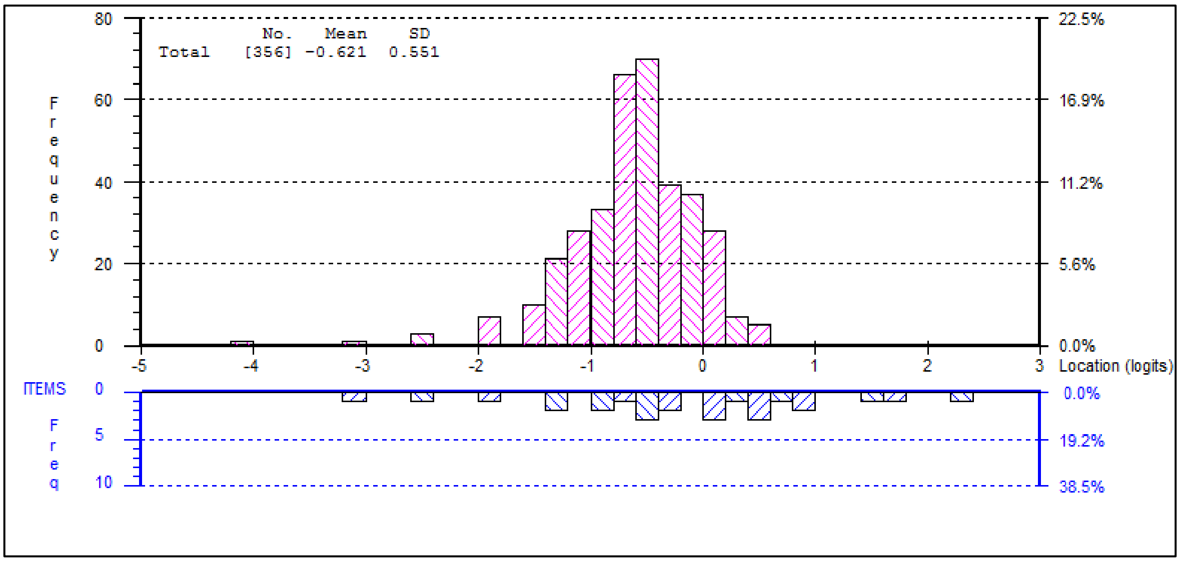

Figure 7.5 Person Item Threshold Distribution for Writing Checklist (n-359)

The item difficulty for writing in the **Writing Checklist** also showed a spread of items from easy to difficult with the easiest being the percentage of readable words and the most difficult being writing exactly on the line.

Individual Subtest Fit

Based on the number of subtests in the checklist, Bonferroni adjustments are included in the chi-square significance tests. In Table 7.6 it can be seen that none of the chi squared tests for any of the individual subtests showed significance indicating each subtest fitted the Rasch model as well. The log residual did not exceed -2.5 to 2.5 thus no over or under discrimination was found and the subtests could be considered as fitting the Rasch model [Wright, 1996].

The subtests with the lower location values for the **Observation Checklist** were Subtest 3 *stability of grasp* and Subtest 5 *movement in hand and fingers* indicating these subtests require more ability, while Subtest 7: *preferred hand and wrist position* had a positive score indicating the need for less ability

In the **Writing Checklist,** the lowest location value was for Subtest 1: *writing analysis* with Subtest 3: *punctuation* being the easier for the students to achieve. The subtest which still showed problems with the item characteristic curves and poor fit was Subtest 3: *punctuation* on the **Writing Checklist** even though it fitted other criteria.

Table 7.6 Residuals and Chi squared values for the revised Observation Checklist and Writing Checklist subtests on the final version of the Handwriting Screening Assessment (n=359)

	Location Value	SE	Log Residual	Chi Squared X^2	df	p
Observation Checklist subtests						
Subtest 1 ***Position and fixation of paper***	-0.47	0.06	1.28	4.35	5	0.50
Subtest 2 ***Maintenance of posture***	0.92	0.04	0.09	4.99	5	0.42
Subtest 3 ***Stability of grasp***	-0.74	0.04	-1.18	8.44	5	0.13
Subtest 4 ***Pen Grasp***	-0.53	0.03	-1.47	9.17	5	0.10
Subtest 5 ***Movement in hand and fingers***	-0.73	0.05	0.21	6.83	5	0.23
Subtest 6 ***Visual function***	-0.52	0.05	0.53	2.34	5	0.77
Subtest 7 ***Preferred hand and wrist position***	2.08	0.12	0.51	2.13	5	0.83
Writing Checklist Subtests						
Subtest 1 ***Writing analysis***	-0.64	0.03	-1.61	5.30	5	0.38
Subtest 2 ***Endurance and fatigue***	-0.09	0.04	-0.40	5.60	5	0.34
Subtest 3 ***Punctuation***	1.42	0.10	0.78	10.62	5	0.06
Subtest 4 ***Corrections and Spelling***	-0.44	0.06	0.99	8.68	5	0.12
Subtest 5 ***Missing letters and words***	-0.26	0.04	0.88	5.53	5	0.35

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

Local dependency of the subtests

The subtests were checked for local dependency to ensure items in one subtest did not influence the scoring on other subtests (Table 7.7). There were no positive correlations above 0.02, the suggested cut-off point on both checklist [Wright, 1996]. This indicates that the items in the subtests do not influence items in the other subtests.

Table 7.7 Correlations for subtests on the Handwriting Screening Assessment Observation Checklist and Writing Checklist (n=359)

Observation Checklist subtests							
	Subtest 1 ***Position and fixation of paper***	**Subtest 2 Maintenance of posture**	**Subtest 3** ***Stability of grasp***	**Subtest 4** ***Pen Grasp***	**Subtest 5** ***Movement in hand and fingers***	**Subtest 6** ***Visual Function***	**Subtest 7** ***Preferred hand and wrist position***
Subtest 1 ***Position and fixation of paper***	1						
Subtest 2 ***Maintenance of posture***	-012	1					
Subtest 3 ***Stability of grasp***	-0.16	-0.15	1				
Subtest 4 ***Pen Grasp***	-0.17	-0.43	-0.29	1			
Subtest 5 ***Movement in hand and fingers***	-0.20	-0.05	-0.18	-0.02	1		
Subtest 6 ***Visual function***	-0.06	-0.05	-0.21	-0.32	-0.16	1	
Subtest 7 ***Preferred hand and wrist position***	0.02	-0.02	-0.13	-0.06	-0.08	-0.02	1

Writing Checklist Subtests					
	Subtest 1 Writing analysis	**Subtest 2 Endurance and fatigue**	**Subtest 3 Punctuation**	**Subtest 4 Corrections and Spelling**	**Subtest 5 Missing letters and words**
Subtest 1 ***Writing analysis***	1				
Subtest 2 ***Endurance and fatigue***	-0.19	1			
Subtest 3 ***Punctuation***	-0.33	-0.26	1		
Subtest 4 ***Corrections and Spelling***	-0.21	-0.25	-0.07	1	
Subtest 5 ***Missing letters and words***	-0.54	-0.45	0.21	-0.14	1

Unidimensionality

To confirm the unidimensionality of the subtests in the checklist equating to tests for both the Observation Checklist and the Writing Checklist were analysed (Figure 7.6). The proportion of significant tests on the binomial distribution was below 0.05 indicating that the unidimensionality in both checklists was acceptable [Tennant and Pallant, 2006].

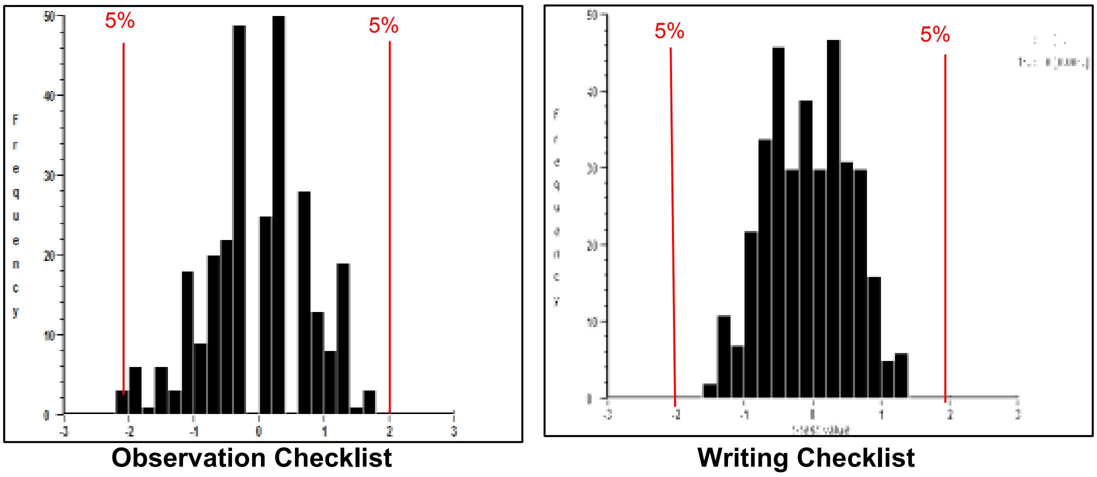

Figure 7.6 Equating t test for the Observation Checklist and Writing Checklists within the cut off (n=359)

7.3.1.1.2 Subtest analysis Handwriting Outcomes

Descriptive statistical analysis of the **Handwriting Outcome** scores for copying speed, legibility and automaticity for the total sample of 359 students' utilised procedures suitable for interval scales.

Copying speed

The mean number of WPM copied for the students was 22.08. (SD 4.85);(Figure 7.7).

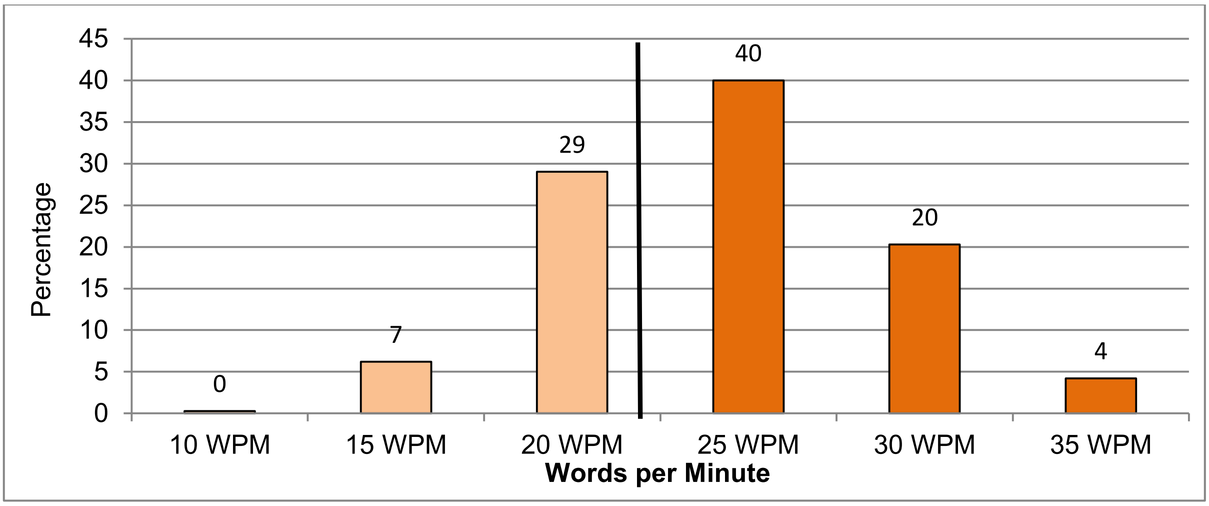

Figure 7.7 Frequency of copying speed – words per minute for students (n=359)

The mean number of WPM copied by typical students was 22.85 (SD 4.15) with a median of 22 words per minute.

Legibility

The legibility score was changed to words unreadable rather than letters unreadable as explained in section 3.4.3.2 (Appendix R). Over 60% of students had writing which fell into the acceptable category in terms of legibility with a score between 1 and 3 and only 16% presented with writing which was not at an acceptable level of legibility (Figure 7.8).

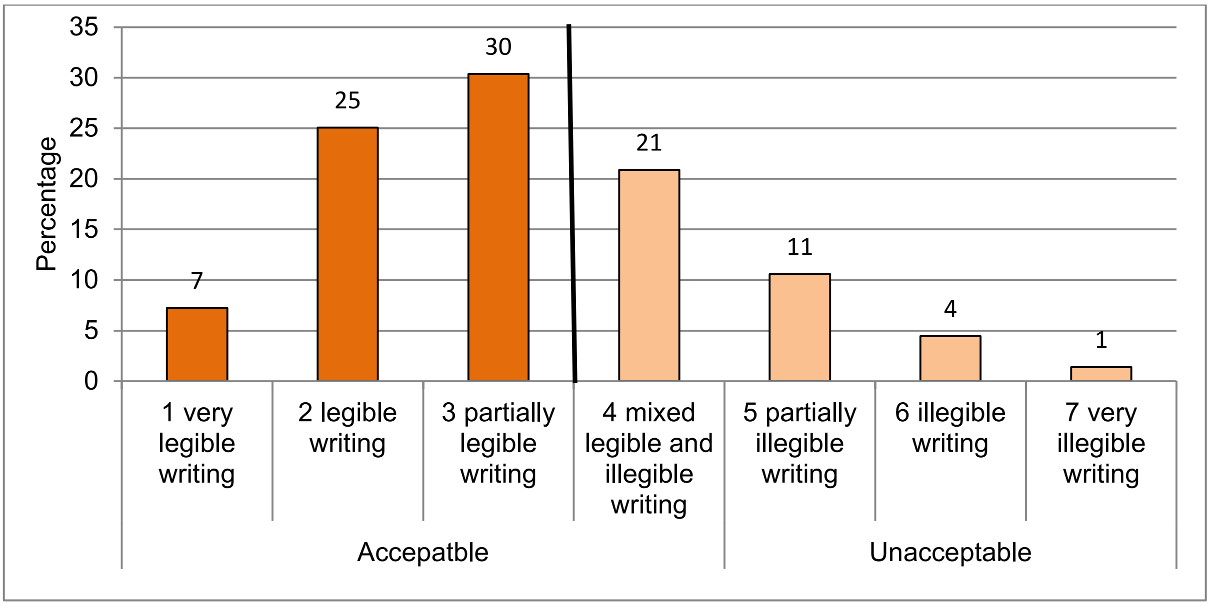

Figure 7.8 Frequency of legibility for students (n-359)

Writing Speed Accuracy Measure (WSAM) Alphabet Task

The mean number of letters written in the WSAM Alphabet task in one minute for the students was 77.81 (SD 23.65) with a median of 81 when writing lower case letters of the alphabet (Figure 7.9). The typical students wrote 83.45 LPM (SD 17.88).

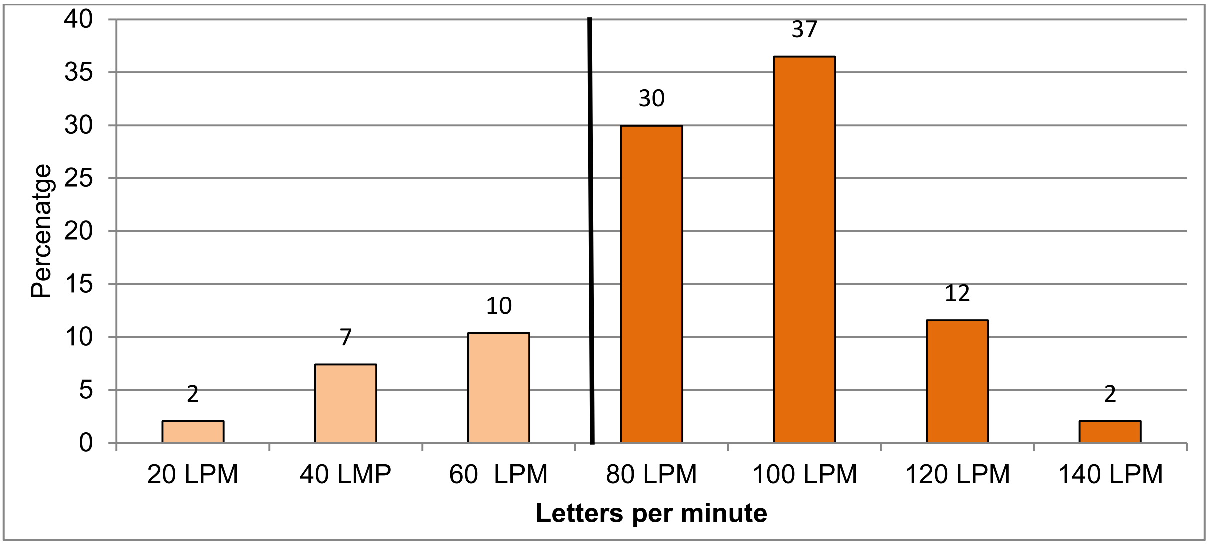

Figure 7.9 Number of letters of the alphabet written in one minute for typical students and those referred for handwriting assessment (n=359)

Local dependency of Observation Checklist, Writing Checklist and Handwriting Outcomes

In order to establish any local dependency of the subtest on the **Handwriting Screening Assessment** Spearman's correlation coefficient was used to compare the scores of the subtests on all three sections (Table 7.8).

This allowed for the determination of any association between the writing components observed in the students, the presentation of their writing and the outcomes that were measures related to copying speed, legibility and automaticity or automaticity of writing

Only Observation Checklist Subtest 6: *Visual function* had moderate correlations with all three subtests of Handwriting Outcomes. In the Writing Checklist Subtest 1: *Writing analysis* and Subtest 2: *Endurance and fatigue* had a moderate negative correlation with Handwriting Outcomes Subtest 2: *Legibility* since a higher score for legibility indicates poor legibility. Within the Handwriting Outcomes the Subtest 3: *WSAM Alphabet task* had a positive moderate correlation with Subtest 1: *Copying speed* and had a moderate negative correlation with Subtest 2: *Legibility*. This indicates writing automaticity assessed by the WSAM Alphabet task has some association with both the speed and legibility subtests in the Handwriting Outcomes section.

Table 7.8 Correlation between the Observation Checklist, Writing Checklist and Handwriting Outcomes subtest scores for typical students and students referred for assessment (n=359)

Handwriting Outcomes	Subtest 1: Copying Speed	Subtest 2: Legibility score	Subtest 3: WSAM Alphabet task
Observation Checklist			
	r	**r**	**r**
Subtest 1 ***Position and fixation of paper***	0.06	-0.14	0.10
Subtest 2 ***Maintenance of posture***	0.08	-0.06	0.09
Subtest 3 ***Stability of grasp***	0.07	0.01	0.04
Subtest 4 ***Pen Grasp***	-0.02	0.09	-0.01
Subtest 5 ***Movement in hand and fingers***	0.14	-0.06	0.14
Subtest 6 ***Visual function***	**0.53***	**-0.42***	**0.45***
Subtest 7 ***Preferred hand and wrist position***	0.06	-0.03	0.01
Writing Checklist			
	r	**r**	**r**
Subtest 1 ***Writing analysis***	-0.04	**-0.49***	0.12
Subtest 2 ***Endurance and fatigue***	0.13	**-0.55***	0.22
Subtest 3 ***Punctuation***	0.01	0.01	0.03
Subtest 4 ***Corrections and Spelling***	0.13	-0.19	0.18
Subtest 5 ***Missing letters and words***	0.14	-0.08	0.09
Handwriting Outcomes			
	r	**r**	**r**
Subtest 1: Copying speed		-0.26	**0.68***
Subtest 2: Legibility	-0.26		**-0.47***

Significance * p≤0.05

The coefficient of determination or r^2 indicated that 22% of the variance in the Handwriting Outcomes Subtest 3: *WSAM Alphabet task* could be explained by the variance in Subtest 2: *legibility* and 46% could be explained by Subtest 1: *words* *per min*. The proportion of variance accounted for by the Observation Checklist Subtest 6: *visual function* and the subtests on the Handwriting Outcomes was between 17% and 28%. For the Writing Checklist Subtest 1: *writing analysis* and Subtest 2: *endurance and fatigue* and **Handwriting Outcomes** Subtest 2: *legibility* the explained variance was 30% and 24% respectively. This indicates that each subtest also assessed components not assessed by other subtests.

In summary, based on the results for the three sections of the Handwriting Screening Assessment for structure of the assessments and lack of local dependency it can be accepted that the Observation Checklist, the Writing Checklist and Handwriting Outcomes all have adequate construct validity. The structure of the checklists fit the Rasch model for all aspects. The fit of the subtests into the Rasch model indicates that each checklist measures a construct related to handwriting and that the subtests can be totalled to reflect either constructs related to the writer in the Observation Checklist or the presentation of writing in the Writing Checklist. The PSI only indicated the difference between the students based on the total scores for the checklists. This supported the division of students into two groups in terms of their ability in handwriting which could be considered a group with and without dysgraphia and handwriting problems but further analysis to determine difference between students for each subtest in the checklist (Table 7.12). Subtests on the checklist had no local dependency with no redundancy and therefore each assesses a different component of handwriting and can be scored and analysed separately. Only a small number of subtests had moderate correlations within the Handwriting Outcomes and to other subtests on the Observation Checklist and Writing Checklist. Since the coefficients of determination also all fell below 60% it was accepted that these subtests do measure components not assessed by other subtests and should they be retained and scored separately.

7.3.1.2 Studies of differences

Differences according to known group factors on Observation Checklist, the Writing Checklist and Handwriting Outcomes

All three sections of the **Handwriting Screening Assessment** were analysed to determine if there were differences for the known group factors of age, gender and school attended in the scoring.

Differential Item Functioning for Observation Checklist *and the* ***Writing Checklist***

The Observation Checklist and the Writing Checklist were analysed using Differential Item Functioning (DIF) in the Rasch analysis.

Observation Checklist

Differential Item Functioning was used to establish if students who differed in age, gender and the school they attended and may not have had an equal probability of success when completing the either the Observation Checklist or the Writing Checklist.

Table 7.9 Differential Item Functioning for the Handwriting Screening Assessment: Observation Checklist (n=359)

Observation Checklist subtests p values												
	Age				**Gender**				**School**			
	MS	**F**	**df**	**p**	**MS**	**F**	**df**	**p**	**MS**	**F**	**df**	**P**
Subtest 1 ***Position and fixation of paper***	2.79	2.91	1	0.09	0.03	0.03	2	0.97	2.74	2.91	2	0.06
Subtest 2 ***Maintenance of posture***	0.44	0.52	1	0.47	1.91	2.24	2	0.11	0.09	0.10	2	0.90
Subtest 3 ***Stability of grasp***	4.58	6.13	1	0.01	1.19	1.59	2	0.21	0.06	0.07	2	0.93
Subtest 4 ***Pen Grasp***	1.83	2.56	1	0.11	0.89	1.25	2	0.29	2.20	3.09	2	0.05
Subtest 5 ***Movement in hand and fingers***	1.41	1.65	1	0.20	0.71	0.85	2	0.43	0.22	0.25	2	0.78
Subtest 6 ***Visual function***	51.72	68.99	1	**0.00***	6.81	7.95	2	**0.00***	1.15	1.27	2	0.28
Subtest 7 ***Preferred hand and wrist position***	6.24	6.89	1	0.01	0.89	0.96	2	0.39	0.92	0.98	2	0.38

Bonferroni corrected Observation Checklist significance p=0.002 *
Significance * p≤0.05
** p≤0.01

This adds to the validity of the assessment as scores should not favour any group based on known demographic factors. Analysis of variance of the residuals (ANOVA) was used to compare the students for age, gender and school attended. The results in Table 7.9 are based on a Bonferroni correction which was completed as part of the DIF analysis in RUMM 2030 to ensure no significant differences between the groups. Therefore, the significance levels for the DIF were set at 0.002 for the Observation Checklist.

The DIF for Observation Checklist Subtest 6: *Visual function* was significant for age and gender. The results indicated the DIF for gender on this subtest was uniform with the males achieved consistently higher scores than the females (p=0.001) on the same locations. This is indicated by the parallel nature of the class intervals indicating one group has a higher mean than the other (Figure 7.10).

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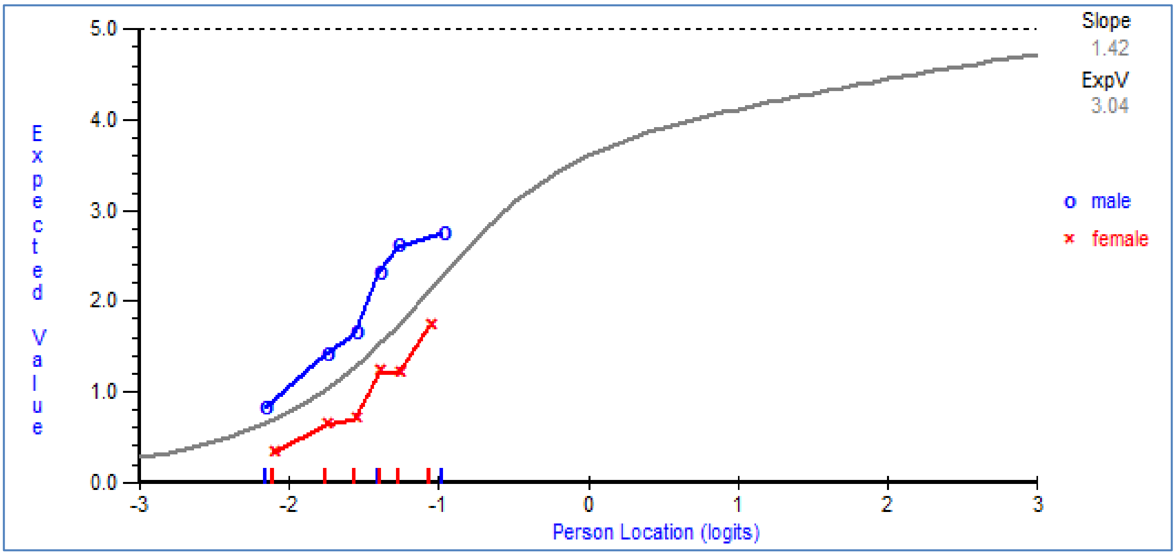


Figure 7.10 Differential Item Functioning for Observation Checklist Subtest 6: Visual function for gender (n=359)

The DIF for age in the **Observation Checklist** Subtest 6: *Visual function* was non-uniform. When the deficit for visual function was severe at person location -2 on the x-axis of Figure 7.11 then the oldest students (25-29 years) had a lower mean score than that of with the younger students (17 to 20 years). The students aged 21 to 24 had the highest mean scores for this subtest.

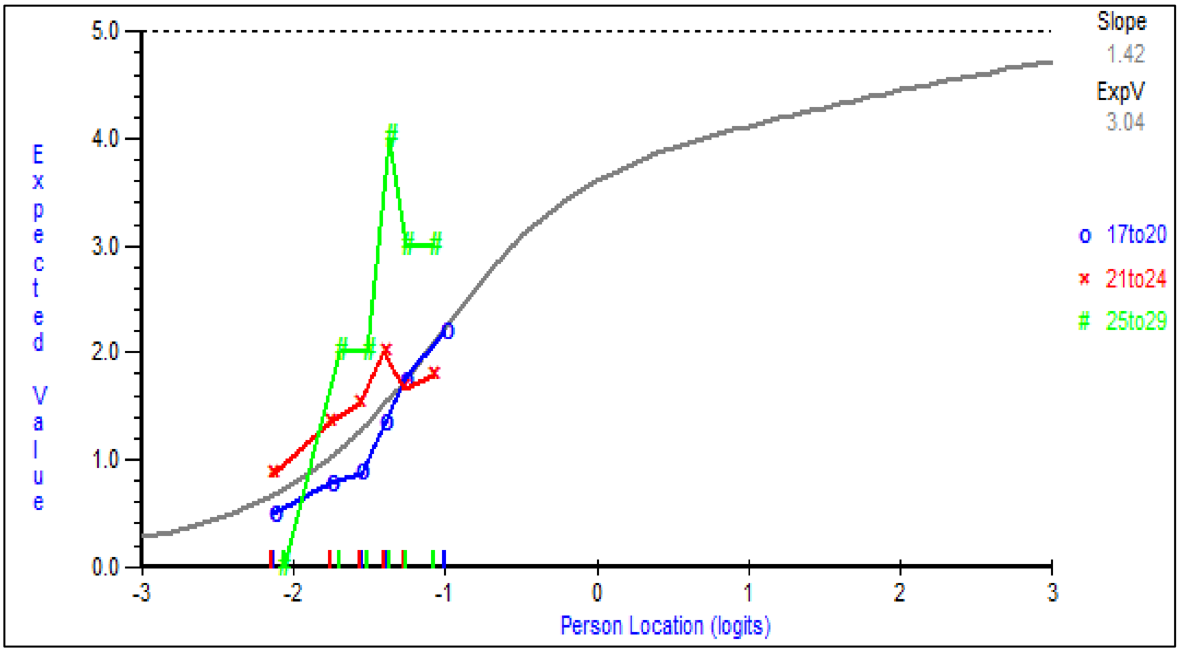


Figure 7.11 Differential Item Functioning for Observation Checklist Subtest 6: Visual function for age (n=359)

However, for students with a milder deficit in visual function at person location-1 on the mean, deficits were reversed with the older students (25-29 years) having the highest mean scores and students aged 21 to 24 having the lowest mean scores. This indicates that students with more severe visual function problems, referred for handwriting assessment were the older students.

Writing Checklist

The significance levels for the DIF were set at 0.002 for the **Observation Checklist**. There were no significant DIF scores for the **Writing Checklist** for any of the variables tested so age, gender and school did not affect performance on this checklist (Table 7.10).

Table 7.10 Differential Item Functioning for the Handwriting Screening Assessment Writing Checklist (n=359)

	Writing Checklist Subtests											
	Age				Gender				School			
	MS	F	df	p	MS	F	df	p	MS	F	df	P
Subtest 1 ***Writing analysis***	0.95	1.43	2	0.24	3.41	5.07	1	0.02	0.57	0.84	2	0.43
Subtest 2 ***Endurance and fatigue***	0.61	0.81	2	0.44	0.05	0.06	1	0.81	3.72	5.05	2	0.01
Subtest 3 ***Punctuation***	0.80	0.93	2	0.39	0.59	0.69	1	0.41	0.35	0.41	2	0.67
Subtest 4 ***Corrections and Spelling***	0.46	0.55	2	0.57	1.21	1.41	1	0.24	1.07	1.28	2	0.28
Subtest 5 ***Missing letters and words***	0.46	0.52	2	0.58	3.45	3.89	1	0.05	0.70	0.81	2	0.44

Bonferroni corrected Writing Checklist significance p= 0.003*
Significance * p≤0.05
** p≤0.01

Differences for known group factors -Handwriting Outcomes

The differences for known group factors of age, gender and school in the **Handwriting Outcomes** were determined using a non-paramedic Kruskal-Wallis test as the data were not normally distributed.

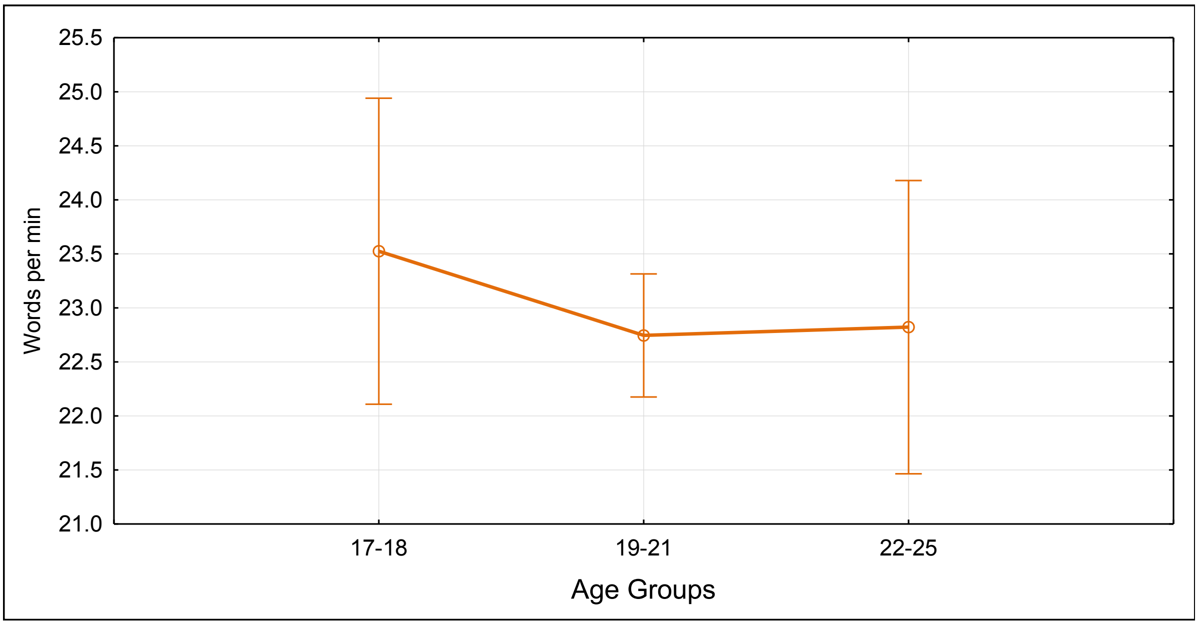


Figure 7.12 Means and 95% confident intervals for copying speed for three age groups of students (n=359).

There was no significant difference between the age groups for Subtest 1: *copying speed*.

The youngest group had slightly better scores for all these subtests as seen in Figure 7.12 and Table 7.11. There were no significant differences for age for Subtest 2: *legibility* or Subtest 3: *WSAM Alphabet task.* The Handwriting Outcomes Subtest 1: *copying speed* and Subtest 3: *WSAM Alphabet task* automaticity scores Subtest 2: legibility, were significantly different for gender and for school attended indicating a difference in the ability of the in the Handwriting Outcomes.

Table 7.11 Comparison of Handwriting Outcomes-for students by age, gender and school attended (n=359)

Age		**Age Group 17-18 years n=135**	**Age Group 19–21 years n=123**	**Age group 22-25 years n=40**	
		Mean (SD)			**p value**
	Copying speed	23.52 (3.85)	22.73 (4.21)	22.87 (4.20)	0.62
	WSAM Alphabet task	86.48 (15.83)	83.21(18.12)	82.44 (18.40)	0.58
	Legibility	3.05 (1.100	3.16 (1.27)	3.52 (1.35)	0.25
Gender		**Males n=116**	**Females n=182**		
		Mean (SD)			**p value**
	Copying speed	21.41 (3.97)	23.75 (4.40)		0 .00**
	WSAM Alphabet task	79.37(18.66)	86.26 (16.83)		0 .02**
	Legibility	3.51 (1.13)	3.00 (1.20)		0 .01**
School Attended		**Private Schools n=52**	**Previously Advantaged Schools n=195**	**Previously Disadvantaged Schools n=141**	
		Mean (SD)		**p value**	
	Copying speed	23.54(4.07)	23.80 (4.33)	21.99 (3.97)	0.01**
	WSAM Alphabet task	90.75 (15.78)	87.17 (18.01)	78.91 (17.23)	0.00**
	Legibility	2.88 (1.26)	2.94 (1.32)	3.47 (1.24)	0.06

Significance * p≤0.05
** p≤0.01

Table 7.11 shows that females had significantly better scores than males for all outcomes and those attending previously advantaged schools had faster copying speed while those attending private schools wrote more letters in the WSAM Alphabet task indicating better automaticity. Legibility was not significantly different for the school attended.

Differences between typical students and students referred for handwriting assessment

The last step in determining the validity of the subtests on the Observation Checklist, Writing Checklist and Handwriting Outcome was to compare the scores for the typical students and students referred for handwriting assessment (Table 7.12).

Parametric t tests results indicated that there are statistically significant differences between the typical students and those referred for handwriting assessment for nine of 15 subtests on the Handwriting Screening Assessment**.**

The scores for the students referred for handwriting assessment were lower on all the subtests with the exception of Subtest 4: *pen grasp* where the small negative effect size confirmed the students referred for handwriting assessment had better mean scores for this subtest.

The scores for Subtest 4: *Pen grasp* as well as Subtest 7: *preferred hand* was also not significantly different for the two groups of students. Effect size was large for Subtest 6: *visual function* and moderate for Subtest 1: *position and fixation of paper* and indicated clinically significant differences as the 95% confidence intervals were both positive.

Subtest 3: *stability of grasp* and Subtest 5: *movement in hand and fingers* had a small effect size which still confirmed the better performance in typical students.

In the Writing Checklist, the total scores as well as the first two subtests, Subtest 1: *analysis of writing* and Subtest 2: *endurance and fatigue* showed significantly higher scores for the typical students when compared to the students referred for handwriting assessment. Effect sizes indicated clinically significant difference for these two subtests as well as for the total score for this checklist.

Table 7.12 Difference in the subtest total scores for typical students and students referred for assessment (n=359)

	Typical Students (n=289)	Students referred for analysis (n=61)	Students t-tests	Effect size Cohen's d	Confidence intervals
	Mean (SD)	Mean (SD)	p value		
	OBSERVATION CHECKLIST				
Subtest 1 ***Position and fixation of paper***	8.00 (0.82)	7.44 (0.99)	0.01**	0.61	0.10 to 1.17
Subtest 2 ***Maintenance of posture***	11.28 (1.32)	10.91 (1.16)	0.05*	0.29	-0.37 to 1.21
Subtest 3 ***Stability of grasp***	13.72 (1.57)	13.22 (1.32)	0.02*	0.34	-0.35 to 1.41
Subtest 4 ***Pen Grasp***	15.55 (2.13)	15.98 (2.13)	0.27	-0.20	-1.58 to 1.06
Subtest 5 ***Movement in hand and fingers***	7.79 (1.13)	7.31 (1.31)	0.01**	0.39	-0.22 to 1.18
Subtest 6 ***Visual function***	6.97 (1.02)	4.93 (1.24)	0.01**	1.79	1.33- 2.58
Subtest 7 ***Preferred hand and wrist position***	4.82 (0.40).	4.75 (0.54)	0.65	0.15	-0.16 to 0.34
	WRITING CHECKLIST				
Subtest 1 ***Writing analysis***	10.68 (1.77)	9.91 (1.91)	0.01**	0.41	0.50 to 2.21
Subtest 2 ***Endurance and fatigue***	7.13 (1.40)	5.81 (1.40)	0.01**	0.93	0.24 to 1.37
Subtest 3 ***Punctuation***	4.63 (0.56)	4.67 (0.54)	0.67	-0.07	-0.41 to 0.71
Subtest 4 ***Corrections and Spelling***	4.34 (0.91)	4.18 (0.97)	0.20	0.17	-0.32 – 1.06
Subtest 5 ***Missing letters and words***	5.78 (1.48)	5.85 (1.52)	0.51	-0.04	-0.56 to 0.68
	HANDWRITING OUTCOMES				
Copying speed	22.85 (4.15)	18.21 (4.16)	0.01**	1.10	0.63 to 2.21
WSAM alphabet score	83.45 (17.88)	69.18 (19.63)	0.01**	0.76	0.18 to 1.23
Legibility	3.20 (1.27)	3.31 (1.38)	0.934	-0.07	-0.88 to 0.72

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

The large effect size confirmed that Subtest 2: *endurance and fatigue* showed the greatest clinical difference between the groups. The subtests which considered errors, spelling, punctuation and missing or added elements in the copying of the paragraph had small effect sizes and did not differ significantly between the groups. The scores for the students referred for handwriting assessment were better than those of the typical students for punctuation and missing letters and words.

In the Handwriting Outcomes two subtests copying speed and: WSAM alphabet score showed significantly higher scores for the typical students with large effect sizes. The large effect sizes for the copying speed and WSAM alphabet task subtests indicted clinically significant differences for these subtests.

The legibility subtest had a small negative effect size indicating the students referred for handwriting assessment had better scores for legibility but this did not differ significantly between the two groups. The percentage of students scoring 5 and below for legibility was similar in both groups of students, with 18.3% of students in the group referred for handwriting assessment and 15.9% of typical students scoring at this level. None of the typical students scored 7 for legibility, while 8% of students referred for handwriting assessment had writing in which less than half the words could be read.

On the basis of the results an exploratory factor analysis was completed on these subtests in Handwriting Outcomes in this phase of the study. The analysis loaded with two factors. Copying speed and automaticity formed one factor (eigenvalue 1.4 and total variance of 47%) and legibility the second factor (eigenvalue 1.1 and total variance 34%) (Appendix N). Therefore, the Handwriting Outcomes was divided into two subtests: - Subtest 1: *Copying speed and automaticity* and Subtest 2: *legibility* for the analysis of the cut off points below.

In summary, these results confirmed that the typical students performed significantly better than the students referred for handwriting assessment on nine subtest scores for the two checklists. In the subtests where there was no significant difference and the overall performance of the two groups of students was considered comparable.

While these findings may affect the construct validity of the Handwriting Screening Assessment the subtests in which the two groups of students did not differ significantly were retained as the students referred for assessment had deficits in these subtests which affected their handwriting and may have placed them at risk for dysgraphia. This was addressed in Phase 3 of the study. Thus, the null hypothesis that there is no difference between the typical students and students referred for handwriting assessment was rejected for nine of the 15 subtests on the Handwriting Screening Assessment.

7.3.1.3 Reliability of the Handwriting Screening Assessment

The reliability of the assessment in this study was established for internal consistency and interrater reliability. The screening assessment was used once to establish the risk for dysgraphia so test retest reliability was not considered.

Internal consistency

The Cronbach's Alpha scores for the total score of each subtest on the Observation Checklist and Writing Checklist were determined. Due to the lack of local dependency between the subtests, the internal constancy was not determined for each checklist. In Table 7.13 some of the Cronbach's Alpha scores for the Observation Checklist reached the acceptable level of 0.7 [Tavakol and Dennick, 2011], and ranged from 0.54 to 0.84.

Table 7.13 Internal consistency for the Subtests and items on the Observation Checklist, Writing Checklist and Handwriting Outcomes (n=359)

Observation Checklist					
Cronbach's α		**Cronbach's α**		**Cronbach's α**	
Subtest 1 Position and Fixation of the paper	0.56	Subtest 4 Pen Grasp	0.70	Subtest 6 Visual function	0.78
Subtest 2 Posture	0.54	Subtest 5 Movement in fingers and hand	0.70	Subtest 7 Preferred hand	0.78
Subtest 3 Stability of grasp	0.61				
Writing Checklist					
Cronbach's α		**Cronbach's α**		**Cronbach's α**	
Subtest 1 Analysis of Writing	0.71	Subtest 3 Punctuation	0.75	Subtest 5 Missing letters and words	0.84
Subtest 2 Endurance and fatigue	0.73	Subtest 4 Corrections and Spelling	0.76		
Handwriting Outcomes					
Copying speed	0.81	Legibility	0.83	WSAM Alphabet task	0.73

The internal consistency of the Writing Checklist was at an acceptable level for most aspects except items under writing analysis and the type of writing. The internal consistency for the Handwriting Outcomes was acceptable for all sections.

Inter-rater reliability for the Observation Checklist and Writing Checklist

The inter-rater reliability of the Observation Checklist and Writing Checklist was completed with five raters (Table 7.14 and 7.15).

Table 7.14 Inter-rater reliability for the Subtests and items on the Observation Checklist, (n=5)

Observation Checklist					
	ICC		**ICC**		**ICC**
Subtest 1 Position and Fixation of the paper	**0.76**	DIP index finger	1.00	**Subtest 5 Movement in fingers and hand**	**0.89**
Paper table	0.67*	IP thumb	1.00	Movement hand	0.93
Paper student	0.87	Firmness of grasp	0.94	Grip and reposition	0.82
Paper copied	0.97	Distance from tip	0.76	Writing movements	0.65*
Fixates paper		Web space	0.97	Dis-association	1.00
Subtest 2 Posture	**0.72**	**Subtest 4 Pen Grasp**	**0.85**	**Subtest 6 Visual function**	**0.64**
Writing hand position	0.87	Finger close tip	0.69	Head movement	0.55*
Non-writing hand position	0.45*	Thumb aligned to index finger	0.96	Follows text	0.67*
Posture	0.76	Thumb supports pen in pinch	0.87	Reading type	1.00
Posture - flexion	0.89	Pen slant		**Subtest 7 Preferred hand**	**1.00**
Maintains position	0.87	Finger pen held to	1.00	Preferred hand	1.00
Subtest 3 Stability of grasp	**0.83**	No fingers on pen	1.00	Wrist position	1.00
PIP index finger	0.69*	Joint level of pen	0.76		

The reliability of the Handwriting Screening Assessment in terms of internal consistency was determined for the items and subtests on the Observation Checklist and Writing Checklist. While most subtests achieved acceptable scores, six subtests (marked with *) particularly on the Observation Checklist did not reach the acceptable level of 0.7. These subtests rely on the raters' observation skills which may affect the reliability of the assessment as some subjectivity, even with the detailed item descriptors may occur.

Inter-rater reliability for the Observation Checklist and the Writing Checklist subtests were acceptable except for Observation Checklist Subtest 6: visual function, Writing Checklist Subtest 3: punctuation and Handwriting Outcomes*: legibility.* Differences between the raters may have resulted in these subtests as behaviour changed during the assessment. Raters needed to observe these changes and score the greatest deficits seen. Students may have missed behaviour such as repositioning the pen in the hand for instance if it occurred when they were not observing the hand.

Precision was needed in assessing the handwriting and car needed to be taken to observe all the errors made in the text. Overall the reliability was considered acceptable for the Handwriting Screening Assessment and was higher for the Writing Checklist as the scoring was more objective when assessing the presentation of the handwriting.

Table 7.15 Interrater reliability for the Subtests and items on the Writing Checklist, (n=5)

Writing Checklist					
	ICC		**ICC**		**ICC**
Subtest 1 Analysis of Writing	**0.97**	**Subtest 2 Endurance and fatigue**	**0.97**	**Subtest 4 Corrections and Spelling**	**0.89**
Lines	0.86	Type of writing	1.00	Corrections copy	0.92
Letters unreadable	0.95	Pressure	0.85	Spelling copied	0.45*
Organisation letters	0.88	Deterioration	0.16*	**Subtest 5 Missing letters and words**	**0.92**
Slant letters	0.93	**Subtest 3 Punctuation**	**0.55***	Missing add letter	0.62*
Size of writing	1.00	Punctuation	0.08*	Missing add words	1.00
Organise of words	0.52*	Capital letters	0.62*	Missing add lines	1.00
Handwriting Outcomes					
Legibility	**0.68**	**WSAM Alphabet task**	**0.78**		

While the results indicated the Handwriting Screening Assessment had adequate validity and reliability the test did not allow differentiation between students according to each subtest on the Observation Checklist and the Writing Checklist or into than two groups or levels of deficits for handwriting on the checklists. Further analysis was therefore performed which identified the students at different levels of risk for deficits in all subtests [Fawcett and Nicolson, 1998].

7.3.2 Part 2: Cut-off points and At Risk Quotients for the Handwriting Screening Assessment

Based on normative scores analysed on the data of the typical students, cut-off points that identified all students at risk for deficits was developed. At risk quotients (ARQ) using z scores were determined so that any students that presented with deficits on items that fell below -1SD in comparison to the performance of typical students, irrespective of the median performance of the entire group, could still be considered for further assessment. Using norms to develop cut-off points and scoring meant that students would only be identified on the subtests where they presented with deficits. Students would also need to present with deficits in a number of subtests before they could be considered to have a handwriting deficit.

7.3.2.1. Normative data for the Handwriting Screening Assessment

Normative data were established for all subtests on each of the Observation Checklist, Writing Checklist and Handwriting Outcomes as this allowed for students to be identified with scores at -1 SD below the mean, as at risk of dysgraphia and those below -2SD as having definite deficits.

The scores for each subtest were analysed in terms of their fit into a normal distribution and the z scores for each subtest were determined to establish in which aspect a student fell-1SD below the mean.

The z scores for the results of the typical students on each subtest were established using a z score converter [Lowry, 2015]. The z scores were rounded to one decimal place so z scores of -3, -2, -1, 0, 1, 2, and 3 were assigned to the scores.

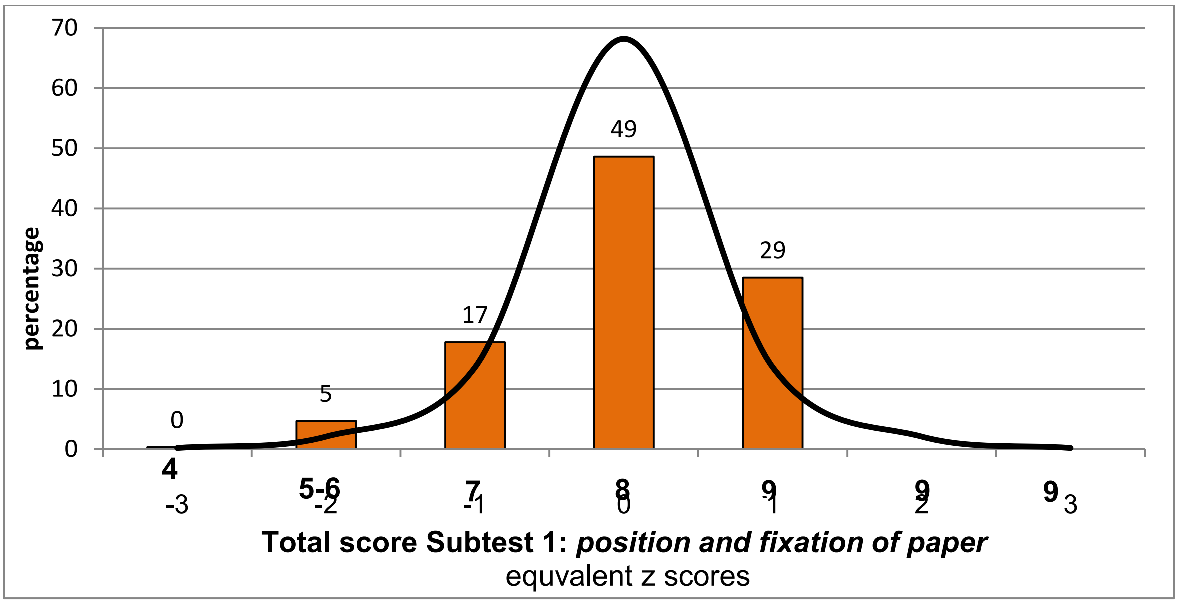


Figure 7.13 z Scores for Observation Checklist Subtest 1: *position and fixation of paper* for typical students plotted against a normal distribution (n=298)

For the Observation Checklist Subtest 1: *position and fixation of the paper* the distribution of scores against the normal distribution is represented in Figure 7.13. The z score equivalent was established for the scores on each subtest.

Each student was then scored according to the subtests as in the example for the first subtests of the **Observation Checklist** and **Writing Checklist** are presented in Table 7.16. If the total score for **Observation Checklist** Subtest 1: *position and fixation of the paper* is 7 then a cross is made in the block below 7 indicating that the z score for that subtest is in the range -1SD below the mean. The score of 8 on **Writing Checklist** Subtest 1: *writing analysis* is marked in the column for a z score in the range -1 SD below the mean.

Table 7.16 Example of summary sheet to score Subtest 1 on the Observation Checklist and Writing Checklist

Observation Checklist subtests	-3 SD	-2 SD	-1 SD	Mean 0	+1- +3 SD	Writing Checklist subtests	-3 SD	-2 SD	-1 SD	Mean 0	+1- +3 SD
Subtest 1 *Position and fixation of paper*	4	5-6	7	8	9	**Subtest 1 *Writing Analysis***	5	6-7	8-9	10-11	12-15
			x						x		

Once the total score for each subtest had been transferred to the z score summary sheet the z scores for each subtest were plotted on a grid so the relationship between the scores for each subtest could be seen and an interpretation of the students' handwriting deficits could be determined (Table 7.16).

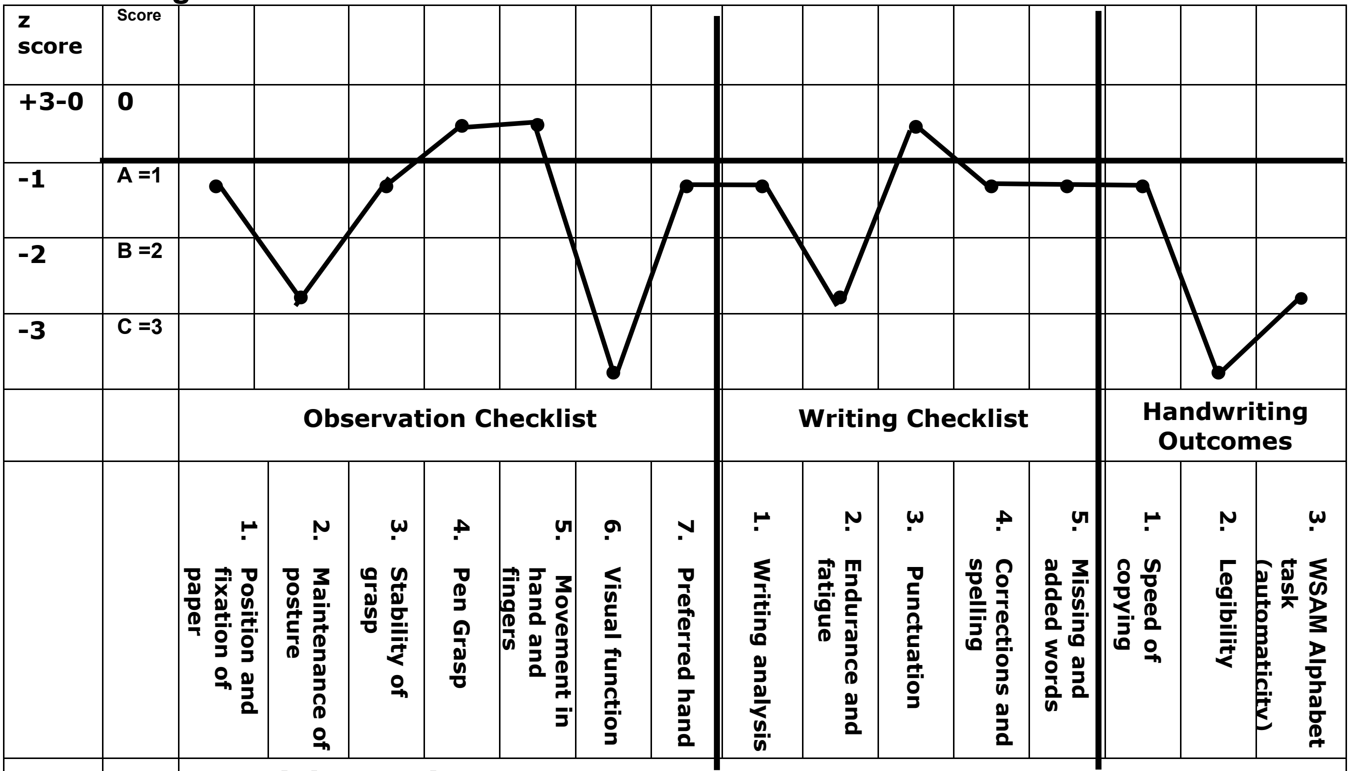
In Table 7.17 the scores that fall into the mean range or are above average are plotted above a dark cut-off line at 0 or +1 to +3 SD and these scores show no deficits. The z scores below the mean for each subtest were plotted in line with A for subtests obtaining a score of -1 SD, those with -2SD were plotted in line with B, and -3 SD in line with C

The subtests on which the students scored deficits were assigned a score of 1 on line A, 2 on line B or 3 on line C in keeping with the severity of the deficit. These scores were totalled. A score of 0 was assigned for those scoring in the mean range or above and they are considered to have no risk for dysgraphia or handwriting deficits.

The example in Table 7.17 presents the number of subtests in which a student is deficient and allows for this to be visually determined. It also allows for identification of subtests in which no problems exist and any points above the dark line scoring can be assumed to present no problem.

The lower the points are on the grid the more severe the problem. The example presented indicates a problem with motor dysgraphia including position of the paper and fixation of the paper, posture, stability of grasp, visual function and preferred hand as the student wrote with a flexed wrist. There were also problems with the quality of writing as well as endurance when writing and corrections made while writing. The copying speed was slightly affected while legibility was poor and this also affected the WSAM Alphabet task where only legible letters are counted.

Table 7.17 Example of z scores on a grid used to plot the z scores for each subtest of the Observation Checklist and Writing Checklists and Outcomes of Writing.



At Risk Quotients

Observation Checklist	Writing Checklist	Handwriting Outcomes
A 3 x 1= 3	A 3 x 1= 3	**Copying Speed and Automaticity**
B 1 x 2 = 2	B 1 x 2 = 2	A 1 x 1= 1
C 1 x 3 = 3	C x 3 = ______	B 1x 2 = 2
D 8 **/7** **= 1.1**	**D** 5 **/5** **= 1**	C 1 x 3 = ____
		D 3**/2** **= 1.5**
		Legibility
		C 1 x 3 = 3

Although the plotting of the deficits gave a clear indication of the type of problems experienced by any one student, it does not allow for the severity of the deficits to be represented numerically in a percentile or recognised score against which the amount of extra time or need for concessions could be determined. Therefore, cut-off scores based on the ARQs [Fawcett and Nicolson, 1998] were established for each of the three sections on the Handwriting Screening Assessment (Appendix V).

7.3.2.2 At Risk Quotients (ARQ)

The scores for deficits on line A, B and C of the grid were totalled separately for the Observation Checklist, Writing Checklist and Handwriting Outcomes in Table 7.17. The total score for the checklists on the Handwriting Screening Assessment was divided by the number of subtests in that section to determine an ARQ or severity of the deficit for each section. The scores for the checklists could be added as the Rasch analysis indicated the checklists were unidimensional. The Handwriting Outcomes was divided with copying speed and automaticity combined into one ARQ and legibility into another as the scores for these could not be added.

The use of ARQs to determine cut-off scores and identify the severity of the risk for dysgraphia or handwriting problems is similar to the scoring provided in the Dyslexia Adult Screening Test (DAST) [Fawcett and Nicolson, 1998]. Since the scores in line A, B and C indicated z scores of -1SD and below, the cut-off scores were calculated according to the three lowest Stanine scores (7-9) as suggested by Fawcett and Nicolson (1998) in the DAST. A mild deficit was represented by ARQs falling into the 20th to 11th percentile in which case the individual can be considered at low risk for dysgraphia or handwriting deficits. A score in the case of a moderate deficit of (10th to 4th percentile) places the individual at high risk for dysgraphia or handwriting deficits and a score of 3 (line C) for a severe deficit (4th to 0 percentile) which places them in a very high risk category [Fawcett and Nicolson, 1998].

In Table 7.18 it can be seen that the ARQs for the typical students were equated to percentile ranks and the score for each section that falls as close to the 20th percentile as possible was used to identify students at low risk [Fawcett and Nicolson, 1998].

A score equivalent to the 10th percentile was used to identify those with high risk for dysgraphia and handwriting deficits and that equivalent to the 3rd percentile as very high risk for each of the three sections. The low risk ARQ for the Observation

Checklist was 0.5, while that for the Writing Checklist was 0.8 and 0.6 for copying speed and automaticity on the Handwriting Outcomes. The low risk for legibility was 1.

Table 7.18 Cut-off At Risk Quotients and percentiles on the Observation Checklist, Writing Checklist and Handwriting Outcomes on the handwriting Screening Assessment (n=298)

	Observation Checklist		Writing Checklist		Handwriting Outcomes			
					Speed and Automaticity		Legibility	
Cut-off	**At risk quotient**	**Percentile**	**At risk quotient**	**Percentile**	**At risk quotient**	**Percentile**	**At risk quotient**	**Percentile**
No risk								
	0	84	0	88				
	0.1	77	0.2	77	0	77		
	0.3	45	0.4	58	0.2	42		
	0.4	32	0.6	37	0.4	32	0	>38
Low risk	**0.6**	**11-21**	**0.8**	**11 -19**	**0.6**	**11-21**	**1**	**11-20**
High risk	**0.7**	**5-10**	**1**	**5- 10**	**0.8**	**5 -10**	**2**	**5-10**
Very high risk	**0.8**	**1-4**	**1.2**	**2-4**	**1**	**2-4**	**3**	**1-4**
	1	**1**	**1.4**	**2**	**1.5**	**1**		
	1.1	**0.1**	**1.6**	**1**	**2**	**0.1**		
	1.2	**0.05**	**1.8**	**0.1**	**2.5**	**0.05**		
	1.3	**0**	**2.0**	**0.1**	**3**	**0**		

In the example in Table 6.17 the student had an ARQ of 1.1 for the Observation Checklist which is in the very high risk range, an ARQ of 1 for the Writing Checklist which is high risk and an ARQ of 1.5 for the Handwriting Outcomes copying speed and automaticity and 3 for legibility which falls into the very high risk level. These scores indicate the student is scoring between the 5th and 0 percentiles for the three aspects of handwriting and should be referred for assessment related to client factors identified in the Observation Checklist and Writing Checklist as well as a standardised handwriting assessment.

In this part of the study normative scores for the typical students were determined according to a normal distribution so cut-off points against which the ability of the student referred for assessment could be identified. A range of cut-off points below the 20th percentile could be established for all the sections of the Handwriting

Screening Assessment. This meant that the deficits that each student presented with could be observed on their scoring grid (Table 7.16) and that further assessments could be suggested if students were identified at risk for dysgraphia or handwriting problems on any or all of the sections of the Handwriting Screening Assessment.

7.3.3 Part 3: Validity studies for the Handwriting Screening Assessment based on At Risk Quotients

Construct validity for the sections of the Handwriting Screening Assessment was established before the cut-off points and ARQs were determined. Further validity studies based on the ARQs were then completed to confirm the use of cut-off points for this assessment. These studies included a comparison of the scores for the typical students and the students referred for handwriting assessment for handwriting using ARQs, the clinical accuracy (sensitivity and specificity as well as the predictive value) of the three sections of the Handwriting Screening Assessment. Convergent and divergent validity were considered in relation to other standardised tests and confirmed by establishing the differences of the DASH 17+ percentile scores and DEM vertical and horizontal scores and the level of risk according to the ARQs.

7.3.3.1 Differences between typical students and students referred for handwriting assessment

A comparison of the results of the ARQs for the typical students and the students referred for handwriting assessment for handwriting problems confirmed a significant difference between the two groups for the three sections of the Handwriting Screening Assessment at $p = 0.01$ for the Observation Checklist, Writing Checklist and Writing Outcomes, except for legibility (Table 7.19 and Figure 7.15).

Highly significant differences were found between the typical students and the students referred for handwriting assessment for the two checklists and speed and automaticity outcomes of the Handwriting Screening Assessment. Large effect sizes found for the ARQs on the three sections of the Handwriting Screening Assessment except legibility.

Table 7.19 Difference in the at risk quotient scores for typical students and students referred for assessment (n=359)

	Typical Students (n=289)		Students referred for analysis (n=61)		Mann Whitney U test	t-tests	Effect size Cohen's d	Confidence intervals
	Mean (SD)	Median	Mean (SD)	Median	p value	p value		
Observation Checklist	0.29 (0.23)	0.28	0.66 (0.31)	0.57	0.01**	0.01**	-1.37**	-0.93 to -2.20
Writing Checklist	0.46 (0.37)	0.40	0.77 (0.53)	0.80	0.01**	0.01**	-0.88**	-0.60 to -2.27
Handwriting Outcomes **Speed and Automaticity**	0.20 (0.44)	0.00	0.80 (0.79)	0.50	0.01**	0.01**	-1.36**	-0.94 to - 2.68
Handwriting Outcomes **Legibility**	0.50 (0.75)	0.00	0.50 (0.90)	0.00	0.99		0	

Significance p ≤0.05*
Significance p ≤0.01**

Small effect size 0.3
Medium effect size 0.5*
Large effect size 0.8**

The histograms in Figure 7.14 confirm the large variance in the standard deviations seen in Table 7.19 indicating that some typical students did present with deficits on all three sections of the Handwriting Screening Assessment. Some and that students referred for handwriting assessment were not at risk on one or two sections of the Handwriting Screening Assessment, particularly presentation of handwriting and legibility

In the Writing Checklist and Handwriting Outcomes 75% of typical students showed no risk for handwriting deficits while 82% of typical students were not at risk according to the ARQs on the Observation Checklist. For the students referred for handwriting assessment, 23% had no risk on the Observation Checklist and 48% for the Writing Checklist. On the Handwriting Outcomes speed and automaticity subtest and the legibility subtest 30.7% and 66.1% of these students were not at risk with respectively (Figure 7.14). In total 82% (50) students referred for handwriting assessment were at risk for dysgraphia or handwriting deficits.

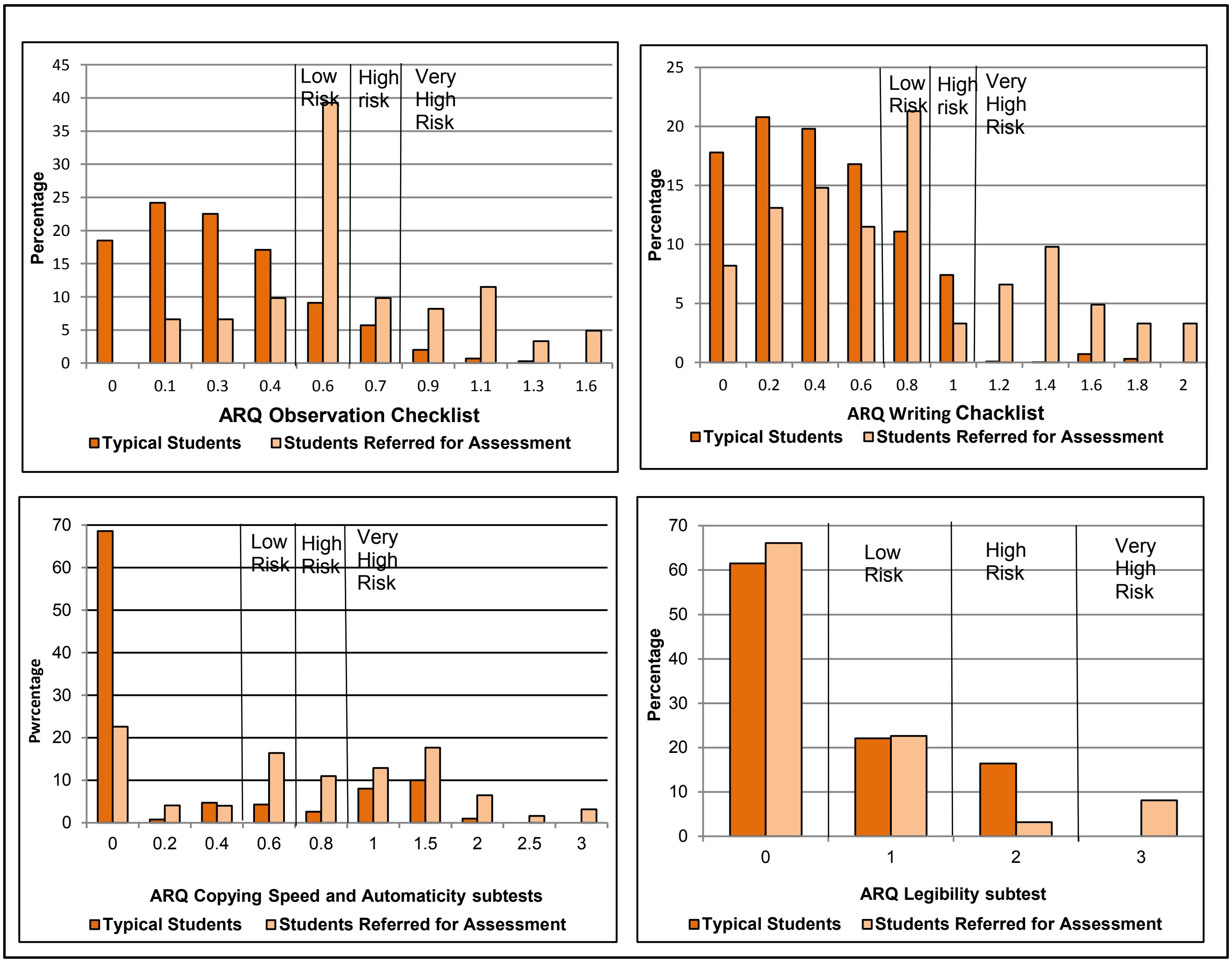


Figure 7.14 Frequency of at risk quotient scores for typical students (n=298) and students referred for assessment (n=61) for the Observation Checklist, Writing Checklist and Handwriting Outcomes.

In summary these results confirmed the importance of screening students on all three sections of the **Handwriting Screening Assessment** as deficits may occur in only one of the three sections and these may be missed if assessments which only consider handwriting outcomes are used. The variance in the results and overlap at the cut-off points meant it was important to consider other validity measures such as sensitivity, specificity and predictive values for the three sections of the Handwriting Screening Assessment.

7.3.3.2 Clinical Accuracy of the Handwriting Screening Assessment.

The sensitivity, specificity and predictive values of the three sections of the Handwriting Screening Assessment at the ARQ cut-off points, was established to confirm how valid the assessment was in identifying which students presented with handwriting deficits and which of these students may need concessions. The accuracy of the screening assessment instrument was based on having sensitivity and specificity levels within acceptable limits. Sensitivity is the ability of the Handwriting Screening Assessment to detect the presence of dysgraphia and handwriting deficits. Specificity, on the other hand, is the ability of a Handwriting Screening Assessment to indicate negative results when dysgraphia and handwriting deficits are absent.

Prevalence was set at 17% (50/298) which reflects the proportion of students referred for handwriting assessment with scores below the cut-off point compared to the sample of typical students (Table 7.20).

Table 7.20 The sensitivity and specificity of the Observation Checklist, Writing Checklist and Handwriting Outcomes Sections of the Handwriting Screening Assessment cut-off ARQs

Cut-off at low risk	Observation Checklist Cut-off 0.6	Writing Checklist Cut-off 0.8	Handwriting Outcomes	
			Speed and Automaticity Cut off 0.6	Legibility Cut off 1
	Percentage (95% confidence intervals)			
Sensitivity	37.70 (25.6-51.0)	31.15 (19.9-44.3)	42.62 (30.0-55.9).	65.57 (52.3-77.3)
Specificity	91.28 (87.5-94.2)	85.57 (81.1-89.4)	85.57 (81.1-89.4)	38.26 32.7-44.0
Positive predictive value	46.9 (32.4-61.9)	30.6 (19.9-44.3)	37.7 (26.2-50.3)	17.9 (13.1-23.5)
Negative predictive value	87.7 (83.6-91.2)	85.9 (81.4-89.6)	87.9 (83.6-91.4)	84.4 (77.2-90.1)
Receiver operating characteristic (ROC) curves area under the ROC curve (AUC)	0.84 (0.79-0.87)	0.66 (0.61-0.71)	0.72 (0.67- 0.76)	0.52 (0.47-0.57)

The results indicated that when using the ARQ cut-off point values the specificity was at an acceptable level above 80% [Friberg, 2010] for the checklists and Handwriting Outcomes copying speed and automaticity subtests. This provided a negative no risk result when no handwriting deficits were present in 86 to 91% of students. This was confirmed by the negative predictive value over 88% for the checklists and the copying speed and automaticity subtest.

However, since the sensitivity and positive predictive values were low, some students with problems may not be identified as having dysgraphia at the cut-off points. The lack of an acceptable level at 80% for both sensitivity at the cut-off points and low positive predictive values for the checklists and Handwriting Outcomes copying speed and automaticity subtest of the Handwriting Screening Assessment was counteracted by the receiver operating characteristic (ROC) curves associated with the sensitivity and specificity. The area under the ROC curve (AUC) was 0.84 for the Observation Checklist and 0.72 for the copying speed and automaticity subtest indicated adequate discrimination between the presence or absence of dysgraphia and handwriting deficits. The AUC was 0.66 for the Writing Checklist which showed a lower but fair ability of the instrument to discriminate between the presence or absence of dysgraphia and handwriting deficits [Portney and Watkins, 2000]. The legibility subtest of the Handwriting Outcomes had a low AUC indicating this subtest does not discriminate students with and without dysgraphia and handwriting problems in this sample of students.

The legibility subtest on the Handwriting Outcomes when using the ARQ cut-off point values indicated both sensitivity and specificity below the acceptable level of 80% [Friberg, 2010]. Thus, as legibility was not useful for discriminating students with dysgraphia and handwriting problems in this sample as confirmed by the AUC of 0.51. The high negative predictive for legibility still the probability of 84% of students identified with no problem definitely do not have dysgraphia or handwriting problems at the cut-off point.

7.3.3.3 Convergent and divergent validity

Convergent and divergent validity were established for the Handwriting Screening Assessment. The reference assessments, the DASH 17+ and DEM, were completed with the 61 students referred for handwriting assessment only and therefore these results were based on this small sample.

Based on the observations made on the Observation Checklist and Writing Checklist it was hypothesised that these scores would be divergent to the DASH 17+ these components are not assessed on the DASH 17+ and no deficits on these checklists were related to handwriting speed, legibility and automaticity except visual function in the current study.

It was hypothesised that the Handwriting Outcomes**:**

- ARQ cut off points for copying speed and automaticity subtest would have positive correlation with the DASH 17+ percentile scores.
- Subtest 1: *Copying speed* would have positive correlation with the DASH 17+ speed scores as these both assessed the performance skill of paces.
- Subtest 3*: WSAM alphabet score* would have positive convergence with the DEM vertical scores as both assess automaticity.

It was also hypothesised that the scores for **Observation Checklist:**

- Subtest 6: *visual function* and the **Writing Checklist** Subtest 5: *missing letters and word scores* would have a positive correlation with the DEM time scores as it was assumed that these subtests assessed similar constructs to the DEM.

All other scores were hypothesised as being divergent

Scores for the Detailed Assessment of Handwriting Speed 17+ and The Developmental Eye Movement Test

The difference between the mean and median scores for the students referred for handwriting assessment for the percentile scores on the DASH 17+ and the time scores and percentiles on the DEM [Powell et al., 2006] indicate that for this small sample the data were not normally distributed (Table 7.21).

Table 7.21 Percentile scores for the Detailed Assessment of Handwriting Speed 17+ and time scores for the Developmental Eye Movement Tests of students referred for handwriting assessment (n=61)

Percentiles	Mean scores	SD	Median scores	Lower and upper quartile
DASH 17+	38.35	35.66	26.00	9.70 -67.20
Time scores – seconds (percentiles)				
DEM Vertical time scores seconds	41.82 (<1)	18.65	36.00 (10)	30.50 -45.00
DEM Horizontal time scores seconds	51.54 (<1)	21.37	43.00 (<1)	38.00-58.00
DEM Ratio scores	7.80 (>1)	24.89	1.25 (10)	1.10-1.42

Correlations between Hand Writing Screening Assessment, Detailed Assessment of Handwriting Speed 17+ and the Developmental Eye Movement Tests

The DASH 17+ percentiles and DEM time scores were correlated with the ARQs on all three sections of the Handwriting Screening Assessment. A low correlation was found for the DASH 17+ and the Observation Checklist and the Writing Checklist but a moderate positive correlation with the Handwriting Outcomes copying speed and automaticity but not legibility

The Observation Checklist, Writing Checklist and Handwriting Outcomes ARQs were found to have weak correlation to the DEM. This indicates divergence with these sections of the Handwriting Screening Assessment and these assessments (Table 7.22).

The z scores for subtests in these checklists Observation Checklist Subtest 6: visual function and the Writing Checklist Subtest 5: *missing letters and word scores* that were assumed to assess visual constructs also had weak correlations indicate these subtests may be related to attention and not visual function. Convergence was found with positive moderate correlations between the ARQs for Handwriting Outcomes, specifically Subtest 1: copying speed and the DASH 17+ percentile scores. The variance accounted in the ARQs for Handwriting Outcomes by the DASH 17+ percentile scores was 30% as indicated by the coefficient of determination (r^2).

Table 7.22 Convergent and Divergent validity of Hand Writing Screening Assessment, Detailed Assessment of Handwriting Speed 17+ and the Developmental Eye Movement Tests of students referred for handwriting assessment (n=61)

	DASH 17+ percentile	**DEM Vertical time score**	**DEM Horizontal time score**
At risk quotients	**rho**	**rho**	**rho**
Observation Checklist	-0.27	-0.08	-0.10
Writing Checklist	0.27	-0.02	0.06
Handwriting Outcomes: Copying Speed and automaticity	**0.46***	0.00	0.00
Handwriting Outcomes legibility	0.19	-0.18	-0.15
Handwriting Outcomes			
z Scores			
Subtest 1:Copying Speed	**0.55***	**-0.45***	-0.36*
Subtest2: Legibility	0.04	-0.14	-0.14
Subtest 3:WSAM Alphabet task	**1.00**	**-0.40***	-0.28
Subtests of Observation Checklist and Writing Checklist			
Observation Checklist Subtest 6 *Visual function*	0.01	-0.11	-0.06
Writing Checklist Subtest 5 *Missing letters and words*	0.14	0.01	0.09

*Significance – $p \leq 0.05$

Scores for Handwriting Outcomes Subtest 1: *copying speed* also had a negative moderate correlation with the vertical time scores of the DEM as did the WSAM Alphabet task. This indicates some association between slow vertical saccades and writing speed and automaticity. The coefficient of determination (r^2) indicated that the variance accounted in the speed of copying an alphabet task by the vertical DEM scores was 20% and 16% respectively.

7.3.3.4 Difference in scores for the Detailed Assessment of Handwriting Speed 17+ and the Developmental Eye Movement test according to level of risk on the Handwriting Screening Assessment

The association of copying speed and automaticity and visual function demonstrated by the correlation coefficients and the validity of the Handwriting Screening Assessment were further evaluated. The differences on the median DASH 17+ percentile scores and the DEM time scores in relation to the specific level of risk for handwriting deficits in the students referred for handwriting assessment were analysed.

Detailed Assessment of Handwriting Speed 17+

The percentile scores on the DASH 17+ indicated a significant difference (Chi-Square=15.66, df=3, p=0.01) among the four groups of students who scored at no risk, at risk and at high and very high risk on the Handwriting Screening Assessment (Figure 715).

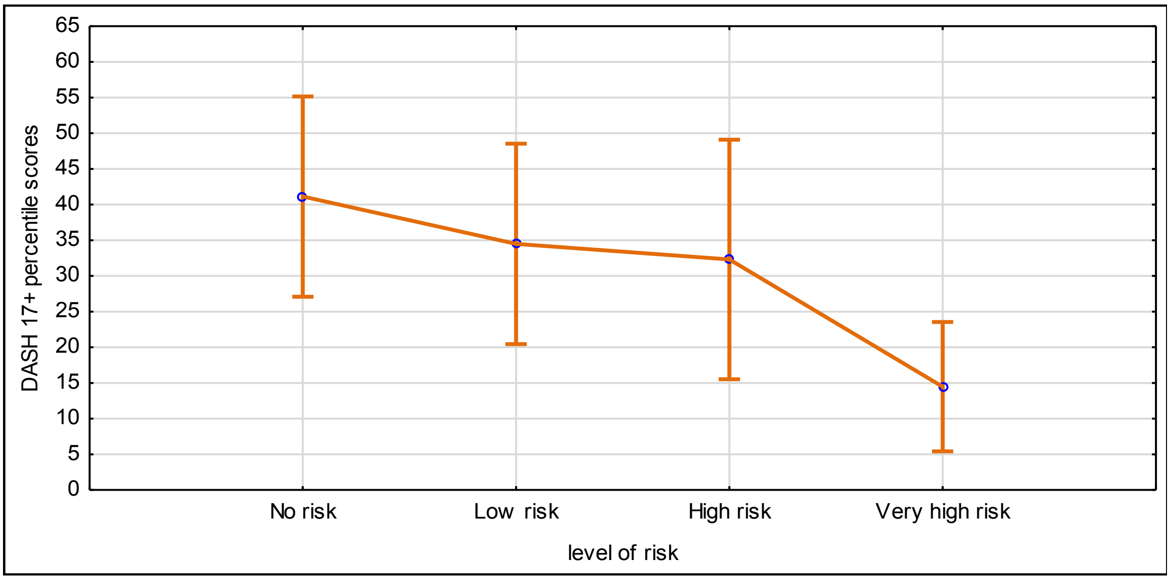


Figure 715 Comparison of students at various levels of risk for handwriting deficits and Detailed Analysis of Handwriting Speed 17+ percentile scores (n=61).

Thus, the scores on the DEM were congruent with the Handwriting Screening Assessment with students at very high risk scoring at just below the 15^{th} percentile on the DASH 17+ and the students at no risk scoring at the 40^{th} percentile.

The Developmental Eye Movement Test

The percentile scores based on the findings of Powell (2006) were compared for the students with no risk and those with various levels of risk for dysgraphia and handwriting problems [Powell et al., 2006]. Figure 7.16 indicated that there was no significant difference between the student groups based on risk for vertical DEM scores (Chi-Square=5.00, df=3, p=0 28). The students at no risk of handwriting deficits presented with the lowest vertical scores the DEM.

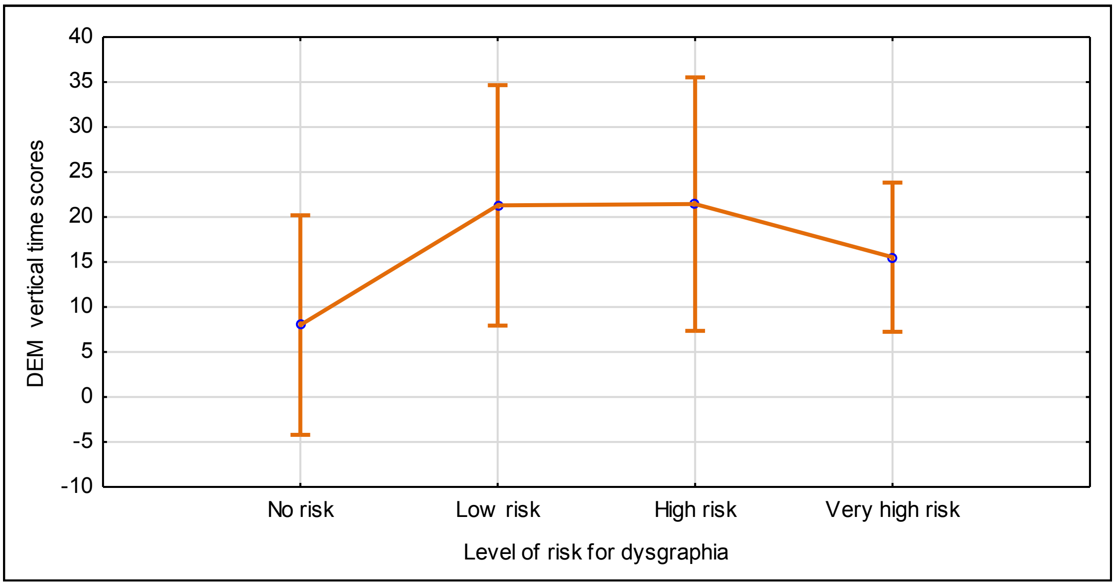


Figure 7.16 Comparison of students at various levels of risk for handwriting deficits and the Developmental Eye Movement Test vertical time scores (n=61).

A similar result was found for the horizontal time scores indicating slightly lower non-significant differences (Chi-Square=4.83, df=3, p=0. 30) for students with no risk of handwriting deficits (Figure 7.17).

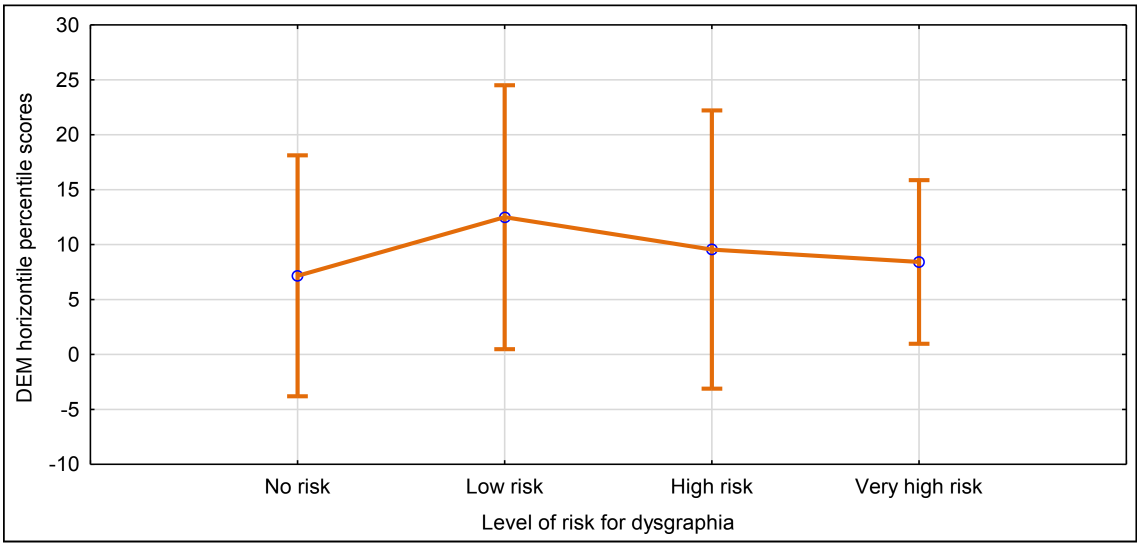


Figure 7.17 Comparison of students at various levels of risk for handwriting deficits and Developmental Eye Movement Test horizontal time scores (n=61).

Figure 7.16 and 7.17 also indicate that students had slightly lower horizontal percentile scores compared to their vertical time scores indicating possible oculomotor dysfunction (Type II Behaviour).

In summary, the three sections of the Handwriting Screening Assessment are valid when ARQs are used to identify students at risk for dysgraphia and handwriting problems except for the legibility subtest. This was confirmed by the highly significant differences between the typical students and those referred for handwriting assessment on the ARQs for the three sections of the Handwriting Screening Assessment as well as the clinical difference shown by large effect sizes. The null hypothesis that there is no difference between the typical students and students referred for handwriting assessment when using ARQs was rejected except for legibility.

The sensitivity and specificity of the three sections of the Handwriting Screening Assessment at the level of the cut-off scores as well as the predictive values indicate the assessment is capable of identifying those without dysgraphia or handwriting problems except for the legibility subtest. The sensitivity and positive predictive values do indicate that some students with problems may not be identified by this assessment although the AUC for each section of the

Handwriting Screening Assessment indicated they had adequate to fair discrimination ability.

The convergence and divergence of the Handwriting Screening Assessment to standardised tests, that measured speed of handwriting and automaticity and oculomotor function, was hypothesised based on the presence of the performance skills of Paces and Flows. The hypotheses proposed for the convergent validity between the Handwriting Outcomes copying speed and automaticity ARQs as well as the score for Subtest 1: *copying speed* and the DASH 17+ were accepted. The DASH 17+ score was also found to differ significantly according to the level of risk for dysgraphia which confirms the correlations found and provides congruence between the copying speed component assessed by the DASH 17+ and the risk scores on the Handwriting Screening Assessment.

The Handwriting Outcomes Subtest 1: *copying speed and automaticity* was convergence with the DEM vertical scores for automaticity. This indicates an association between both components for the performance skill Flows and indicates that automaticity rather than oculomotor function may affect copying speed.

The hypothesis that the scores for Observation Checklist: Subtest 6: *visual function* and the Writing Checklist Subtest 5: *missing letters and words* scores would have a positive correlation with the vertical and horizontal DEM time scores was rejected as it appears that these subtests do not assess visual function related to automaticity and oculomotor function. The difference between the DEM scores for students referred for handwriting assessment at different levels of risk on the ARQs showed no significant difference and confirms the divergence of visual function and risk for dysgraphia.

The ARQs for the Observation Checklist and the Writing Checklist did not correlate with the DASH 17+ or with the DEM scores. Therefore, the hypotheses that these subtests were divergent were accepted. This confirms checklists are assessing constructs related to handwriting that are not assessed by these standardised assessments. This also indicates that the components assessed on the Observation Checklist and the Writing Checklist cannot be directly associated with the Handwriting Outcomes. For individual students deficits identified on the checklists may affect any one of the outcomes of handwriting.

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CHAPTER 8
DISCUSSION PHASE 2

8.1 Introduction

Phase 2 of the study was used to evaluate the psychometric properties of the Handwriting Screening Assessment and to establish the ability of the assessment to identify students at risk for handwriting deficits. This phase of the study considered the technical adequacy of the Handwriting Screening Assessment based on the criteria for evaluating screening assessments provided by Glover and Albers in 2007 [Glover and Albers, 2007]. The chapter conformed that the Handwriting Screening Assessment has adequate validity and reliability.

This chapter includes a discussion of the adequacy of the sample and the demographics of typical students and those referred for handwriting assessments. The construct validity and the reliability of the Handwriting Screening Assessment as well as the clinical accuracy of each section of the screening assessment were determined. The proportion of students identified with different levels of risk and the convergent and divergent validity of the Handwriting Screening Assessment is also discussed.

In answer to the research question can a valid and reliable assessment of handwriting which can differentiate between Wits students with and without handwriting deficits be developed it was found that the construct validity of the Handwriting Screening Assessment was satisfactory although certain aspects could be improved. The item validity of the subtests was acceptable as was the reliability of the Handwriting Screening Assessment. The clinical accuracy studies and the differences between the typical students and the students referred for handwriting assessment indicated that the three Handwriting Screening Assessment sections, with the exception of the legibility subtest, did discriminate between these two groups of students. Not all items and subtests on the Handwriting Screening Assessment provided evidence of adequate differences between the two groups of students however. Analysis of the items for each section was completed in Phase 3 to determine if these items contributed to the usability of the assessment to make the final determination in terms of which subtests should be retained in the final version of the Handwriting Screening Assessment.

The negative predictive values were between 84% and 87% indicating some students without handwriting deficits may be identified with problems which confirm the need for further assessments. More concerning was the low sensitivity which indicated students with deficits may be missed. Therefore, as with all new assessments certain aspects require re-evaluation, including the sensitivity of the scales used in the checklists as well as the clarity of some of the descriptors.

The Handwriting Outcomes Subtest 1: *copying speed and automaticity* were convergent with the DASH 17+ and the vertical scores on the DEM 2.0. This indicates the assessment of other components on the Handwriting Screening assessment provide information relate to handwriting deficits which are not associated with the speed of handwriting. Differences between typical students and the students referred for handwriting assessment indicate these are important in determining the risk for dysgraphia and handwriting problems

8.2 Participants

While the sample of 298 typical students was adequate for the analyses used, the sample of 61 students requesting assessment for handwriting concessions over a two year period was small but represented 80% of students referred over that period. These 61 students represent 0.24% of undergraduate students at Wits, which is a small percentage of students with disabilities attending the university. Although there are no reliable figures available for the number of disabled students attending South African universities, the number seems to be in line with the figure of less than 1% of students utilising disability service at universities reported by Foundation of Tertiary Institutions of the Northern Metropolis (FOTIM) in 2011 [Healey et al., 2011]. This indicates that a very small number of students with dysgraphia appear to be accessing higher education at Wits which may be related to the lack of support and concessions at school level, particularly at public schools. Significantly more students applying for concessions had attended private schools.

The age range, year of study and the number of years repeated were significantly different for the students referred for handwriting assessment when compared to the typical students. The higher percentage of first year students applying for concessions relative to the number of typical students was related for the most part to students from private schools that had already had assessments and support and were aware of their need for concessions when starting at university.

The increase in the percentage of students applying for concessions in the fourth year of study may have been due to students who had not been identified at school with dysgraphia or a handwriting problem. Most of these students reported that they had managed to pass in first and second year but could not accommodate to workload in third or fourth year. They reported that they were unaware of the availability of extra time and other concessions both at school and university. They had often attended either previously advantaged or previously disadvantaged public schools where there appeared to be less support and knowledge of concessions for examinations (Table 7.2). Although clear documentation on concessions is available from Provincial Education Departments [Gauteng Department of Education, 2012] concessions are not provided at these schools due to an apparent lack of access to suitable professionals to complete the assessments required to apply for the concessions. The 5% of students from previously disadvantaged public schools who had had extra time concessions came from schools for learners with special education needs (LSEN) where disabilities of various types are accommodated and professionals are employed by the schools to complete assessments required for concessions.

The decline in student numbers from first to fourth year in the current study is representative of the failure and dropout rates of 46% seen at South African universities [Cloete, 2014]. The small number of students in fourth year is also due to a large number of three year undergraduate degrees in a number of faculties. The number of typical students who had repeated courses was under 20%, while only 2% had repeated three years which is similar to figures reported by the Council for Higher Education in 2010 [Council on Higher Education, 2010].

It was noted during the history taking that students were also reluctant to apply for concessions which they felt may be associated with poor academic ability by lecturers and other students. This meant they struggled academically without appropriate help early in their university careers. This was confirmed by the significantly higher number of years the student referred for handwriting assessment repeated when compared with typical students (Figure 7.2). These factors indicate an area in the higher education system where students may well be compromised in the support they receive in their academic careers, which effect their chance of succeeding, if unrecognised handwriting problems exist.

The gender distribution of the typical students and those referred for handwriting assessment were significantly different (Table 7.1). There were more female students in the typical student group which was representative of the higher percentage of female students enrolled at Wits in 2014, although the number of females in the current study was still higher than the 55% reported by the university [University of the Witwatersrand, 2015a]. The higher number of male students referred for handwritingassessment was in line with the higher incidence of SLD in males where the incidence is reported to be 2:1.3 (male to female) or 60% for males [Cortiella and Horowitz, 2014].

The age of the typical students was in keeping with undergraduate students completing three and four year degrees. The Wits annual report indicated a higher percentage of students over the age of 20 years (44%) but included postgraduate students in this figure. The higher percentage of younger students, under the age of 20 years assessed in the current study was due to the high number of 1st year students (Figure 7.1).

The applications from the students in an accounting, for concessions also accounted for the high percentage of students from the Faculty of Commerce, Law and Management relative to the percentage of students registered in this faculty (Table 7.3). This may have been due to the four and five hour examinations written in the accounting programme at the time of the study which compromised students with dysgraphia and handwriting deficits. The percentages of students from other faculties reflect the percentage of students registered in the faculties except for Engineering and the Built Environment. The examinations in this faculty do not include long essay type questions for the most part and students with handwriting problems appear to manage the type of examinations presented more easily.

8.2.1 Handwriting and concessions

Most of the students applying for concessions did so, on the advice of a lecturer or staff from student support office because of problems of not completing examinations. Some had discussed the problem with other students, after they had failed tests or were repeating a year. This could be due to students appearing to be unaware of the problems, which may affect their ability to write examinations. Students in both groups were unable to judge the quality of their handwriting and often did not realise what discomfort and pain they experienced and how quickly this started after they began writing. They appeared to become aware of this during the writing exercise when being assessed and when they were asked about the pain in their hand. The site of pain the forearm, thenar eminence and the thumb which occurred after a short period of writing in the current study was similar to that reported by Summers and Catarro (2003) in [Summers and Catarro, 2003]. A number of students in this study also reported pain in the hypothenar eminence which appeared to be related to the pressure with which they their hand down onto the paper while writing.

There was a difference between the 74% of students who reported pain and discomfort in the study by Summers and Catarro (2003), and the 50% of typical students who reported similar symptoms when writing long examinations in the current study. The reported high levels of pain which occurred in 5.4% of typical students in the first few minutes of starting to write, was also low compared to 33% in the study by Summers and Catarro (2003). It is not clear why South African students should present with less pain in their hands when writing examinations when compared to students in Australia, but these results indicate that the presence of pain and discomfort when writing long examinations is not unusual and in itself cannot be considered as a reason for concessions to be provided.

A significant difference was found between the level of reported pain and discomfort in the typical students and those referred for handwriting assessment (Table 7.4). Thus pain is an important factor to consider when assessing students at risk for dysgraphia and handwriting problems since the higher incident of pain occurring in students referred for handwriting assessment appeared to be associated with various aspects of dysgraphia and handwriting deficits. These students reported the presence of pain and discomfort within a few minutes of starting to write which interrupted the automaticity of their writing as they needed to rest their hands from time to time during examinations due to the pain. This was highly frustrating for them, when they knew they would not finish the examination in the allotted time. This is supported by Smeulders et al. (2001) in their study on individuals with chronic wrist pain who adapt by using rest so they can continue to write although this may affect the fluency of movement and speed of writing [Smeulders et al., 2001]. It was noted that some students also changed their pen grasp or repositioned the pen in their hand so that they could continue to write when they experienced pain during the handwriting assessment.

In the present version of the **Observation Checklist** items on various subtests have been associated with the behaviours that indicate pain. It is clear that pain should be considered separately in students presenting with handwriting problems as discussed below.

8.3 Psychometric analysis of the Handwriting Screening Assessment

8.3.1 Part 1: Construct validity and the reliability of the Observation Checklist, Writing Checklist and Handwriting Outcomes

The first objective for this phase was to determine the construct validity of the Handwriting Screening Assessment by establishing and confirming the dimensionality of the assessment and the local dependency of the subtests of the Observation Checklist, the Writing Checklist and the Handwriting Outcome for typical students and those referred for handwriting assessment.

In order to determine construct validity and the ability of the assessment to measure the constructs of handwriting associated with the writer, presentations of handwriting and handwriting outcomes various analyses was completed.

Confirming the subtest validity and dimensionality of the Observation Checklist, the Writing Checklist was achieved using Rasch subtest analysis. The Rasch analysis in Phase 2 resulted in findings similar to those in Phase 1. No significant difference was found for any subtests in Phase 2 indicating all subtests did fit the model including Subtest 4: *Preferred hand* on the Observation Checklist and Subtest 3: *Punctuation* on the Writing Checklist.

The low correlations between the subtests indicated no local dependency so scores on one subtest did not affect scores on the other subtests. Thus, no subtests were changed or discarded. The unidimensional nature of Observation Checklist and the Writing Checklist subtests was confirmed with equating t-test analysis. The relationship based on correlations between the subtests of the Observation Checklist and the Writing Checklist and the Handwriting Outcomes were also used to confirm the local dependency of the subtests. The results did indicate that all three Handwriting Outcomes subtests did correlate moderately with the Observation Checklist Subtest 6: *visual function* (Table 7.12). This finding was supported by Cheng-Lai et al. (2013) who showed a strong relationship between automaticity and oculomotor function as well as handwriting speed and automaticity in children with SLD [Cheng-Lai et al., 2013]. However, in this study the coefficient of determination indicated that only between 20% to 28% of the explained variance for handwriting outcomes in terms of copying speed and handwriting automaticity on the WSAM alphabet task were due to visual function measured on the Observation Checklist for university students. These correlations were not confirmed by the studies using the ARQs or the convergent validity with the DEM 2.0 however.

Therefore, it is possible that the client factors were being assessed by the Observation: Checklist Subtest 6: *visual function* need to be considered when copying. These may include visual attention which includes components of fixation, attention and memory as well as eye movements rather than eye movements related to automaticity and oculomotor function, alone [Bosse et al., 2014]. This was discussed under convergent validity.

The moderate correlation between Handwriting Outcomes Subtest 2: *legibility* and visual function has not directly been supported in the literature and is also not easily explained. Writing does depend on visual function, co-ordination of eye movements as well as eye and hand movements to transfer input from visual information to output in the form of fine motor movements [Lerner and Johns, 2014]. The production of aligned letters within the lines although usually associated with motor function, may be dependent on to some extent on visual functioning [Benbow, 2006]. Thus legibility may possibly be affected by problems with visual function but this aspect would need further investigation, particularly the role of visual motor integration in students in higher education which was not considered in the current study

The Handwriting Outcomes Subtest 2: *legibility* did correlate moderately with Writing Checklist Subtest 1: *quality of writing as* expected as these subtests do consider the performance skills of Flows and Organises. The moderate correlation of the legibility subtest to the Writing Checklist Subtest 2*: endurance and fatigue* may also be accounted for by the performance skill of Flows. This supports the findings of Kushki et al.(2011) in children whose legibility decreased as they fatigued. The same study and as well as that by Summers and Catarro (2003), supported the lack of correlation between legibility and copying speed which as confirmed in the current study [Kushki et al., 2011; Summers and Catarro, 2003].

The moderate correlations of between the WSAM Alphabet task the other two subtests of the Handwriting Outcomes indicate that this subtest for automaticity did assesses components that were similar to copying speed such as Paces where the coefficient of determination indicated was 46%. Components that were similar to legibility such as the performance skill Flows were also assessed by the WSAM alphabet task to a lesser extend (Table 7.12) as the coefficient of determination was 22%. Thus, more variance was accounted for in the WSAM alphabet task for automaticity by copying speed than legibility as indicated by the factor analysis. This supports the findings of Barnett et al. (2011) indicating the WSAM Alphabet task is a valid measure for handwriting ability in population. These results indicated that all the subtests in Handwriting Outcomes assessed the factors not accounted for by the other subtests.

Studies on differences

According to guidelines set by the AERA for screening instrument development differences between those with and without deficits for known group factors are also used to provide evidence of the construct validity of screening assessments [American Educational Research Association, 2014; Glover and Albers, 2007].

Differentiation studies in the Rasch analysis on the person-item distribution indicated clustering on the person threshold location and a low PSI for both checklists. The low PSI was attributed to insufficient items or insufficient options in items resulting in a lack of discrimination between students in adequately determining different levels of ability. This meant the students could only be divided into two groups in terms of ability and this was acceptable for a screening assessment where one cut-off point could identify those needing further assessment. This did not however provide the type of cut-off needed to determine the different concessions that should be provided for handwriting deficits in these students. This finding was reflected in the lack of sensitivity found for the ARQs for the checklists where small scales were used to score items and indicates that the inclusion of a four or five point scoring scale should be investigated.

Differences in known group factors

Further analysis for differences in the known factors (gender, age and school) to determine that the test did not advantage some students also indicate that some disparities. No difference for age, gender and school attended was found on the DIF analysis in the Rasch analysis, except for Subtest 6: Visual function on the Observation Checklist.

This subtest had uniform DIF for gender which suggested females were disadvantaged by this subtest (Figure 7.9). No other research evidence to support these findings was found. These findings and this difference may be accommodated in the scoring on the assessment when other research has been done to understand if this is necessary. By accommodating the uniform DIF it is likely that the non-uniform DIF related to age will be resolved and therefore does need to be addressed for age (Figure 7.10). The finding may be due to a specific item on Subtest 6: *visual function.* However, where turning the head to look at what was being copied was scored as: - *not noticeable* or *looking at every one to* *two words* when copying. These two observations were difficult to distinguish, as the first observation was not clearly defined. This particular subtest also had interrater reliability which was below 0.7 (Table 7.15) indicating the descriptors for the item are problematic and need to be clarified and reformatted.

Significant differences were found when the interval scales for Handwriting Outcomes were compared based on gender and type of school attended for all three aspects (Table 7.2). Female typical students had higher scores for Handwriting Outcomes Subtest 1: copying speed, Subtest 2: legibility and automaticity on Subtest 3: WSAM Alphabet task. This is similar to findings reported by Ziviani and Watson-Will (1998) and van Drempt et al. (2011) but as suggested by Mergl et al. (1999) this factor has not been incorperated into the assessment of handwriting [Mergl et al., 1999; van Drempt et al., 2011; Ziviani and Watson-Will, 1998].

Typical students who attended private schools also had the best scores for legibility and automaticity on the WSAM Alphabet task, while those who attended previously advantaged schools had the highest copying speed. The relatively lower scores for all three aspects of Handwriting Outcomes for those attended previously disadvantaged schools is of concern but is not necessarily related to dysgraphia but may be as a result of some environmental, cultural, or economic disadvantage. While it is important to understand the implications that schooling systems in South Africa may have on students' ability in handwriting, this factor was not incorporated into the final scoring on the Handwriting Screening Assessment as the mean scores for all groups fell into a normal or average range for speed, legibility and automaticity for this sample of students and did not put them at risk for handwriting problems.

Based on the definition dysgraphia and handwriting deficits should not be confused with lack of educational opportunities [LD OnLine, 2016]. Therapists using the assessment should be made aware of these results so they can make informed recommendations for further assessment and be aware of the possible effects of other barriers to learning experienced by students previously. These may need to be addressed by assisting the student in achieving skill and not providing concessions.

When Handwriting Outcomes were considered for age, no significant differences were found between the three age groups identified for the current study. The younger students had higher scores for speed, legibility and automaticity on the WSAM Alphabet task (Figure 7.12 and Table 7.11). This is contrary to the findings on the DASH 17+ developed in 2010, where they found that speed of copying and writing increased with age [Barnett et al., 2010]. When the same paragraph copied in the current study was used in unpublished research in 2000 it was found to be in agreement with Barnett et al. (2010), as typical students who were over 20 years wrote faster and all students completed the passage at an average speed of four minutes as opposed to the average speed of five minutes found in 2013. The change found in the students' speed of handwriting can be equated to the Flynn effect, which indicates that assessments need to be adjusted with time as the ability of typical individuals may increase or decrease due to the effect of biological and environmental circumstances [Hiscock, 2007].

It appears that students are copying more slowly than in the past and that the decrease of speed with age found in the current study may be due to the decreased use of writing seen in university students due to the increasing use of technology. Most students report using technology, even if they do not own computers or tablets as these are available on campus. The expectation is also that assignments be typed and many students only write when they are in examinations, as laptops, tablets and phones are frequently used for note taking and presentations. The increased use of technology at university also supports the slower writing speed of older students. Younger students may well have better writing speed and endurance as handwriting is still practiced in many school classrooms in South Africa. The decrease in legibility, which decreased with age in students in the current study may be related both to a decrease in writing endurance due to a lack of practice and the expectation of longer written answers in examinations in later years of study [Kushki et al., 2011; Peverly, 2006].

The differences between typical students and student referred for handwriting assessment

The differences between typical students and those referred for handwriting assessment on all three sections of the Handwriting Screening Assessment. The

Observation Checklist, the Writing Checklist and Handwriting Outcomes were considered. Some of the subtests which did have significant differences between the two groups of students, these results could not be compared to other studies as similar findings for these components other than handwriting outcomes were not available. The literature review indicated while some studies considered differences in students in higher education for some of the items in the subtests none of them were comparable to the subtests per se except for Writing Outcomes Subtest 4: *Corrections and spelling.* Tops et al. (2013) had shown significant differences between students with and without dyslexia when summarising a passage for these components [Tops et al., 2013]. Significant differences were also shown for students with and without dysgraphia on the components assessed in the Handwriting Outcomes Subtest 1: *copying speed* and Subtest 3: *WSAM Alphabet task* by Barnett et al. (2010) in the development of the DASH 17+ [Barnett et al., 2010]. These findings are supported by Rosenbaum (2005) who found that the WSAM Alphabet task differentiated between children with and without handwriting deficits particularly in terms of speed [Rosenblum, 2005].

Even though some subtests did not show a significant difference between the typical students and those referred for handwriting assessment they were retained at this stage (Table 7.12). However, some items in all the subtests on the three sections of the Handwriting screening Assessment did show significant differences between the groups and deficits were still seen more frequently in students referred for assessment than in typical students indicating the importance of identifying the students who scored poorly on these subtests. This approach was supported by the lack of significant difference in the Writing Checklist for Subtest 4: *punctuation* where incorrect punctuation combined with the incorrect use of capital letters was found for 30% of students referred for handwriting assessment compared to 10% of typical students. Since both these items assess allographic mechanisms, in which problems are commonly seen in dysgraphia [Mohanty, 2015] it was felt that it was important to assess students on this subtest so the students with low scores and deficits could be referred for further assessment for dyslexia and this was addressed in Phase 3 of the current study. The same argument applies to subtests related to corrections and missing words and lines of text as well as legibility assessed on Handwriting Outcomes which scored below 5, as these deficits also occurred more frequently in students referred for assessments.

It was apparent for the Observation Checklist that Subtest 4: *pen grasp* as assessed in the current study did not appear to affect handwriting and that stability of the grasp and movement in the hand were more important in relation to deficits in handwriting. The pen grasp component was retained at this stage due to the possible relationship between pen grasp and pain. The items for slant of the pen and number of fingers on the pen did differ significantly between the group groups of students so these items need to be re-evaluated. A closed web space is usually associated with the pen pointing away from the student and using two rather than one finger to support the pen need to be reviewed in relation to stability of grasp.

A similar approach was taken for preferred hand and wrist position as it was noted that students referred for handwriting assessments that reported pain, often wrote with an increased angle of extension [Chang et al., 2015] and this was addressed in Phase 3 of the current study. Screening assessments need to have adequate reliability as well as validity. The reliability provides indicators of the consistency of the items in assessing the students' performance for each subtest and section of the **Handwriting Screening Assessment** as well as the effect of different raters administering and scoring the assessment [Hallgren, 2012].

Reliability of the Handwriting Screening Assessment

Reliability in the form of internal consistency was used for each subtest of the Handwriting Screening Assessment separately as each subtest had been shown to be independent and assess a different component of handwriting. The Cronbach's alpha score however, did not reach the accepted level for three subtests of the Observation Checklist although it was acceptable above 0.7 for all aspects of the Writing Checklist and Handwriting Outcomes (Table 7.14). No subtests reached an alpha score above 0.9 which would have indicated that there were possibly redundant items in those subtests [Tavakol and Dennick, 2011].

A low value for internal consistency for the subtests of the **Observation Checklist** indicates a lack of uniformity which may be related to an insufficient number of items in a subtest or poor interrelatedness amongst items [Tavakol and Dennick, 2011]. Since these subtests did not have the lowest number of items it was assumed that there was a problem with the interrelatedness of the items which could affect the accuracy of the **Handwriting Screening Assessment**.

Observation Checklist**:** Subtest 2 *posture* for item 8: *the student is flexed to within 20cms of the table* and item 9: *student remains still or moves.* Ambiguity in terms of the client factors which were related to the observation on these items. While item 8 was included in the subtest as students with poor postural control appear to use excessive flexion to within 20cms of the table, to stabilise their trunk when writing [Amundson, 1992; de Almeida et al., 2013] it was noted that students with deficits in visual function adopted the same posture. When assessing item 9: *student remains still or moves,* although most students moved while writing due to poor postural control [de Almeida et al., 2013], those with constant pain also moved. It is clear that certain behaviours may need to be assessed in different subtests and a subtest for pain behaviour would add value to the assessment. This is discussed in Phase 3 of the current study, in relation to the descriptors for these items.

Another possible factor affecting internal consistency in the Observation Checklist: Subtest 3 *stability of grasp* was found for Items 11, 12 and 13 which consider finger joints. The position of individual index finger and thumb joints assessed in these items differed greatly amongst students as some students apply force on the pen using their index finger while others use the IP joint of the thumb and some use both. These individual differences are difficult to accommodate for and these items may need to be collapsed into one item indicating the force used in the fingers and thumb. These items did differentiate between the typical students and those referred for handwriting assessment and wee further evaluated in Phase 3 of the current study (Appendix W).

Since the Handwriting Screening Assessment was designed to screen university students requesting concessions for examinations it was important that it can be administered by different therapists in contexts where these students are studying. Thus, it is important that the assessment had adequate interrater reliability. Interrater reliability was assessed with raters who were trained on the assessment and had guidelines explaining each item as well as how to assess the writing (Appendix Q).

Some subtests of the Observation Checklist which had lower scores were based on the observation of performance skills while the students were writing. Scoring, therefore, depended on paying attention to detail and understanding the constructs being observed and evaluated, which required training on the Handwriting Screening Assessment,

Poor interrater reliability was found for the Observation Checklist Subtest 6: *Visual function* and the problems related to the item on head movement have been discussed above. The raters found it difficult to differentiate between -not noticeable and -looks every one to two words. The other subtest on the Writing Checklist Subtest 3: *Punctuation* had low inter-rater reliability. This was due to the raters not observing the written test carefully for punctuation and comparing it to the original paragraph and missing some capital letter errors, especially when the writing was illegible. This applied to number of items which were also problematic in the interrater reliability study, particularly those that require carefully scrutiny of the writing in terms of, spelling and deterioration of writing (Table 7.15).

This problem can be overcome with further training but the low score for legibility and the number of unreadable words may remain a problem. The Handwriting Outcomes Subtest 2: *legibility* presented a number of problems in the current study. The identification of which words were unreadable was subjective and in some cases little agreement was found. This is affected by the fact that the raters knew what the words were supposed to be and it was difficult to visualise each word in isolation to determine the readability. This is a weakness of the Writing Checklist and this problem has been reported in other handwriting assessments for global scales although the interrater reliability reported for unreadable words was in an acceptable range [Au et al., 2012].

Assessing the legibility by determining the number of unreadable words rather than letters in the text for in adult handwriting was found to be appropriate. It is the readability of words that is important as when marking examinations. Words that are very poorly written may be read in context but this may take time and effort on the part of the reader. Graham et al. (2011) point out that it is the speed with which words can be read and comprehended that is important in assessing handwriting [Graham et al., 2011]. This is based on the presentation and the legibility of the handwriting and in the current study the presentation rather than the legibility of handwriting discriminated between the typical students and those referred for handwriting assessment whereas legibility did not. This indicated the importance of assessing the presentation of the handwriting as well legibility.

The legibility subtest was retained although there was not a difference between the typical students and those referred for handwriting assessment due to the severe legibility problems found only with students referred for handwriting assessment. This was further investigated in Phase 3 of the current study.

8.3.2 Part 2 Cut-off points and At Risk Quotients for the Handwriting Screening Assessment

The second objective of this phase the study was to determine the psychometric properties of the subtests in the three sections of the **Handwriting Screening Assessment** in identifying students at risk for handwriting deficits by firstly determining the norms for the typical students which were then used to establish ARQs and cut-off points below which handwriting can be considered deficient were established

Norms were determined for each subtest for the typical students on which the identification of ARQs could be based. It was impossible to compare the mean scores obtained for the subtests on the Observation Checklist and Writing Checklist with other studies as no norms have previously been published for the components covered in these subtests. Criteria were met in terms of the normative data as the sample was representative of the same context as the students referred for handwriting assessment and data were collected from a sufficiently large sample of typical students in a similar time frame.

Therefore, the use of this normative data in determining z scores to assess the students' performance with a cut-off at the 16^{th} percentile or -1SD below the mean (equivalent to a standard score of 85) was appropriate. This is the cut-off used by the Standards and Testing Agency, the JCQ in the United Kingdom in their guide on examination concessions.[Joint Council for Qualifications, 2015]. No cut-off level on standardised tests was available on South African websites with requirements for examination concessions for Education Departments, IEB or universities.

Based on the severity of these deficits ARQs were used to identify students as at risk, high risk or at very high risk for dysgraphia or handwriting problems (Table 7.18). The use of ARQs to identify different levels of risk in students is an appropriate method of determining the severity of the deficits and in providing recommendations for further assessment and concessions.

8.3.3 Part 3 Validity of the Handwriting Screening Assessment based on the at risk quotient scores

The third objective of this phase of the study was to determine the validity of the Handwriting Screening Assessment based on the ARQs. The difference between the typical students and those referred for assessment using ARQs was determined as well as the sensitivity, specificity and predictive values of the three sections of the Handwriting Screening Assessment**.** Convergence and divergent validity in relation to ARQs and scores on reference standardised tests were also established.

The significant difference between the typical students and those referred for assessment confirmed the validity of using this method of determining ARQs for the identification of students at risk for dysgraphia and handwriting problems. The use of ARQs was shown to be valid in discriminating between the typical students and those referred for handwriting assessment. The percentage of students referred for handwriting assessment that did not present with risk on one of the three sections of the Handwriting Screening Assessment needs to be noted. This confirmed the importance of considering scores from all three sections of the Handwriting Screening Assessment as students may have deficits in one section and may not be at risk of deficits in another.

In order to establish if the ARQs were valid in the identification of students that should and should not be referred for further assessment, the sensitivity and specificity of each of the three sections of the Handwriting Screening Assessment.

Table 7.20 indicates that at these points specificity was high and sensitivity was low except for legibility .[Marc Campo, 2010].

This meant for the Observation Checklist, Writing Checklist and Handwriting Outcomes copying speed and automaticity subtest the high specificity that 86% of students scoring below the cut-off can be considered as having a deficit and can be accepted as having problems related to handwriting and dysgraphia. This assessment like many others does have limited precision and errors which means the cut-offs points used favour specificity at the expense of sensitivity so that it can be confirmed that 86% of students scoring below the cut-off can definitely be said to have deficits This reduces the risk of identifying students without a problem having further assessments unnecessarily [Marc Campo, 2010]. However, the low sensitivity does mean some students with deficits may be missed using the Handwriting Screening Assessment and cognisance needs to be taken of this fact by those using the assessment.

Based on the specificity of 86% and the ROC curve AUC showing only the Observation Checklist, Writing Checklist and the Handwriting Outcomes copying speed and automaticity subtest have adequate to fair ability to discriminate [Portney and Watkins, 2000] students with handwriting problems. Using this criterion approximately 40% (121) of the typical students scored at risk on one or more of the three sections of the Handwriting Screening Assessment while 90% (55) of students referred for assessment were found to be at risk. The subtest scores of students meeting this criterion should reviewed and a decision made whether the students has deficits that indicated further assessment for handwriting or other possible deficits related to dyslexia or hand function. On review, it was decided that risk on one section of the Handwriting Screening Assessment, unless it is a very high risk, does not place the student at risk for dysgraphia and handwriting deficits that require further assessment and concessions. Based on this criterion 75 (17%) of typical students and 50 (82%) of students referred for assessment could have been considered for further assessment

The negative predictive value of the Handwriting Screening Assessment was at an acceptable level for all three sections and subtests. This was accepted as adequate for this screening assessment as an expected percentage of typical students were identified at risk or below the 20th percentile and over 80% of students referred for handwriting assessment were appropriately referred. It was found that other students referred for handwriting assessment did present with problems related to dyslexia and other conditions such as anxiety and they were referred for other appropriate assessments.

When students are identified with handwriting deficits it is important that other available standardised tests can be used to assess the deficits in more detail to confirm the outcomes. The students referred for handwriting assessment were assessed with reference standardised assessments, the DASH 17+ and the DEM 2.0. The median score for these students on the DASH 17+ was at the 26th percentile with 48% of students scoring at or below the 15th which indicated problems with their copying speed (Table 7.21). Since all these students were referred for handwriting problems, this finding supports the need to broaden the scope of handwriting assessment to other components such as those measured in the Handwriting Screening Assessment as not all students have deficits in speed of handwriting.

Percentile scores for the students on the DEM 2.0 horizontal and vertical times were lower with only 34.5% of students scoring above the 15th percentile. This may indicate some problems with the validity of this test with this population, although the high rate of deficits identified may just reflect that the students referred for assessment were correctly referred and that they have deficits for which compensation is needed. Ayton et al. in their study in 2009 did find that the DEM 2.0 was useful in identifying poor reading and visual processing deficits in a clinical situation [Ayton et al., 2009]. The use of the DEM 2.0 to confirm findings related to components of handwriting, especially for examinations where reading does need further investigation.

Hypotheses were generated about which components in the Handwriting Screening Assessment would be convergent and divergent with scores on these reference tests. Only moderate correlations were found between the scores with the convergence between the DASH 17_+ percentile scores and the Handwriting Outcomes ARQs and the Handwriting Outcomes Subtest 1: *copying speed and automaticity* being due to the difference in the copying tasks used. Therefore, although both tests addressed copying speed the method of assessment differed and the amount of reading required in the Handwriting Screening Assessment resulted in a slower mean copying time. These results should also be interpreted in the light of the scores for the WSAM alphabet task being identical for both tests. This convergence was confirmed by the significant different in the DASH 17+ scores related to the students' level of risk for dysgraphia (Figure 7.16) confirming the validity of Subtest 1 *Copying speed and automaticity*; in the handwriting Screening Assessment.

A divergence of the components measured in the Observation Checklist and Writing Checklist to speed of handwriting assessed by the DASH 17+ percentile scores confirmed the lack of association between components measured on the checklists and handwriting speed. This indicates that individual differences occur in students with handwriting differences and components of handwriting cannot be linked to specific outcomes. Lack of stability of grasp may affect legibility of one student's handwriting while it results in slow handwriting for another student. The relationship between these factors needs to be assessed for each student to justify the awarding of concessions.

A moderate negative correlation was found between the Writing Outcomes Subtest 1: *Copying speed and automaticity* and the vertical scores on the DEM as hypothesised (Table 7.22). This finding supports the correlation reported on in part 1 of this phase of the study. The students reading speed may be affected by motor control of the extraocular muscles and saccadic efficiency which will affect the speed at which they copy accurately[Cheng-Lai et al., 2013; Lam et al., 2011]. Therefore, it would appear that automaticity or RAN, rather than the horizontal scores which assess oculomotor dysfunction), show convergence with the Handwriting Screening Assessment. The RAN measured by the vertical scores has also been associated with phonological and orthographic coding in spelling which may further account for the convergence seen.

Although divergence between the Observation Checklist and the Writing Checklist and the DEM 2.0 scores was expected it was hypothesized that the Observation Checklist Subtest 6: *visual function* and Writing Checklist Subtest 5: *missing letters and words* would show convergence with the DEM 2.0 vertical scores and specifically with the horizontal scores as these items assessed components that could be associated with the symptomatology of oculomotor dysfunction [Tassinari and DeLand, 2005]. No convergence was found for any of these scores for this sample of students and thus this hypothesis was rejected.

This result indicates that the Observation Checklist Subtest 6: *visual function* and Writing Checklist Subtest 5: *missing letters and words* are not an assessment of oculomotor visual function but rather visual attention related to the performance skill of Attends (Table 4.1) and visual inattention related to the performance skill Notices and Responds (Table 4.2). These results are supported by Lambert et al. (2011) who found that in adults visual attention includes the simultaneous processing, in a single fixation of the eyes, of several elements when copying text. They can continue to write a word while visually and orthographically processing the next word they need to copy [Bosse et al., 2014; Lambert et al., 2011]. This does however depend to the familiarity with the words being copied. Farrar et al. (2001) also found that the missing lines of text was more common when children with ADHD copy text and may be related to visual inattention [Farrar et al., 2001].

Further research is needed to clarify the client factors associated with these subtests and what is being assessed so students can be referred for appropriate further assessments. As mentioned previously the Observation Checklist Subtest 6: *visual function* subtest requires revision and should be re-evaluated.

Therefore, convergence was only achieved between the reference tests and the Subtest 1: *copying speed and automaticity* of the Handwriting Outcomes section of Handwriting Screening Assessment. This was not unexpected as there are no tests of handwriting that provide scores for the components of handwriting which affect the writer and the presentation of handwriting even though in the current study they have been shown to be valid measures of handwriting deficits. The findings for divergence between the reference tests and the Observation Checklist and Writing Checklist and legibility confirm the need for a multidimensional assessment as these results indicate students may have deficits in one dimension and not in others. An assessment which is inclusive of all factors which may affect handwriting such as the Handwriting Screening Assessment should be used to screen for deficits related to handwriting. .

CHAPTER 9: METHODOLOGY AND RESULTS PHASE 3:

9.1 Introduction

The final phase of the study aimed to provide data on the characteristics of deficits in handwriting components to support the interpretation of the assessment by service providers. The presence of handwriting deficits in this population as well as the presence of problems related to handwriting were determined. The association of the components of handwriting with the risk for dysgraphia were also establish to guide the need for further assessment and referral of the target population of students referred for handwriting assessment. To support the utility of the Handwriting Screening Assessment for the target population of students identified with dysgraphia and handwriting deficits the different types of dysgraphia were linked to recommendations for concessions. The possible benefit of the Handwriting Screening Assessment for students was explored in terms of the concessions for extra time they received, on their academic outcomes [Glover and Albers, 2007].

9.2 Objectives of Phase 3

Part 1: Clarification of deficits related to handwriting in students referred for assessment

- To determine if factors assessed on the history of handwriting problems questionnaire differentiated students in terms of scores on the Handwriting Screening Assessment and the risk for dysgraphia.
- To determine the frequency of deficits of components of handwriting assessed by the items and subtests in the Handwriting Screening Assessment and their association with the risk for dysgraphia to establish the clarify the need of the type of further assessment and referral to the services required.

Part 2: Utility of the Handwriting Screening Assessment for students identified with dysgraphia or handwriting deficits

- To establish the utility of the Handwriting Screening Assessment: -
    - by determining different types of dysgraphia in students with handwriting deficits to guide the recommendations of concessions.
    - by exploring the students' academic outcomes after extra time concessions were awarded.

9.3 Methodology - Usability of the Handwriting Screening Assessment for the target population

9.3.1 Part 1: Deficits related to handwriting in students referred for assessment

9.3.1.1. Research Design

A descriptive comparative cross sectional research design was used for this phase of the study. Data which were gathered in Phase 2 of the study were drawn at one point in time, from a sample of students referred for handwriting assessment that was representative of a larger population. The design was descriptive as no manipulation of variables was required and comparative as differences and correlations of the data were used [Kielhofner, 2006]. This study design was appropriate as although the factors related to handwriting problems and the subtest ARQs were analysed in terms of the identified risk for dysgraphia or handwriting problems, no causal relationship was established.

9.3.1.2 Participant Selection

This phase of the study was completed with the same 61 students referred for handwriting assessment by CHWC who were assessed using the Handwriting Screening Assessment in Phase 2 of the study. The student selection and sample size were presented in section 3.4.5.2.

9.3.1.3 Measurement Tools

History of Handwriting Problems Questionnaire

Additional data related to medical information from this questionnaire used in Phase 2 of the study was analysed (Appendix Q).

9.3.1.4 Research Procedure

Permission from the relevant authorities (Appendix C) and ethical clearance for this phase of the project was obtained (Appendix A) at the same time as Phase 2. Data for this phase of the study were collected in Phase 2. The item scores for the sections of the Handwriting Screening Assessment (Appendix R) and the ARQs for the students who were referred for assessment for handwriting problems were analysed to fulfil the first three objectives of this phase of the study (section 1.6.3.2).

9.3.1 5 Data Analysis

History of Handwriting Problems Questionnaire

The variables on the History of Handwriting Problems Questionnaire that had not been analysed in Phase 2 of the study and that were specific to handwriting problems were analysed using descriptive statistics including frequencies. Problems related to handwriting were compared for the three sections of the Handwriting Screening Assessment as well as the total risk for dysgraphia on a scale of 1 to 4 according using Chi-squared tests.

Handwriting deficits

The frequencies of each item score for the Observation Checklist and the Writing Checklist and subtests for the Handwriting Outcomes were analysed to determine the deficits commonly found in this sample of students referred for handwriting assessments. This provided the characteristics of deficits in students in higher education.

Handwriting components related to the level of risk for dysgraphia or handwriting problems

Students' scores for items and subtests on the three sections of the Handwriting Screening Assessment were correlated with the level of risk for dysgraphia based on the ARQs. Due to the small number of students and data that were not normally distributed (Lilliefors ≤0.10) [Razali and Wah, 2011] a non-parametric

Spearman's correlation coefficient was used to correlate the level of risk with all the items or subtests in the Handwriting Screening Assessment. The interpretation used for correlations are the same as those in Table 6.2.

9.3.2 Part 2: Utility of the Handwriting Screening Assessment for students with dysgraphia or handwriting deficits

9.3.2.2 Research design

A descriptive comparative research design similar to Part 1 was used to explore the utility of the Handwriting Screening Assessment by establishing if different types of dysgraphia could be used to guide the recommendations for concessions. The students' academic outcomes were accessed at two points in time to determine if they passed of failed their courses. No manipulation of variables was required and comparative differences of the data were used [Kielhofner, 2006].

9.3.2.3 Participant Selection

This phase of the study was completed on the 50 students identified as having dysgraphia or handwriting deficits from the sample of 61 students referred for handwriting assessment by CHWC.

9.3.2.4 Measurement Tools

Academic Outcomes

The academic outcome for student who received a concession was determined in the year they received a concession and the following year if they were still studying at Wits. Their pass-fail status was accessed from the Student Information Management System (SIMS) at Wits which tracks student progress while they are registered at the university.

8.3.2.5 Research Procedure

Permission from the relevant authorities (Appendix C) and ethical clearance for this phase of the study was obtained (Appendix A) at the same time as Phase 2.

The literature presents descriptors related to the ability in spelling, fine motor function and organisation of writing which can be used to determine the difference between motor, dyslexic and spatial dysgraphia. Therefore, the scores on Item 3:

organisation of letters and Item 13: *spelling* on the Writing Checklist as well as Item 25: *writing movements* on the Observation Checklist were compared to determine if students could be identified with different types of dysgraphia.

Data provided by CHWC on the extra time concessions awarded to students, based on assessments completed as a result of referral based on the risk for dysgraphia or handwriting deficits identified on the Handwriting Screening Assessment was available. This data was used in conjunction with data from SIMS on the final result for each student. Data from Sims was collected at the end of the academic year in which they were assessed and the end of the following year if they were still studying at Wits.

9.3.2.6 Data Analysis

Types of dysgraphia

Since spelling in copied text and fine motor control differentiate between the different types of dysgraphia the scores for Item 13: *Spelling* on the Writing Checklist were compared to Item 25: *Writing movements* on the Observation Checklist which reflected fine motor function. These variables were identified as differentiating between motor and dyslexic dysgraphia [Berninger, 2008; Deuel, 2001]. The differences between these groups were analysed using a Chi squared test as all groups had more than five participants[Bearden et al., 1982] and the scales although interval were not normally distributed. The scores for Writing Checklist Item 3: *organisation of letters* was used to differentiate students with spatial dysgraphia using a Chi squared test.

Academic outcome of concessions

The students' academic outcomes for the end of the year they received concessions and the following year if they were still at the university were analysed. Descriptive frequencies and Chi squared test were used to determine if there was a significant difference between the percentage of students who failed after receiving extra time concessions.

9.4 Results – Phase 3

9.4.1 Part 1: Characteristics of deficits related to handwriting in students referred for assessment

The sample for this part of the study consisted of the same 61 students referred for handwriting assessment in Phase 2. In order to guide recommendations for further assessments the characteristics of the deficits for the factors on the students' history of handwriting problems questionnaire and their scores on the items and subtests of Handwriting Screening Assessment were analysed. The Handwriting Screening Assessment for this sample was also reviewed in terms of the association of the components and items with the level of risk for dysgraphia or handwriting problems.

9.4.1.1 History of Handwriting Problems

The demographic profile of the students referred for handwriting assessment in this phase of the study was determined. In terms of factors related to problems associated with handwriting, just over a third of the students referred for handwriting assessment (34%) reported that they had previously had occupational therapy for fine motor dysfunction, visual perceptual dysfunction and handwriting problems as children. Approximately half the students (49%) brought evidence in the form of medical reports indicating that they had been diagnosed with a learning disability, mostly ADHD. Four students had been diagnosed with dyslexia (Table 9.1).

Other diagnoses reported by this sample of students were anxiety and panic attacks, back pain and one student had a complication related to a chronic cardiac problem. Just over 8% of students had acute upper limb or hand injuries. Approximately a third of the students were taking medication. Most of those who were taking medication had attention deficits and were taking methylphenidate or atomoxetine for concentration. Some students had been prescribed other medications appropriate to their diagnoses.

Table 9.1 History related to handwriting problems of students referred for handwriting assessment (n=61)

	n (Percentage)			
	Yes		No	
Previous occupational therapy as a child	21	34.4%	40	65.6%
Previously had extra time	34	55.7%%	27	44.3%
	Diagnosis		No previous diagnosis	
Diagnosed with learning disability	30	49.2%	19	31.1%
Diagnosed with other illness	7	11.5%		
Diagnosed with hand or upper limb injury	5	8.2%%		
	Taking medication		Not taking medication	
Taking medication for concentration	11	18%	42	68.8%
Taking medication for pain	3	4.9%		
Taking other medication	5	8.3%		

9.4.1.2. Other factors affecting handwriting

Students referred for handwriting assessment reported other problems which they felt interfered with their handwriting including poor visual acuity, eye strain and sore eyes. They also reported eye movement symptomatology which including having to reread sentences and missing lines of text when reading (Table 9.2).

Table 9.2 Other factors related to the history of handwriting problems in students referred for handwriting assessment (n=61)

	n (Percentage)			
	Yes		No	
Visual problems (no glasses)	13	31.3%	48	78.7%
Glasses	15	24.6%	46	75.4%
Eye movement symptomatology	48	78.7%	13	31.3%
Weakness in hand	7	11.5%	54	88.5%
Problem taking notes in class	47	77.0%	14	33.9%
Not able to finish tests and examinations	58	95%	3	5%

Weakness in the hand and difficultly keeping up when taking notes in class were also reported by the students, with 95% of them reporting problems finishing timed written tests and examinations

9.4.1.3 Difference in level of risk for dysgraphia for factors in history of handwriting problems

The risk for dysgraphia or handwriting deficits was scored from 1 for no risk to 4 for very high risk based on all four ARQs on the Handwriting Screening Assessment for the students referred for handwriting assessment.

Table 9.3 Differences for the presence and absence of factors related to the history of handwriting problems and ARQs of the three sections of the Handwriting Screening Assessment (n=61)

		Observation Checklist			**Handwriting Outcomes**		
History of handwriting problems		**At Risk Quotient**			**Copying Speed and automaticity**		
					At Risk Quotient		
		Median (lower and upper quartile range)	Chi squared (df)	p value	Median (lower and upper quartile range)	Chi squared (df)	p value
Pain in hand and arm	Yes				0.25 (0.00-0.50	3.41(1)	0.05**
	No				0,50 (0.00-1.00)		
Visual problems and eye movement symptoma-tology	Yes	0.67 (0.67 – 0.86)	4.83(1)	0.02*	0,50 (0.00-1.00)	4.78(1)	0.02**
	No	0.57 (0.26 – 0.87			1.00 (0.5-2.00)		

Significance * p≤0.05
** p≤0.01

Differences in the ARQs on three sections of the Handwriting Screening Assessment and the level of risk for dysgraphia based on these scores from 1-4 were determined based on the presence or absence of factors in the history of handwriting problems questionnaire.

Only factors which had significant differences using Chi Squared tests are reported in Table 9.3. No significant differences were found for the ARQs on the Writing Checklist and for the legibility subtest on Handwriting Outcomes. The ARQs for Subtest 1: *copying speed and automaticity* on the Handwriting

Outcomes were significantly lower for students who reported pain in the hand and arm. Similar results were found for this subtest and the ARQs on the Observation Checklist for visual problems and eye movement symptomatology.

Significant differences for factors on the history of handwriting assessment and total risk in Table 9.4 indicated a previous diagnosis of SLD and the presence of pain in the hand and arm placed students at significantly higher risk for dysgraphia of handwriting deficits.

Table 9.4 Difference in the total risk for dysgraphia or handwriting deficits for factors related to the history of handwriting problems (n=61)

History of handwriting problems		**Level of risk for dysgraphia 1-4**		
		Median (lower and upper quartile range)	Chi squared (df)	p value
Previous diagnosis of specific learning disability	Yes	3.50 (2.00-4.00)	7.46 (3)	0.05*
	No	2.00 (2.00-4.00)		
Pain in hand and arm	Yes	4.00 (3.00-4.00)	10.19(3)	0.01**
	No	2.00 (2.00-3.00)		

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

In summary, on the history of handwriting problems questionnaire it was found that approximately 50% of students had been diagnosed with SLD while approximately 20% had other illnesses or hand and upper limb injuries. Significant differences based on the risk for dysgraphia were found for pain in the hand are arm, visual problems related to oculomotor symptomatology and a previous diagnosis of SLD.

9.4.1.4 Characteristics of deficits of handwriting

For the students referred for handwriting assessment, the characteristics of the scores on the items in each subtest on the three sections of the Handwriting Screening Assessment were analysed to determine what deficits could be identified in the handwriting components of these students. The scores for the items in each subtest were also correlated with the ARQs on the three sections of the Handwriting Screening Assessment to determine if any items or subtests could be associated with a higher level of risk for dysgraphia or handwriting problems.

Observation Checklist

Subtest 1: Positioning and fixation of the paper

Figure 9.1 represents the Observation Checklist Subtest 1: *Positioning and fixation of the paper.* On Item 4: *fixation of the paper,* 75% of students referred for handwriting assessment scored a 1 indicating they did not fixate the paper they were writing on with their non-writing hand. A low score of 1 for Item 1: the *position of the paper on the table* (where the paper being written on was placed vertically or horizontally on the table) was recorded for 38% of these students.

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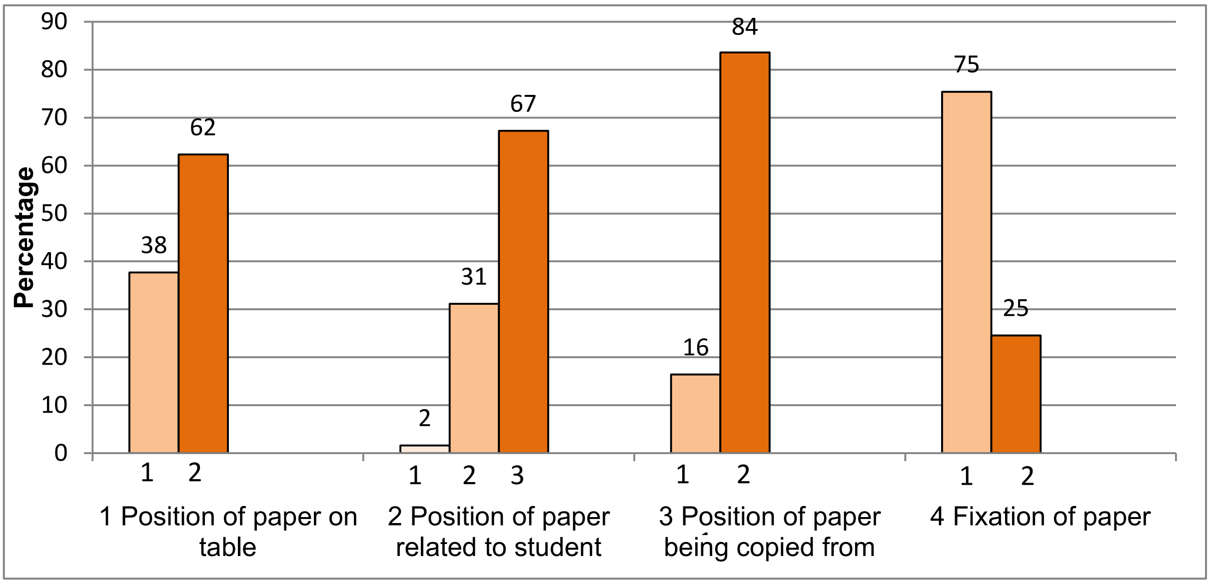

Figure 9.1 Frequency of scores for Observation Checklist Subtest 1: Position and fixation of paper (n=61).

Approximately a third of students scored 2 for Item 2: position of paper related to the student as they placed the paper to the side of the preferred hand when writing.

Subtest 2: Maintenance of Posture

In Figure 9.2 the lowest scores recorded in the **Observation Checklist** Subtest 2: *Maintenance of posture* were for Item 5: *writing hand position.* This indicated most students positioned their entire forearm and elbow of their writing arm on the table (85%).

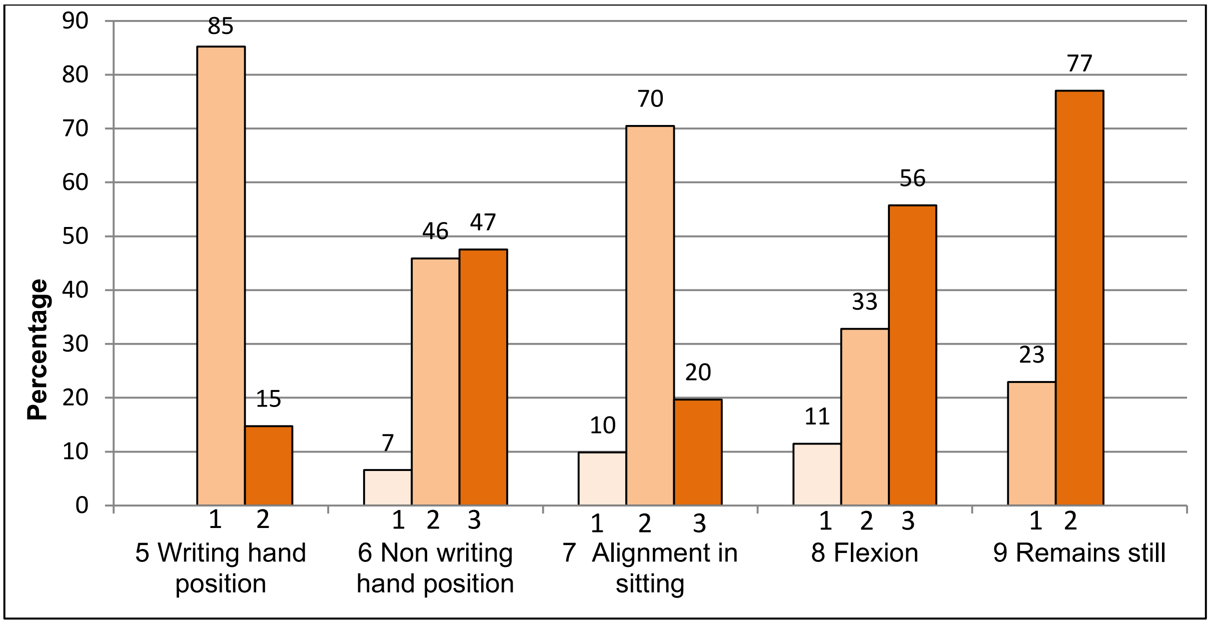

Figure 9.2 Frequency of scores for Observation Checklist Subtest 2: Posture (n=61)

For Item 7: *alignment in sitting,* 70% the students referred for handwriting assessment scored 2 for lateral flexion of the trunk in sitting while writing and 10% scored 1 for rotated posture. Observations for Item 9: *remains still,* indicate 23% of the students moved around when writing. For Item 8: *flexion,* in which flexion forward over the work is assessed, 11% of students scored 1 as they flexed their head to within 20cms of the table or lay with their head on their arm while writing.

Subtest 3: Stability of grasp

For the **Observation Checklist** Subtest 3: *Stability of grasp* a higher percentage of students referred for handwriting assessment had low scores in the on all items except Item 15: *web space* (Figure 9.3). A low score of 2 observed was for 80% of students on Item 13: *firmness of grasp* as they held their pen very tightly when writing.

More than half the students referred for assessment also had low scores for Item 11: *DIP joint of the index finger*, where hyperextension was observed (score 1) and for Item 12: *IP joint of the thumb* where hyperflexion was observed (score 2).

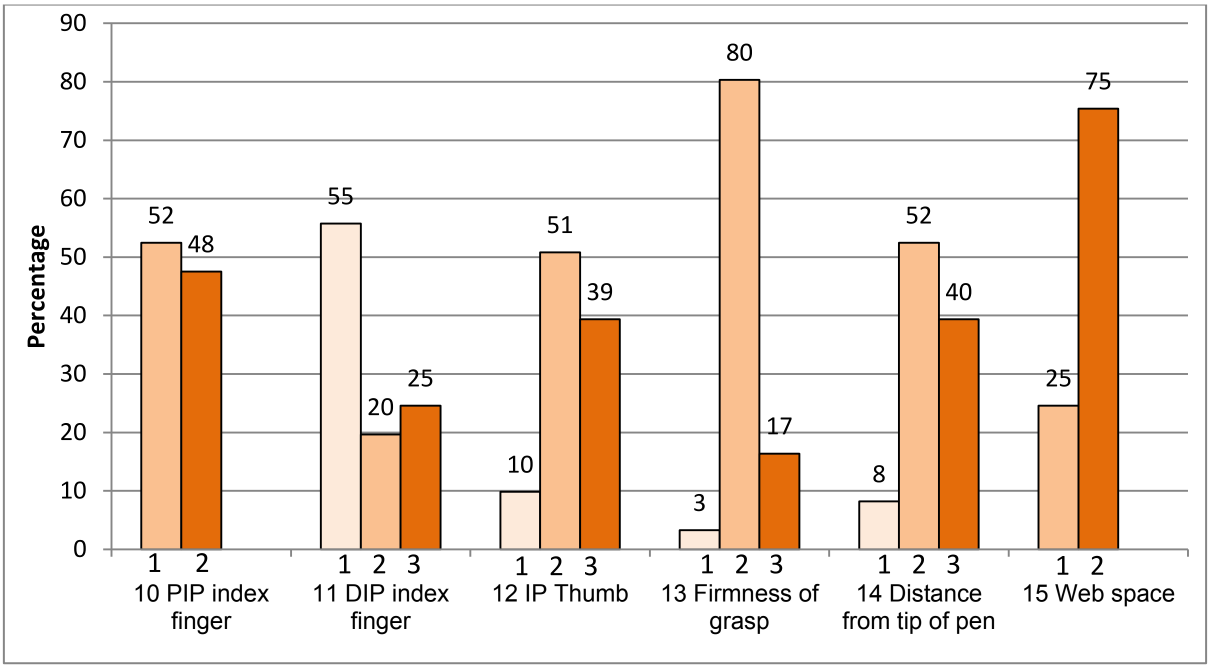

Figure 9.3 Frequency of scores for Observation Checklist Subtest 3: Stability of Grasp (n=61)

Subtest 4: Pen grasp

The fourth subtest in the **Observation Checklist** Subtest 4: *Pen grasp* showed that the majority of the students scored the highest score possible for all items (Figure 9.4). The exception was for Item 16: *the finger closest to the tip of the pen* where 51% of the students held the index finger rather than the thumb closest to the tip (score 2).

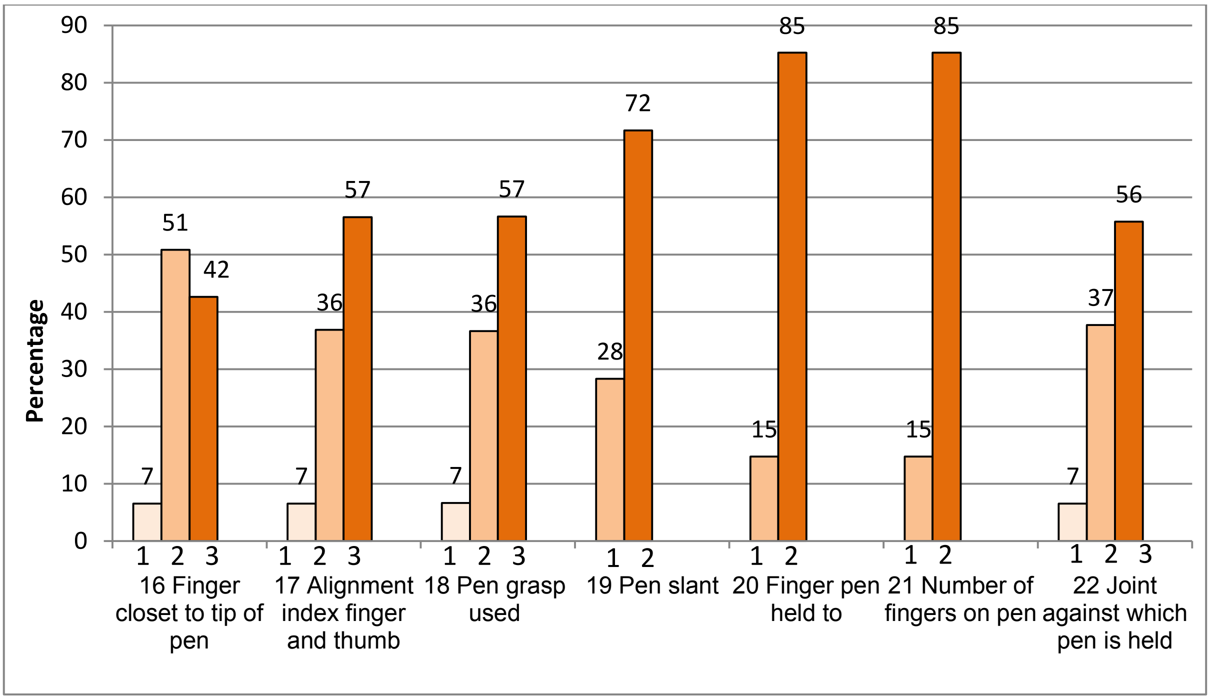

Figure 9.4 Frequency of scores for Observation Checklist Subtest 4: Pen Grasp (n=61)

Subtest 5: Movement in fingers and hand

Figure 9.5 indicates that the majority of students referred for handwriting assessment presented with the highest scores possible for this subtest which considered repositioning of the pen in the hand, shaking the hand as well as dissociation of the radial and ulnar sides of the hand while writing.

On Item: 25 *writing movements performed by* 31% of the students wrote with their hand (score 2) and 18% with their thumb only (score 1) rather than with finger and thumb movement. Therefore, only half the students in this sample wrote using finger and thumb movement (score 3).

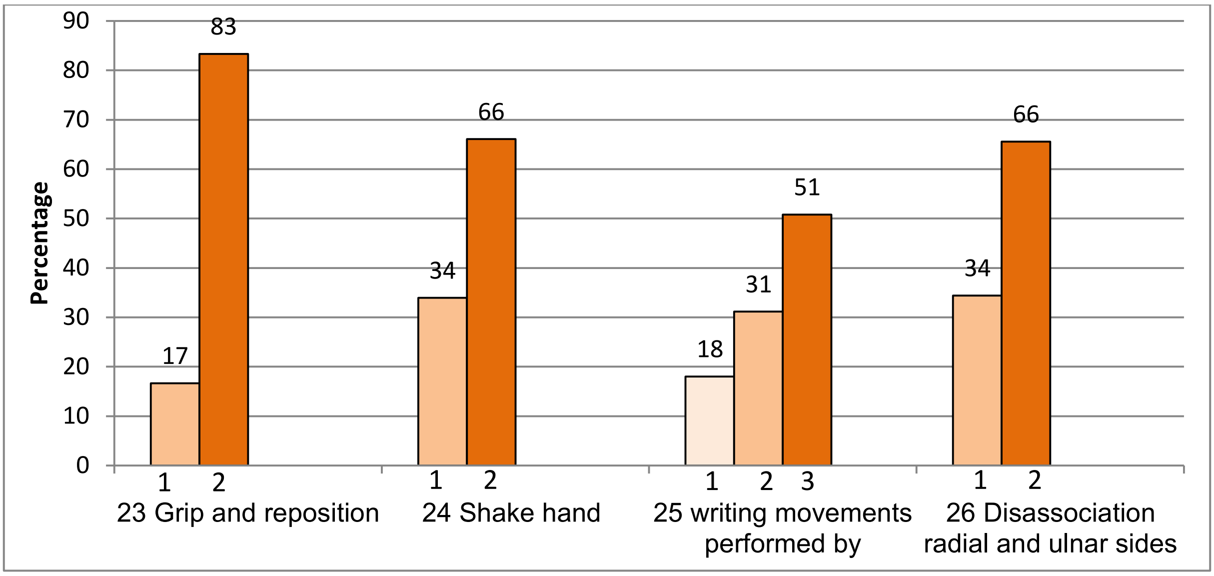

Figure 9.5 Frequency of scores for Observation Checklist Subtest 5: Movement in fingers and hand (n=61)

Subtest 6: Visual function

On the **Observation Checklist** Subtest 6: *Visual function* the majority of students had a low score when Item 27: *head movement* was analysed (Figure 9.6).

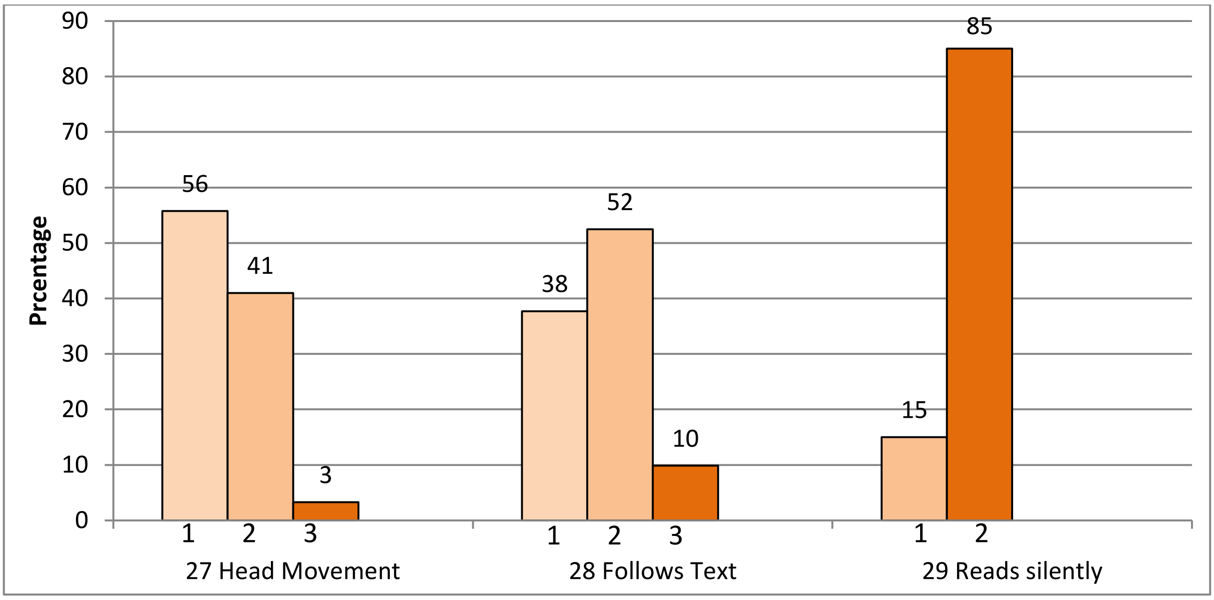

Figure 9.6 Frequency of scores for Observation Checklist Subtest 6: Visual function (n=61)

More than 40% of the students needed to look at every word (score 2) as they copied and 56% did not complete a word before looking at the passage being copied again to check what they were copying (score 1).

For Item 28: *follows text*, more than half of the students scored 2, as they followed text with their finger and 38% hesitated and stared at the text for more than 7 seconds as they tried to find their place in the text they were copying. Deficits on Item 29: *reads silently* which assessed subvocalizing or mouthing words was observed in 15% of the students (Score 2).

Subtest 7: Preferred hand and wrist position

The right hand was the preferred hand with which the students wrote as seen in Figure 9.6. Item 30: *preferred hand* confirmed that 18% of the students were left hand dominant.

Over 90% of students wrote with the wrist in extension and only 8% of the students some of whom were not left handed wrote with their wrist in a flexed position.

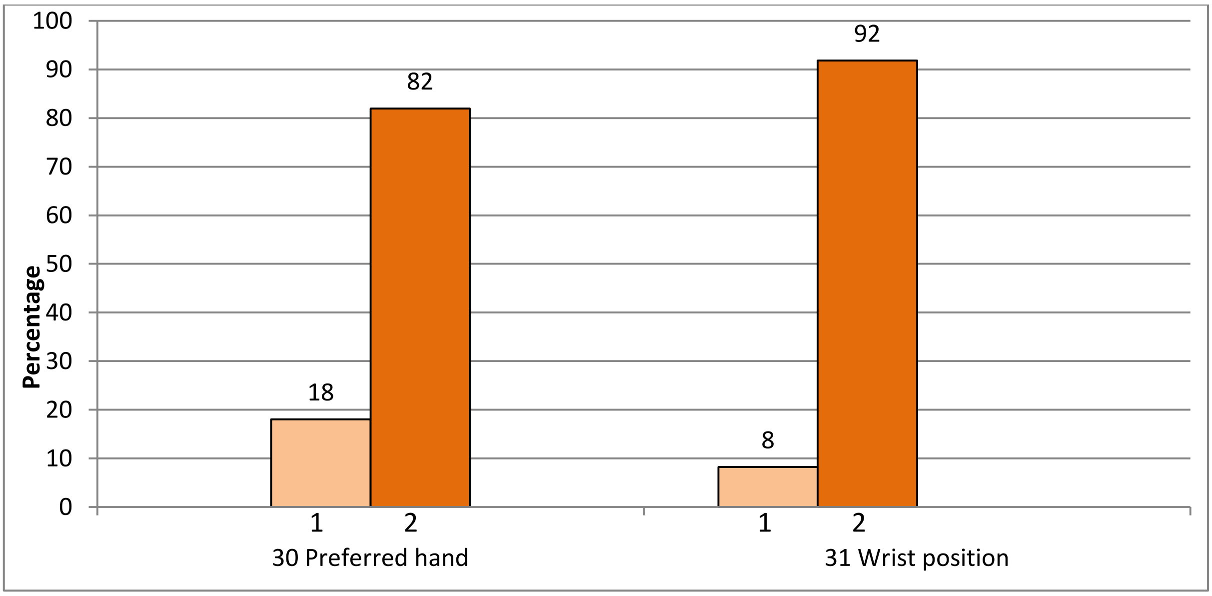

Figure 9.7 Frequency of scores for Observation Checklist Subtest 7: Preferred hand (n=61)

Writing Checklist

Subtest 1: Writing Analysis

The item scores in the **Writing Checklist** Subtest 1: *Writing analysis* showed the majority of students had low scores in every item. For Item 2: *unreadable words* over 75% of students had a score of 2 indicating up to 20% of the words written were illegible (Figure 9.8). This score means the writing has enough illegible words to make reading the writing more difficult.

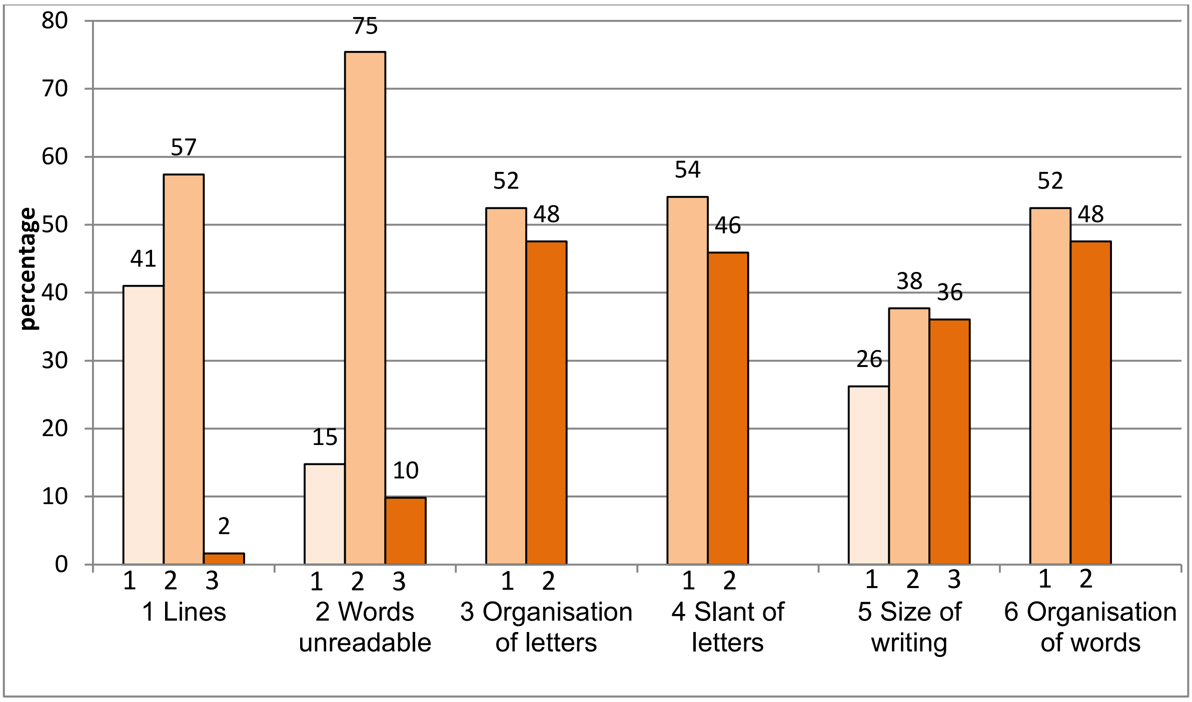

Figure 9.8 Frequency of scores for Writing Checklist Subtest 1: Writing Analysis (n=61)

The lack of uniformity observed in most students' writing however, was due to the low scores for Item 3: *organisation of letters*, Item 4: *slant of letters* and Item 6: *organisation of words*. Ninety eight percent of students scored 1 or 2 for Item 1: *lines as v*ery few students wrote on or close to the lines.

Subtest 2: Endurance and fatigue

In Figure 9.9 it can be seen that for the **Writing Checklist** Subtest 2: *Endurance and fatigue* 56% of students referred for handwriting assessment scored 1 on Item

7: *type of writing* as they used cursive writing. Only 28% of students used mixed printed and cursive writing and scored 3.

The results for Item 8: *pressure used to write*: indicated 52% of the sample used so much pressure when writing that indentations could be seen on the next page. Less than half the students scored 2 and 3 for Item 9: *deterioration* as their writing deteriorated or changed in the short period of the assessment.

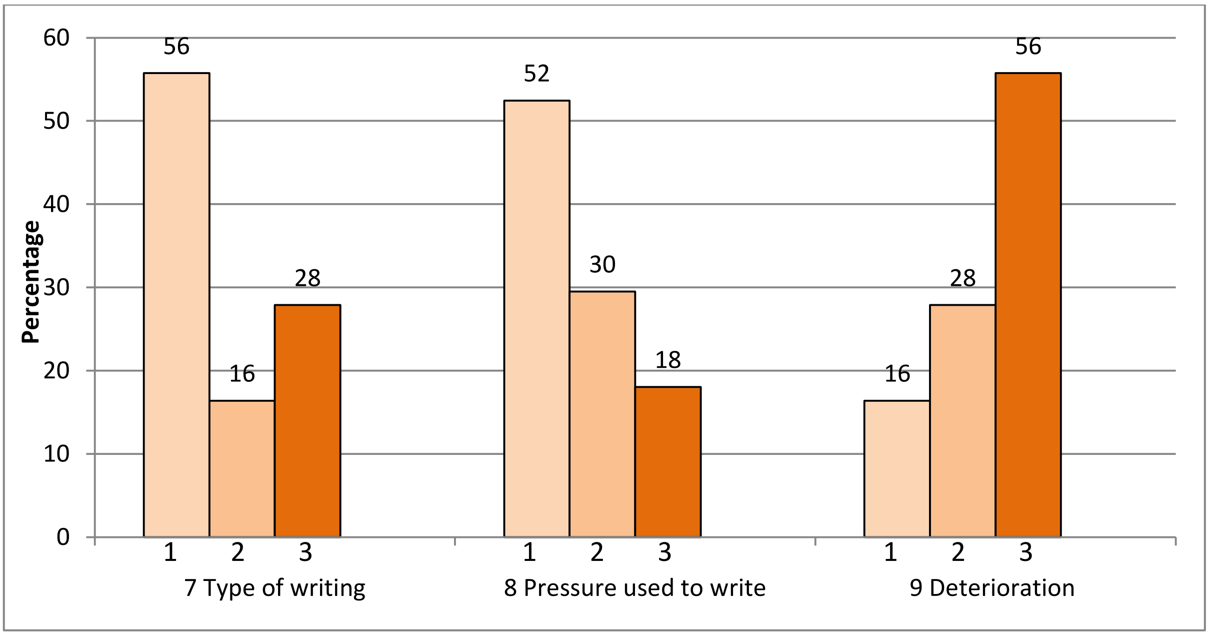

Figure 9.9 Frequency of scores for Writing Checklist Subtest 2: Endurance and fatigue (n=61)

Subtest 3: Punctuation

In **Writing Checklist** Subtest 3: *Punctuation* errors for the capital letters were seen for 22% of the students referred for handwriting assessment (Figure 9.10). Only 10% of students made punctuation errors (score 1).

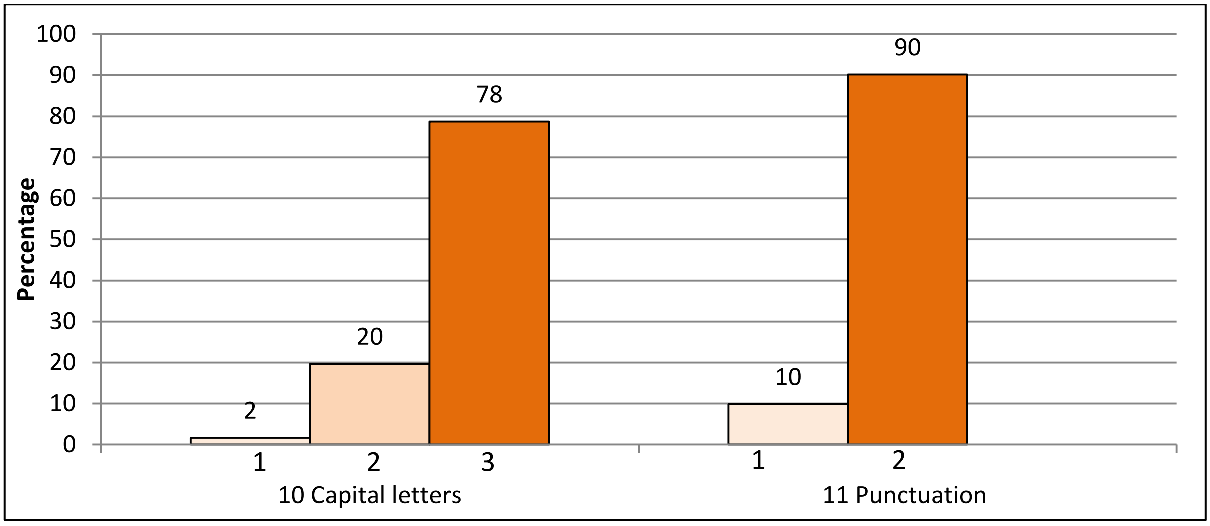

Figure 9.10 Frequency of scores for Writing Checklist Subtest 3: Punctuation (n=61)

Subtest 4: Corrections and Spelling

Between one and three corrections and spelling mistakes on Items 12: *corrections* and Item 13: *spelling* (score 2) were made by 56% of students referred for handwriting assessments when copying on Writing Checklist Subtest 4: *Corrections and Spelling* (Figure 9.11).

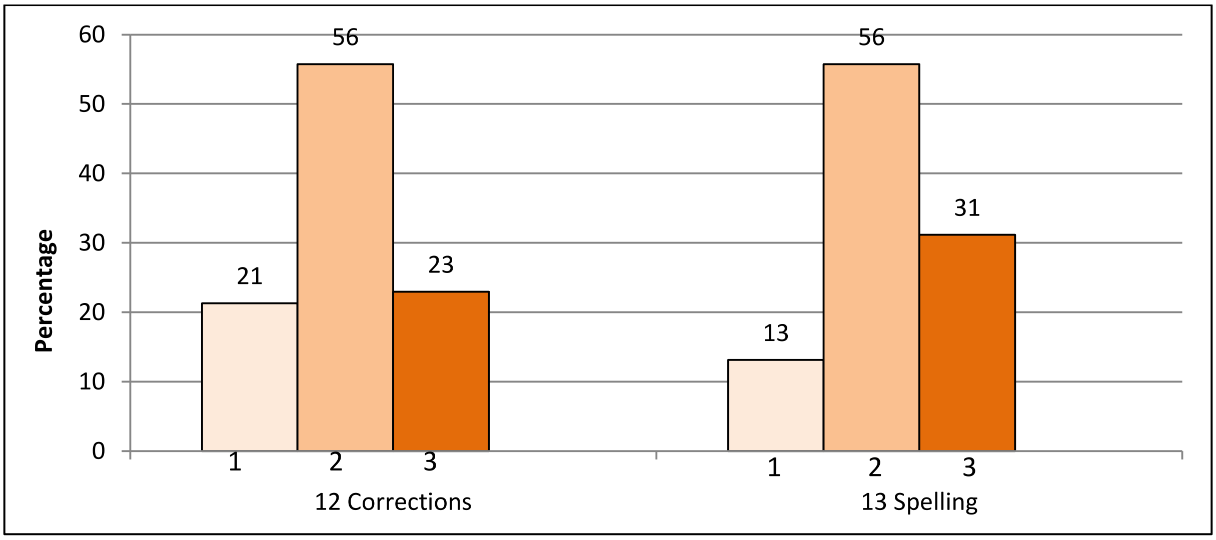

Figure 9.11 Frequency of scores for Writing Checklist Subtest 4: Corrections and spelling (n=61)

Less than a third of the students made no corrections or no spelling mistakes when copying.

Subtest 5: Missing letters and words

On the Observation Checklist Subtest 5: *Missing letters and words* low scores were observed for approximately a third of the students referred for handwriting assessment on Items 14: *missing letters at the end of words* and Item 15: *missing words* (Figure 9.12). Only 11% of the sample failed to copy all the lines of text in the paragraph (score 1) as reported for Item 16: *missing lines of text*.

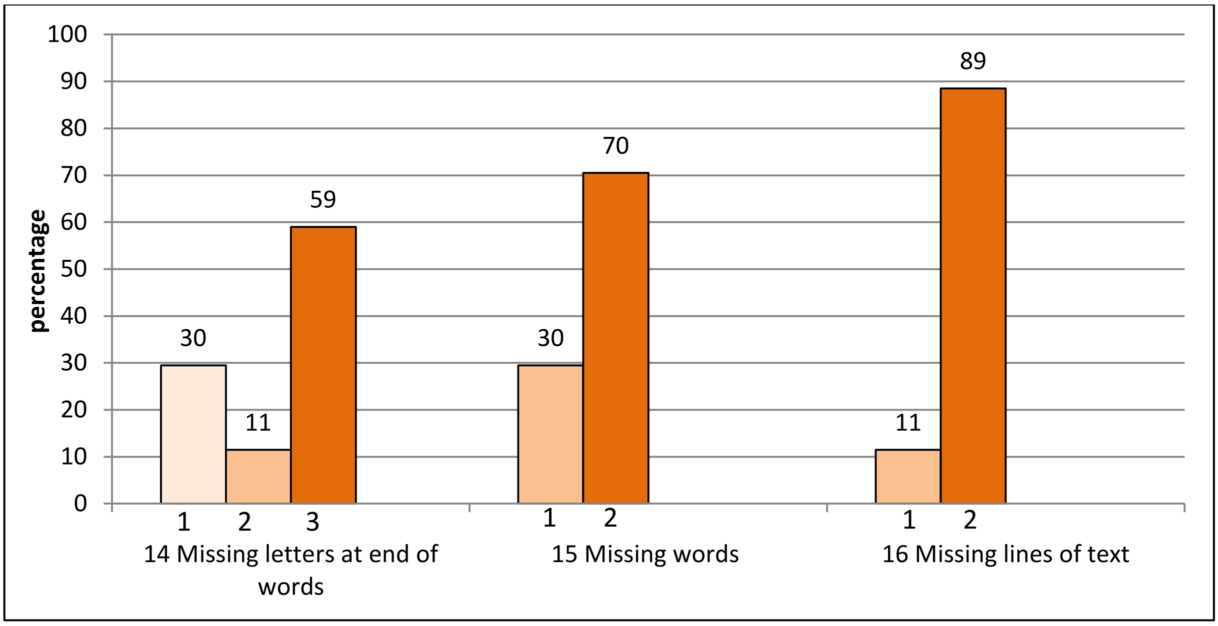

Figure 9.12 Frequency of scores for Writing Checklist Subtest 5: Missing letters and words (n=61)

Handwriting Outcomes

Copying speed

In Figure 9.13 the mean number of WPM copied by typical students was 18.20 (SD 4.06) with a median of 18 words per minute which was significantly lower than the mean range of 23 WPM for the typical students (Table 6.12).

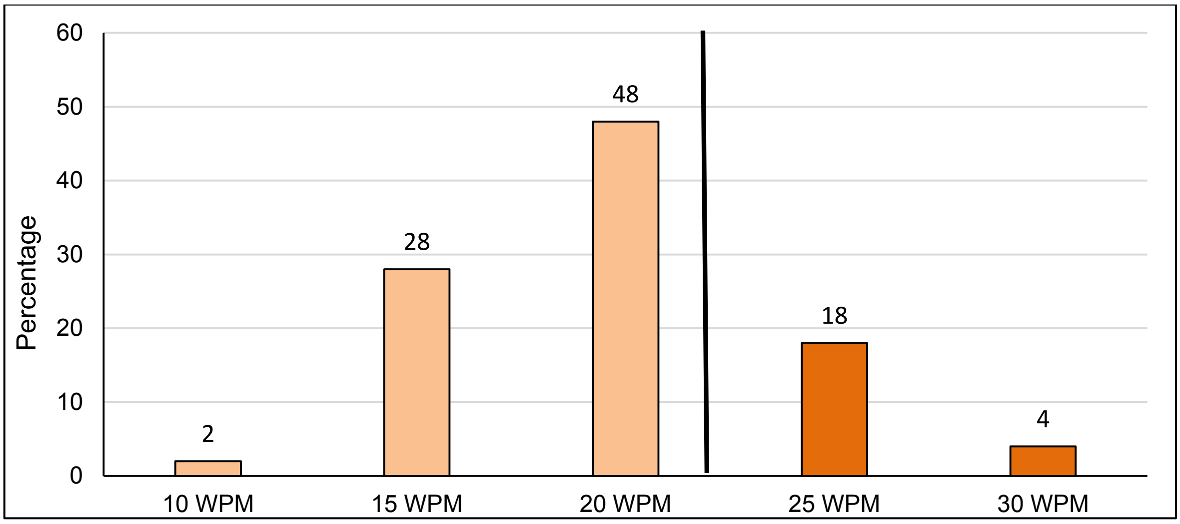

Figure 9.13 Frequency of copying speed – words per minute for students (n=61)

Legibility

Over 50% of students' writing fell into the acceptable category in terms of legibility with a score between 1 and 3 based on the mean score of 3 for typical students (Table 6.12), while 10% presented with writing which was very illegible (Figure 9.14).

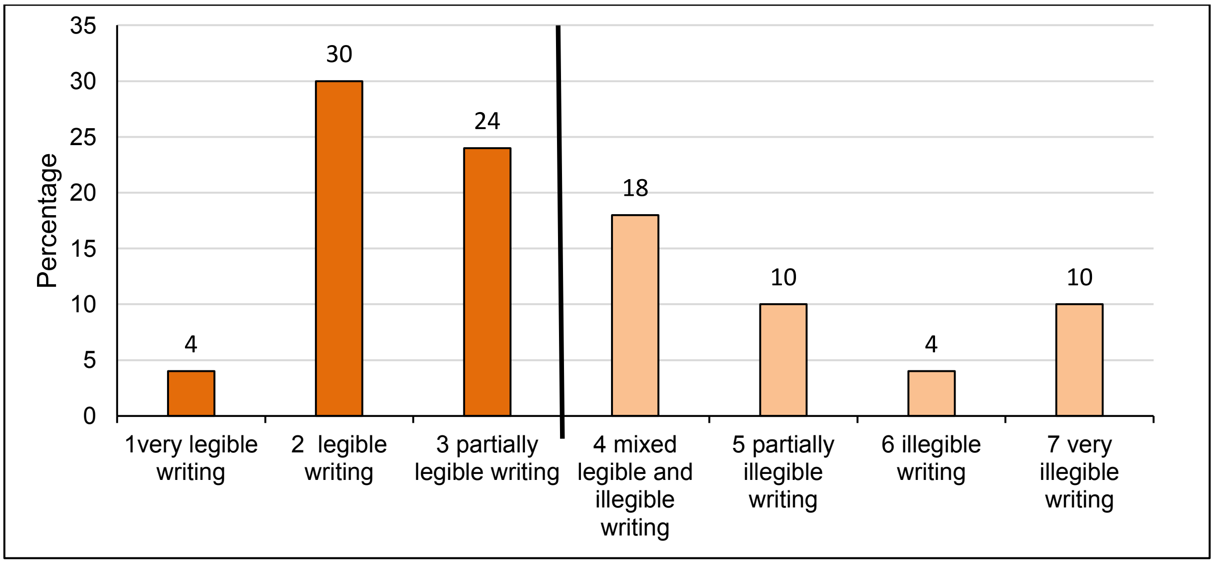

Figure 9.14 Frequency of legibility for students referred for handwriting assessment (n-61)

Writing Speed Accuracy Measure (WSAM) Alphabet Task

The mean number of letters written in the WSAM Alphabet task for the students referred for handwriting assessment was 69.118 (SD 19.62) with a median of 69 (Figure 9.15). This falls below the mean 83 LMP written by typical students (Table 6.12).

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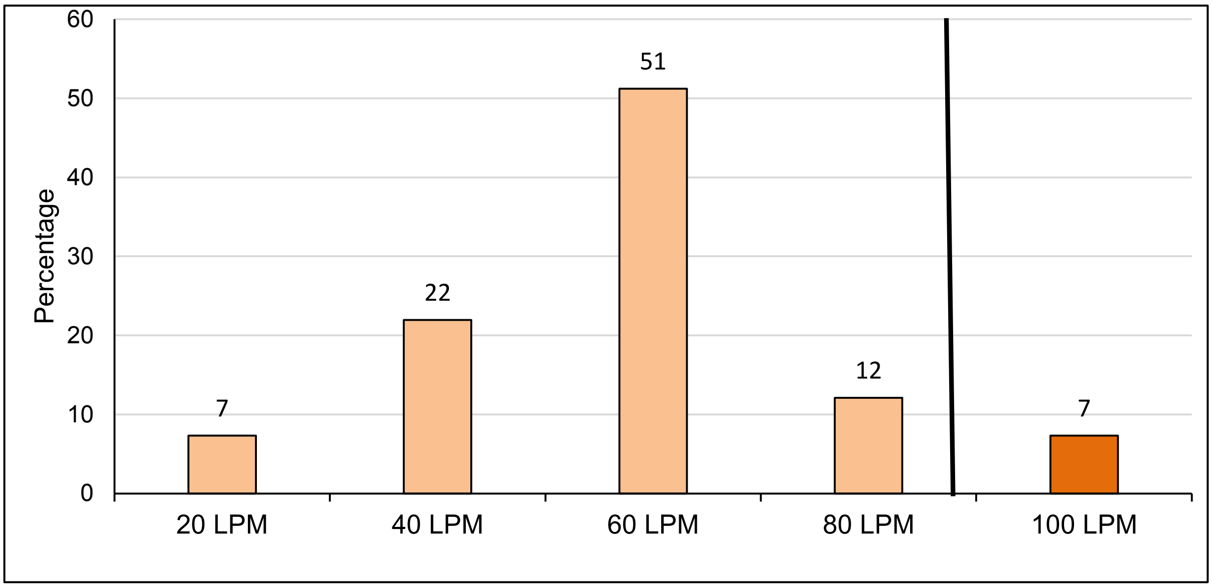

Figure 9.15 Frequency of letters per minute written on the WSAM Alphabet Task for students referred for handwriting assessment (n-61)

9.4.1.5 Correlations between the items/subtests and level of risk for dysgraphia or handwriting problems on the Observation Checklist, Writing Checklist and Handwriting Outcomes.

The correlations between the items on the Observation Checklist and the Writing Checklist as well as the subtests on the Handwriting Outcomes, in relation to the ARQs or level of risk were determined for the students referred for handwriting assessment. Table 9.5 and Table 9.9 presents the significant strong and moderate negative correlations representative of the items with lower scores which are associated with a greater risk for dysgraphia for the Observation Checklist, the Writing Checklist and Handwriting Outcomes.

Table 9.5 Correlations coefficients between the items in the subtests and at risk quotients indicating level of risk for dysgraphia or handwriting problems and the Observation Checklist (n=61)

Items on Handwriting Screening Assessment	ARQ-- Level of risk on Observation Checklist	ARQ-- Level of risk on Writing Checklist	ARQ-- Level of risk on Handwriting Outcomes	
			Subtest 1: Copying speed and automaticity	Subtest 2: Legibility
Observation Checklist				
	r	**r**	**r**	
Subtest 1: ***Position and fixation of Paper*** Item 1 Position of paper on table	**-0.47***	-0.15	-0.18	0.29
Subtest 2: ***Maintenance of posture*** Item 8: flexion	**-0.46***	0.14	-0.29	0.18
Subtest 3 ***Stability of grasp*** Item 11: DIP of index finger	0.00	**0.40***	0.18	-0.35*
Subtest 3 ***Stability of grasp*** Item 12: IP of the thumb	0.12	-0.19		**-0.44***
Subtest 6: ***Visual function*** Item 27: Head Movement	**-0.46***	0.06	-0.06	0.20
Subtest 7: ***Preferred hand and wrist position*** Item 30: Preferred hand	**-0.60***	-0.10	-0.38*	0.02
Subtest 7: ***Preferred hand and wrist position*** Item 31: Wrist position	**-0.40***	0.21	-0.21	0.30

Significance p≤ 0.05 *

Lower scores related to the writer for the position of the paper on the table as assessed by the Observation Checklist were moderately associated with a higher risk for dysgraphia or handwriting problems, as were head movement when copying and the position of the wrist when writing. Writing with the left hand indicated a strong association with a higher risk for dysgraphia or handwriting problems.

The positive moderate significant correlation for the position of the DIP joint of the index finger and IP joint of the thumb indicated less risk for dysgraphia or handwriting problems. This indicated that when writing with the index finger DIP in hyperextension and the IP joint of the thumb in hyperflexion the presentation of writing and legibility assessed by the Writing Checklist and Handwriting Outcomes obtained a higher score.

Table 9.6 Correlations coefficients between the items in the subtests and at risk quotients indicating level of risk for dysgraphia or handwriting problems and the, Writing Checklist and Handwriting Outcomes (n=61)

Items on Handwriting Screening Assessment	ARQ-- Level of risk on Observation Checklist	ARQ-- Level of risk on Writing Checklist	ARQ-- Level of risk on Handwriting Outcomes	
			Subtest 1: Copying speed and automaticity	Subtest 2: Legibility
Writing Checklist				
Subtest 1: ***Writing analysis*** Item 1: Lines	-0.19	0.29	0.04	**0.41***
Subtest 1: ***Writing analysis*** Item 2: Words Unreadable	-0.03	0.23	0.08	**0.63***
Subtest 1: ***Writing analysis*** Item 3: Organisation of letters	-0.16	**-0.41***	0.22	**0.44***
Subtest 1: ***Writing analysis*** Item 4: Slant of letters	0.01	0.20	0.13	**0.40***
Subtest 1: ***Writing analysis*** Item 6 Organisation of words	0.04	0.25	0.04	**0.50***
Subtest 2: ***Endurance and fatigue*** Item 9: Deterioration	0.00	**-0.40***	-0.03	0.28
Subtest 3: ***Punctuation*** Item11: Punctuation	-0.20	**-0.55***	-0.18	0.01
Subtest 4: ***Corrections and Spelling*** Item 12: Corrections	-0.11	**-0.49***	-0.27	0.21
Subtest 4: ***Corrections and Spelling*** Item 13: Spelling	-0.03	**-0.40***	-0.17	0.23
Subtest 5: M*issing letters and words* Item 14: Missing letters at the end of words	-0.13	**-0.68***	0.02	0.32
Subtest 5: M*issing letters and words* Item 15: Missing words	-0.17	**-0.65***	0.02	0.23
Subtest 5: ***Missing letters and words*** Item 16: Missing lines of text	-0-01	**-0.53***	-0.10	0.01
Handwriting Outcomes				
Subtest 1: Copying speed and automaticity	-0.21	-0.22		-0.03
Subtest 2: Legibility	0.07	**0.40***	-0.03	

Significance p≤ 0.05 *

The items in the Writing Checklist associated with a higher risk for dysgraphia were related to the presentation of writing including organisation of letters, deterioration in writing, errors in punctuation, corrections, spelling errors and missing letters and words. Low scores on the Handwriting Outcomes Subtest 2: *legibility* also had moderate correlation to risk for dysgraphia or handwriting problems in this section of the Handwriting Screening Assessment.

Both slow copying speed and poor automaticity of handwriting were not associated with any of the items on the checklists or legibility for risk of dysgraphia or handwriting deficits. Legibility however had moderate and strong correlations to all items on the Writing Checklist Subtest 1: *Writing analysis* except size of writing. This indicated that those with poor legibility and low scores for organisation of letters and words, alignment of the writing to the lines and inconsistent slant in writing were not inexpertly were at risk for dysgraphia or handwriting deficits due to poor legibility of their handwriting.

In summary, the results on the items/subtests of the Handwriting Screening Assessment were analysed to determine the characteristics of the deficits in the components and outcomes of handwriting for the students referred for handwriting assessment. Items in the subtests can be associated with specific client factors which may indicate deficits and guide the referral for further assessment. Items in the Observation Checklist Subtest 4: *Pen grasp* and Subtest 7: *Preferred hand and wrist position* as well as Writing Checklist Subtest 3: *Punctuation* and Subtest 5: *Missing letters and words* indicated the majority of students presented with no deficits. However, when the item scores on the Observation Checklist and the Writing Checklist moderately and strongly associated with a higher risk for dysgraphia or handwriting problems were analysed, all these subtests with the exception of pen grasp, had items that correlated with the risk for dysgraphia.

Low scores on the Handwriting Outcomes Subtest 2: *legibility* also had moderate correlation to risk for dysgraphia for scores on the Writing Checklist while both slow copying speed and poor automaticity of handwriting were not associated with any items or subtests for risk of dysgraphia or handwriting deficits on Handwriting Outcomes.

9.4.2 Part 2: Utility of the Handwriting Screening Assessment for students with dysgraphia or handwriting deficits

Only 50 of the 61 students referred for handwriting assessment were identified with risk for dysgraphia or handwriting problems on the Handwriting Screening Assessment. The utility of the Handwriting Screening Assessment was investigated by determining the different types of dysgraphia that some items may reflect for these 50 students, to assist and guide recommendation for specific concessions. Their academic outcomes of these 50 students were also determined to assess the possible benefit of the concessions they received after handwriting deficits were confirmed after deficits were identified on the Handwriting Screening Assessment.

9.4.2.1 Types of Dysgraphia

The literature indicates that fine motor function, spelling and organisation of writing which can be used to determine the difference between motor, dyslexic and spatial dysgraphia. Spelling and orthographic coding are more affected in dyslexic dysgraphia while in motor dysgraphia spelling ability may be intact but fine motor function is affected. On the other hand spatial dysgraphia is characterised by poor organisation of letters in words but spelling and fine motor function may not be affected [Berninger, 2008; Deuel, 2001]. The definitions of dysgraphia according to Deuel (2001) all mention legibility problems but what makes writing illegible was not defined [Deuel, 2001].

Deuel (2001) compared the legibility of copied and spontaneously freely written text but this comparison could not be made in the current study as only samples of copied text were available, so legibility was not used to determine the types of dysgraphia. The scores on Item 3: *organisation of letters* and Item 13: *spelling* on the Writing Checklist as well as Item 25: *writing movements* on the Observation Checklist were therefore used to determine if different types of dysgraphia could be identified in students at risk of handwriting deficits.

In Figure 9.16 an example of motor dysgraphia or graphomotor handwriting problems described by Berninger (2009) is presented She indicated that this type of dysgraphia has intact spelling or orthographic coding but poor fine motor function or finger sequencing [Berninger, 2009; Deuel, 2001]. In motor dysgraphia, the legibility of copied and written text is usually more severely affected.

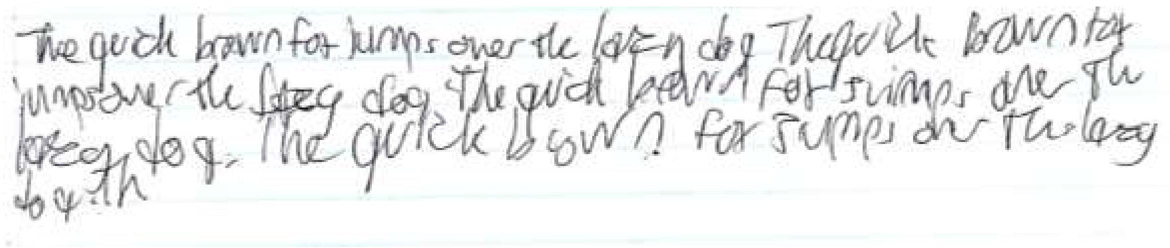

Figure 9.16 Example of motor dysgraphia

Therefore, to determine if motor dysgraphia could be identified in this sample of students, a Chi-squared test was used to analyse Item 13: *spelling* scores on the Writing Checklist and the Observation Checklist Item 25: *writing movements* which reflected the fine motor function and in-hand manipulation when writing (Figure 9.17).

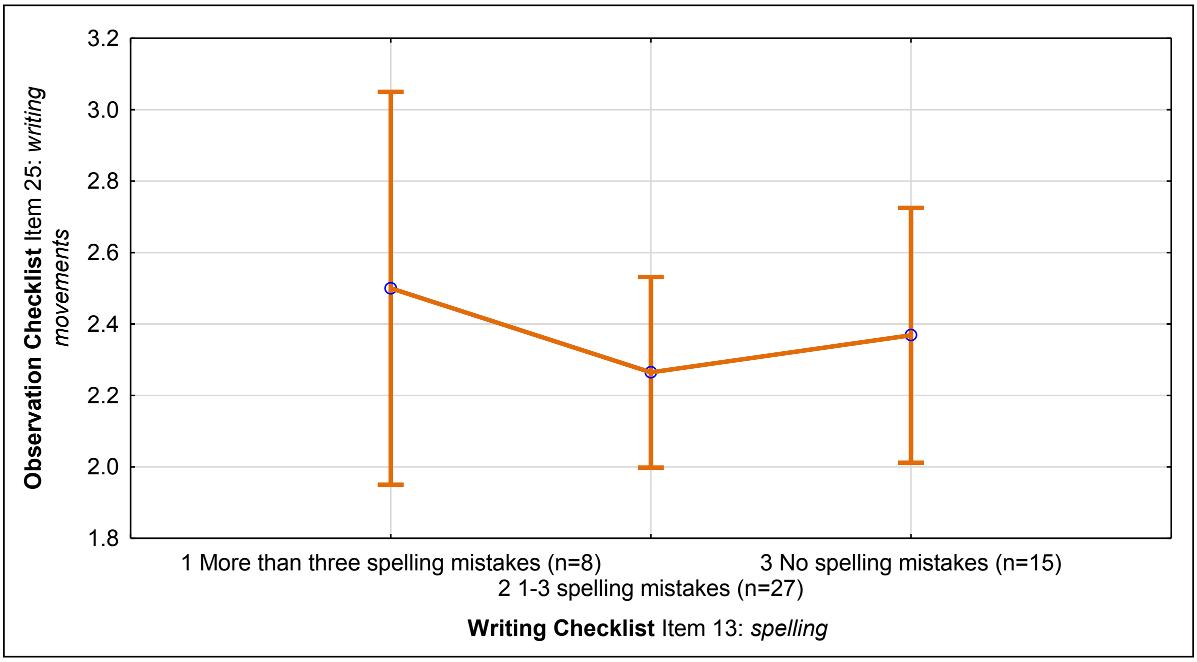

Figure 9.17 Comparison of spelling scores and fine motor function on Observation Checklist Item 25: *writing movements* I (n=50)

Although no significant differences were found students making fewer spelling mistakes had lower scores for writing movements (Chi-Square=5.55, df=2, p=0.71).

Dyslexic dysgraphia in which fine motor function or finger sequencing is intact but where spelling is poor [Berninger et al., 2008a; Deuel, 2001] can also be identified by the results in Figure 9.17. Students who made spelling mistakes had higher scores for writing movements indicating their fine motor function was not as affected. In Figure 9.18, an example of dysgraphia dyslexia the three spelling errors (underlined in red) differ from the s missing from the end of *movement* and *interval* (underlined in black) which are scored as missing letters at the end of the word. Legibility has been relatively preserved in this copied written text as suggested by Deuel (2001) for dyslexic dysgraphia [Deuel, 2001].

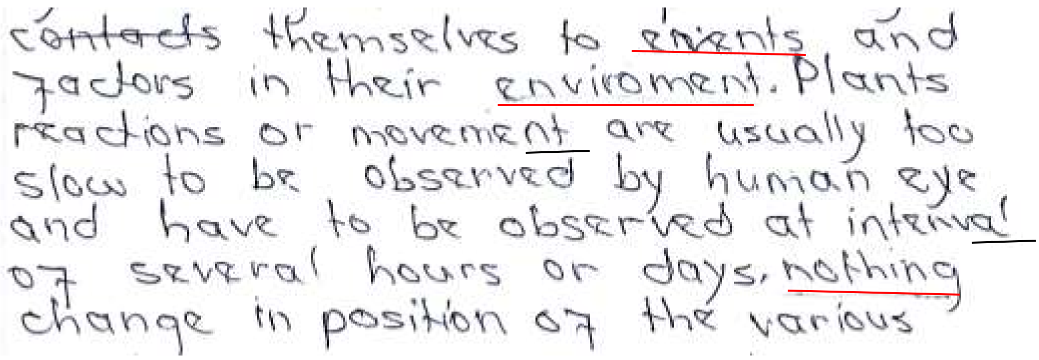

Figure 9.18 Example of dyslexic dysgraphia

In spatial dysgraphia spelling and fine motor function is preserved while spatial organisation of the writing on the page is affected. Figure 9.19 provides an example of writing where the spacing of the letters and incomplete letters (underlined) results in writing that is crowded to such as extent that it affects legibility.

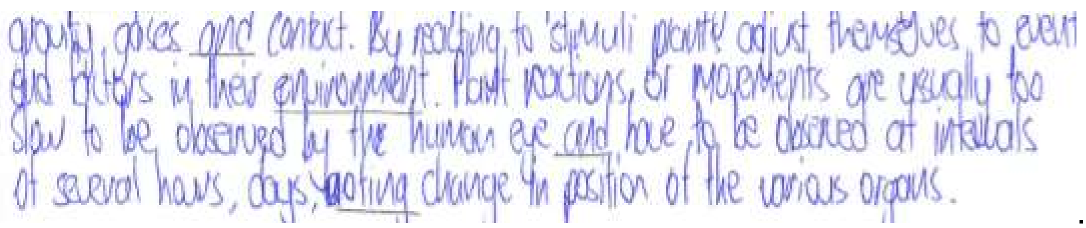

Figure 9.19 Example of spatial dysgraphia

In Figure 9.20 the differences on the scores for Item 25: *writing movements* on the Observation Checklist were compared to scores for the Writing Checklist Item 3: *organisation of letters* representative of spatial visual perception, to determine if spatial dysgraphia could be identified [Deuel, 2001]. The scores for organisation of words were higher for students who had lower scores for writing movements indicating less fine motor control when writing. This difference was however, not statistically significant (Chi-Square = 2.30, df = 2, p = 0.31).

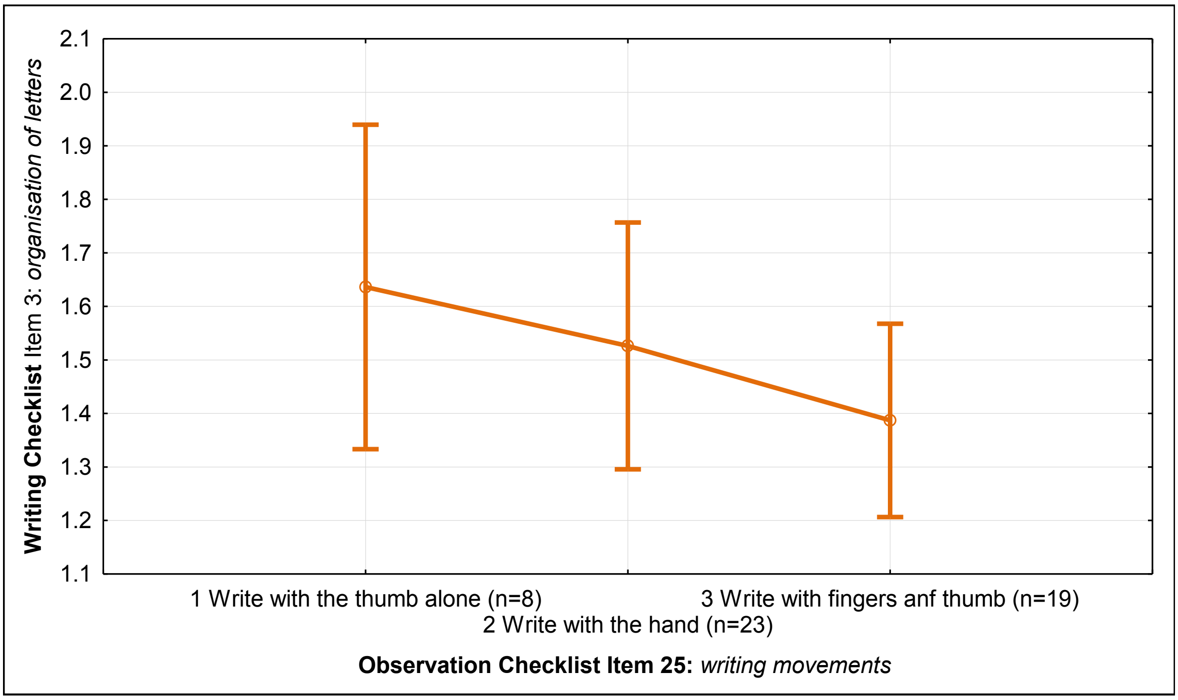

Figure 9.20 Comparison of writing movements and Writing Checklist Item 3: Organisation of letters (n=50)

Determining if the students could be identified as presenting with different types of dysgraphia was important so appropriate further concessions could be suggested. In summary although the differences between the items used to identify each type of dysgraphia were not significant, it was clear that students were inclined to present with lower scores for either spelling or organisation of letters when they had higher scores for writing movements. This provides some indication of the possible underlying client factors associated with dysgraphia and what concessions students may need to support them in compensating for their specific deficits related to the type of dysgraphia with which they present.

9.4.2.2 Academic Outcomes

The final aspect of determining the usability of an assessment is to determine if the decisions made based on the assessment are effective. For the 50 students found to be at risk for handwriting problems, recommendations for further assessment based on the results of the Handwriting Screening Assessment were determined. The students were assessed by an occupational therapist using appropriate assessments based on the components of handwriting and client factors identified as having deficits. Where indicated they were referred to other professionals for assessment. Although a number of different concessions were recommended the majority of these recommendations were for extra time and therefore other concessions such as those for typing and spelling were not analysed in these results. Recommendations for concessions and extra time were made after further assessments of the student were completed and these recommendations are followed up by health professionals at the CHWC who confirm the final concessions to be awarded.

The academic outcomes of the 50 students were analysed at the end of the year in which they received extra time concessions and the end of the following year (Table 9.7).

There was no significant difference in the number of students who had failed before (38%) and the number who failed the year in which they were awarded extra time (28%). Of the 14 students who failed, three left the university. Eight of these students (16%) had repeated previously and six were first year students (12%).

In total 72% of students passed their examinations in the year they received extra time concessions, with 16% of these students completing their programme and graduated.

Table 9.7 Academic outcomes (n=50)

	Passed the year	Passed and complet ed course	Repeated the year or repeated a course	Failed and left or was excluded for one year		
	n (%)				Chi Squared (df)	p value
Academic outcome - year concession awarded (n=50)	28 (56%)	8 (16%)	11 (22%)	3 (6%)	1.67 (1).	0.66
Academic outcome - year after concession awarded (n= 39)	31 (79.5%)	5 (12.8%)	2 (5.1%)		5.10 (1)	0.02**

Significance * p≤0.05
** p≤0.01

In the year following that in which extra time concessions were given the academic outcomes for the 38 students remained. The number who needed to repeat their course decreased significantly as only 5% of the students failed in that year. Eight students, who had failed the previous year passed and five completed their programme and graduated.

In summary in the academic outcomes of these 50 students who were awarded extra time showed that there was no significant decrease in the number of students who failed in the year that they were awarded extra time. In the following year however, significantly fewer students repeated courses although this could not be directed associated with the concessions they received.

CHAPTER 10
DISCUSSION PHASE 3

10.1 Introduction

In this phase of the study the usability of the Handwriting Screening Assessment was considered. Since screening assessments are designed to measure risk, to increase the usability and utility of the assessment, it is important to understand the components most likely to present with deficits in the population for which the screening assessment is designed. Objectives for this phase of the study were therefore considered the characteristics of the deficits in components of handwriting for the three sections of the Handwriting Screening Assessment in relation to the sample of students referred for handwriting assessment. These results will support decision making when referring students at risk for dysgraphia to other services for further assessment and when recommending concessions.

By identifying the characteristics of the target population to inform stakeholders using the assessment in terms of administration of the assessment and the interpretation of the results, the usability of the assessment was ensured.. It is important to understand that the presence of visual function as well as pain and a previous diagnosis of SLD differentiated students referred for handwriting assessments in terms of their scores on the Handwriting Screening Assessment and their risk for dysgraphia. Since the Handwriting Screening Assessment had been shown to have acceptable validity and reliability the characteristics of the common deficits on the Observation Checklist and Writing Checklist as well as the subtests on the Handwriting Outcomes were established which indicate what deficits can be expected in the target population. The results confirmed that students in higher education present with many of the same deficits as children with dysgraphia or handwriting deficits. The assessment already met the criteria for low cost, ability to be administered in a variety of settings and suitable for recommendation of concessions that were available provided by existing services at Wits and possibly at other universities with disability units. [Glover and Albers, 2007].

The results confirm the relationship items/subtests three sections of the Handwriting Screening Assessment and the level of risk for dysgraphia or handwriting problems determined by ARQs for this sample of students. This confirms that different components on each of the three sections of the Handwriting Screening Assessment are valid in providing assessments which identify students at risk for dysgraphia or handwriting problems. Therefore, when screening these students, it is important to consider, not only Handwriting Outcomes, but also the effects of the writer or student and the presentation of their writing.

Identifying and understanding the different types of dysgraphia provides information in terms of the interpretation of the Handwriting Screening Assessment for those who administer the assessment and those who need to confirm concessions for the students. This guides the recommendation and justification for concessions.

The brief study on the academic outcomes related to the extra time concessions needs to be extended to determine the benefits of screening students for dysgraphia or handwriting problems in terms of their academic outcomes. The percentage of students needing to repeat courses did decrease but this cannot be directly related to the awarding of an extra time concession.

10.2 Part 1

10.2.1 History of handwriting problems

Students reporting problems with finishing written examinations and tests are usually referred for assessment of handwriting. These students often reported an inability to complete examinations even though they passed the questions they answered. Less than half the students requesting assessment had failed a year, but most were concerned about failing as they often did not answer 20%-30% of the question paper. Many students reported having problems finishing examinations at school and even at university these problems with examinations were only addressed when they failed a test or examination [Casale, 2009]. Approximately 16% of the students had repeated at least one year before applying for a handwriting assessment.

When students do apply for concessions, it would appear that the referrals from CHWC for screening for handwriting problems was appropriate, as 82% of students referred did present with handwriting deficits. The students referred reported various problems (Table 9.1) with some not sure of why they were not able to complete their examinations. Therefore detailed history of their handwriting problems was needed to determine if the student should be considered as having problems related to their handwriting and components associated with handwriting.

Problems were first identified in relation to the ability to cope in the academic context. Many students referred for handwriting assessment reported other issues related to handwriting other than finishing examinations which affected their ability to perform in the academic setting. They reported problems with reading question papers and having to reread questions which slowed them down in examinations. They also had problems with taking notes when this was necessary or with reading the power point slides in the classroom and textbooks. This resulted in them having inadequate information from which to learn or having to spend extra time copying from other students' notes. These are issues that must also be considered when recommending concessions to support the students in preparing for examinations.

The profile of the students assessed on the history of handwriting problems related to their medical diagnoses was similar to that reported in the record review in Phase 1. The results of this phase of the study confirmed that most students referred for assessment of handwriting did present with SLD but that a number of other diagnoses can also impact on handwriting. In phase 3 approximately 50% of students referred for handwriting assessment had been formally diagnosed SLD which is higher than the 33% found in Phase 1. The use of medication for concentration was also nearly double that reported in Phase 1. This supports the reported trend that more students with SLD are achieving entrance into university as they are better supported at school [Ward, 2006].

It was not unexpected therefore that a diagnosis of SLD indicated a significant risk for dysgraphia or handwriting problems in the current study (Table 9.4). These students were likely to have attained their potential at school due to early diagnosis and support provided. Approximately two thirds of these students with SLD had attended occupational therapy as children and most of these students had been assessed by educational psychologists and had been awarded extra time and other concessions at school.

It is of concern that approximately 30% of the students had not been previously identified as having any diagnosis but were referred for possible handwriting deficits. This may be due to students presenting with milder learning disabilities and thus being able to cope at school without support. Their problems may have gone unnoticed or support for these problems may not have been available. Many public schools in South Africa have no access to services required for the assessment of SLD and other conditions which affect academic performance including handwriting [Moolla and Lazarus, 2014].

The problems identified in the demographic profile of students in Phase 1 were the visual problems and pain which they reported most interfered with their handwriting. The results for the sample of students in Phase 3 confirmed that the presence of visual problems and pain did significantly affect handwriting. Pain was found not only to significantly affect the performance on the Observation Checklist and outcomes of students' writing in relation to copying and automaticity but also placed them at higher risk for dysgraphia (Table 9.3 and 9.4). The presence of pain, particularly if pain was observed in the short time needed to complete the Handwriting Screening Assessment, was a clear indication that these students were at risk for dysgraphia or handwriting deficits and required referral for further assessment.

The short duration of the Handwriting Screening Assessment does not allow for the effect of pain behaviour to be determined in a long examination. This confirms the importance of assessing pain related to handwriting and interpreting the effects of pain behaviour with the possible addition of a subtest to the Handwriting Screening Assessment to reflect this as suggested in Phase 2 of the study.

Visual function also impacts on handwriting performance and outcomes although its relationship to risk for dysgraphia or handwriting deficits is not as clear. This was discussed in Phase 2 of the current study and under the Observation Checklist Subtest 6 *visual function* below.

10.2.2 Deficits in the components of handwriting

10.2.2.1 Specific deficits associated with handwriting dysfunction in students referred for assessment

The characteristics of the deficits that occurred in more commonly in students referred for handwriting assessment were considered. It was important to determine if these items and subtests could be related to those reported in the literature for children and adults so that the link to possible client factors deficits could be confirmed. Various items of the Observation Checklist and the Writing Checklist and subtests of Handwriting Outcomes were associated with the risk for dysgraphia and handwriting problems. Although these items form part of subtests where no significance difference was found between typical students and those referred for handwriting Assessment, the items themselves should be retained as students with low scores on these items are at significant risk for dysgraphia and handwriting deficits subtests scores. The items are discussed below related to the characteristics of deficits found and suggested further assessments.

Observation Checklist

The main finding for the Observation Checklist is that although a number of items assessed on this checklist placed students at risk for dysgraphia and handwriting problems these were not directly associated with the outcomes of handwriting. Individual variations meant that the deficits observed resulted in slow handwriting in some students and a lack of legibility in others with no consistent pattern seen. For some students, no association with handwriting outcomes were found the short screening assessment but as discussed below they presented with observable deficits that affect their ability to produce handwriting efficiently.

The results of the current study confirmed the effect of the positioning and the fixation of the paper on which the student writing. This component has been reported as important for children when learning to write, with limited published studies which consider the effects paper placement and their role in dysgraphia in adults [Lohman, 1993; Pollock et al., 2009]. The findings of Lohman (1993) which indicated that the position of the paper on the table affected legibility was not supported in the current study. where the position and fixation of the paper was related to observed components of handwriting related to the writer [Lohman, 1993]. Approximately 30% of students referred for assessment placed the paper vertically and 6% placed it horizontally on the table. It was noted that the position of the paper appeared to be associated with the positioning of the writing hand on the table, wrist position and posture when writing. When the paper was positioned vertically fewer students positioned their forearm on the table and they flexed their trunk laterally away from the writing hand. These students also wrote with an increased range of extension or wrist flexion. The increased extension of the wrist noted in the current study needs to be added to the Observation Checklist as this position as well as wrist flexion have been associated with pain when writing [Chang et al., 2015; Yu and Chang, 2011]. Less lateral flexion of the trunk was noted in students who positioned the paper horizontally but they supported their entire forearm on the table when writing.

Lateral flexion of the trunk was recorded for 80.3% of students (Figure 9.2) indicating that this is the most common posture used when writing. Therefore, it appears that the posture used when writing does not dictate the position of the paper on the table and that the position of the paper on the table is specifically associated with a higher risk of dysgraphia or handwriting problems.

The effect of posture associated with the performance skill of Aligns, on handwriting in adults is not clear. The items with lower scores the posture commonly recorded for the majority of students referred for handwriting assessment did not correlate with a higher risk for dysgraphia or handwriting problems. This was also true for the position of the forearm on the table has been associated with poor postural control and proximal stability in children [Feder and Majnemer, 2007; Pollock et al., 2009]. This position of the forearm was used by 80% of students in the current study may indicate the need to compensate for postural control but may also be used by the students to reduce the energy required to stabilise the upper limb while writing. The latter assumption is supported by research which indicated that decreased stability of grasp and decreased movements in the thumb and fingers (found for 49% of students in the current study), has been associated with an increased in EMG activity at the shoulder and elbow when writing [de Almeida et al., 2013; Engel-Yeger and Rosenblum, 2010; Naider-Steinhart and Katz-Leurer, 2007]. These results support the need for further assessment of upper limb strength, endurance and postural control in the students referred for assessment.

Although the position of the non-writing hand on the table and fixation of the paper with the non-writing hand were not related to the risk for dysgraphia, resting both hands on the table and fixation of the paper when writing is advised for proficient handwriting [Exner, 1989]. While most students did rest their non-writing hand or forearm on the table, 52% of them used this hand to follow the text they were copying and thus were unable to fixate the paper on which they were writing. Students seemed to be unaware of the need to stabilise the paper even when the paper they were writing on moved as they wrote which affected the efficiency of their handwriting.

While 46% of students rested their entire forearm of the non-writing hand on the table which may be associated with deficits in postural control or proximal stability, 7% of students placed their non- writing hand in their lap or used it to support their head. This latter placement of the non-writing hand may reflect problems with bilateral co-ordination [Amundson, 1992; Feder and Majnemer, 2007]. As suggested by Benbow et al. (1992) the observations reported for fixation of the paper and the used on the non-writing hand in the task may be related to deficits related to bilateral integration and midline crossing which were present in childhood [Amundson, 1992; Benbow et al., 1992] which may now have become habituated.

A third of students also flexed their trunk forwards while writing. This flexed posture where some students leaned so far forward that their faces were within 20cms of the table was associated with a higher risk for dysgraphia or handwriting deficits (Table 9.5). This is supported by the findings of Rosenblum et al. (2006) in their study with children where they found a strong correlation between flexed posture and poor fluency in writing [Rosenblum et al., 2006]. In the current study posture and initially it was assumed that flexed posture may associated with poor postural control due to low postural tone and an inability to sustain an upright position against gravity [Amundson, 1992; Rigby and Schwellnus, 1999]. However, a number of students were found to have visual acuity problems which meant they could not see what they were writing without flexing close to the page. Thus, the descriptors need to be reviewed and changed under Observation Checklist Subtest 2: *Posture.* The descriptors need to differentiate between posture that becomes increased flexed over time due to fatigue related to low tone and postural control from the immediate very flexed posture due to visual acuity, evident as soon as the student starts to copy. The latter observation should be assessed under Observation Checklist Subtest 6: *Visual function*.

Another issue with the descriptors in observation Checklist Subtest 2: *Posture* was related to the ability of the students to remain still while writing also needs to be expanded. Initially it was assumed inability to remain still was related to poor postural control due to low postural tone which affects the students' ability to maintain an upright position [Amundson, 1992]. Although these adjustments were observed in 23% students, it was noted that some students adjusted their posture due to the presence of pain in their trunk rather than poor postural control. In conjunction with the history of handwriting problems questionnaire the cause of a student's flexed posture and postural adjustments while writing must be determined by differentiating the appropriate the reason for the observed deficits. Appropriate referral for further assessment can then be made.

It is not always easy to suggest which further assessments should be used with these students to confirm the observations recorded on the Observation Checklist. Assessments for components such as postural control, proximal stability and bilateral integration for adults are usually designed for patients with more severe deficits than those seen in the students in the current study. While standardised assessments for sitting posture are helpful it was found that muscle strength assessments were not always useful in determining deficits in proximal stability. However, for some students, assessment of passive range of motion and joint laxity may provide the evidence for a lack of proximal stability.

The use of standardised job samples such as that for fine dexterity from the Valpar International Corporation [Valpar International Corporation, 1996] can be used to evaluate bilateral function and may prove useful for assessing the ability to use both hands in other tasks. The use of these assessments can be recommended based on the observations of the poor use of the non-writing hand to support recommendations.

The first of the subtests identified in relation to holding a pen in the current study was Observation Checklist Subtest 3: *Stability of grasp* associated with the performance skill of Calibrates. The item which was associated with a risk for dysgraphia on this subtest was the position of the DIP joint of the index finger. Hyperextension of the DIP joint of the index finger observed in over 60% and hyperflexion of the IP joint of the thumb observed in 51% of the students referred for handwriting assessment (Figure 9.3), have been considered to interfere with the use of a dynamic tripod pen grasp [Benbow, 2006]. In the current study, however the hyperextension of the DIP joint of the index finger and hyperflexion of the IP joint of the thumb were associated with a lower risk of dysgraphia or handwriting problems for presentation and legibility of handwriting (Table 9.5). Students using hyperextension of the DIP joint and hyperflexion of the PIP joint achieved handwriting that was more presentable which may be associated with excessive force being applied to the pen or an accommodation for joint laxity to afford fine motor control for the production of neater more legible writing handwriting [Selin, 2003; Summers, 2001]. Therefore, it appears important the position of the DIP joint of the index finger and the IP joint of the thumb be recorded separately and not combined into one item as suggested in Phase 2 of the current study.

Benbow (2006) suggested that if this use of force or poor joint position when holding a pen is not addressed when learning to write, the poor grading of force and pen grasp developed becomes automatic and difficult to change adulthood [Benbow, 2006]. This appears to the students in the current study and this inappropriate use of force in the hand appears to result in fatigue and pain associated with an overuse phenomena resulting in fatigue involving ligaments, tendons and soft tissues with the risk of work related upper limb syndrome or cumulative trauma injury [Freund and Takala, 2001; Lay et al., 2002]. This occurs particularly when writing is required over a period of time as in higher education situations. This has resulted in severe pain when writing even for a short time as seen in half the students referred for handwriting assessment in the current student [Engel-Yeger and Rosenblum, 2010; Summers and Catarro, 2003].

The second component of pen grasp associated with the performance skill Grips, as defined and assessed in the current study considered where the pen was held in the hand and the classification of the pen grasp used. None of the items for this subtest present with low scores for the students referred for handwriting assessment (Figure 9.4). This indicates that this subtest is probably redundant and that the items under pen grasp are not related to identifying risk for dysgraphia in this sample of students. This is supported by Schwellnus et al. (2013) in a recent study which found that the type of pen grasp has no effect on the force with which the pen is held or legibility of handwriting [Schwellnus et al., 2013a]. The type of pen grasp sheet was removed from the Handwriting Screening Assessment as it appears that this component does not need to be assessed.

The third component related to holding the pen that was defined in the current study was writing movements associated with the performance skills of Manipulates and Coordinates. While none of the items in the subtest for this component was associated with the risk for dysgraphia, the deficits were noted for 18% of students who wrote using the thumb alone or 31% who wrote with hand movement rather than finger and thumb movement (Figure 9.5). The use of the thumb or hand movement to write, results in a static grasp which requires more proximal muscle activity and proximal stabilisation as well as greater postural adjustments [de Almeida et al., 2013].

Using hand movement rather than the finger or thumb to write has also been associated with a static grasp which limits the use of intrinsic muscles in the hand. This appeared to account for the number of students reporting forearm pain when they wrote as they used extrinsic muscles in the forearm rather than intrinsic muscles in their hands [Contreras-Vidal et al., 1998]. Writing using thumb movement has also been linked to a closed web space and pain in the thumb and forearm due to the inefficient use of one digit in performing writing movements [Benbow, 2006]. Therefore, although items on the Observation Checklist Subtest 5: *Movement in fingers and hand* were not related to the risk for dysgraphia and most students did not present with deficits on these items this subtest, the items on this subtest were linked to pain when writing. The subtest was retained as it provided evidence for further assessments for fine motor function which were used to determine the possible cause of pain when writing.

It is suggested that assessments for proprioception and kinaesthesia also be completed with students with low scores on Observation Checklist Subtest 3: *Stability of grasp*. The assessment of pinch and grasp strength should also be considered. Other assessments of fine motor dexterity such as the Purdue Peg Board [Lafayette Instrument, 2002] and Nine-Hole Peg Test [Mathiowetz et al., 1985] can also be used to confirm deficits related to the use of the preferred hand as well as fine motor control and in-hand manipulation observed and scored Observation Checklist Subtest 3: *Stability of grasp* and Subtest 5*: Movement of the fingers and hand* .

The items in the Observation Checklist Subtest 7: *preferred hand and wrist position* were associated with a risk for dysgraphia and handwriting problems. This may be related to the increased activation in wrist and shoulder muscles when writing with the left hand [Park, 2013] placing students at risk of cumulative trauma injuries and pain in the hand and arm. Compared to Phase 1, there was a high percentage of left handed students (18%) in this phase of the study. This may reflect the higher percentage of students with SLD. This result is supported by the findings of Goez and Zelnik (2008) who reported that left-handedness occurred more often in conjunction with learning disabilities [Goez and Zelnik, 2008].

Although wrist flexion has been associated with left handed writing [Park, 2013] very few left handed students in the current study used wrist flexion. The use of wrist flexion when writing with the right hand appears to be related to the need to stabilise this proximal joint to assist with fine motor control of the fingers and thumb which may be related to the stability of grasp discussed above. These results indicate that this subtest should be retained in the Handwriting Screening Assessment as although very few students wrote with their left hand or wrist flexion, those that did were more likely to be at risk for handwriting deficits or dysgraphia.

All of the components assessed and discussed above were related to motor dysgraphia. Another component that was included in the Observation Checklist that has not been addressed in other handwriting assessments was the Subtest 6: *Visual function.* This was considered an important component for reading and transcribing information and copying numbers in examinations. This component was identified in the current study as significantly affecting copying speed and automaticity of handwriting. This was confirmed in Phase 2 where the scores for this subtest correlated with the scores for three subtests of the Handwriting Outcomes.

As discussed in Phase 2 Subtest 6: *Visual function* appears to assess fixation, visual attention [Valdois et al., 2004] rather than saccades and oculomotor function. This was confirmed by the Item 27: *head movement* which had a moderate negative correlation with the risk for dyslexia or handwriting deficits (Table 9.5). This item assesses how many words a student wrote before needing to look at the paragraph copied again or whether they can read the next word while writing the previous one [Bosse et al., 2014]. As suggested in Phase 2 he addition of an item which better assesses possible oculomotor function should therefore be considered for the Handwriting Screening Assessment.

Eye motility assessment should also be completed for students with visual function deficits, specifically those suggested for use by occupational therapists [Scheiman, 2002]. If possible referral of students to a vision optometrist should be considered if deficits are noted in eye tracking, fixation, convergence and binocular vision.

Writing Checklist

Deficits in the Writing Checklist Subtest 1: *Writing analysis* of handwriting were associated with the legibility of handwriting but not the outcomes of copying speed and automaticity. As for the Observation Checklist, other components assessed by the Writing Checklist placed the students at risk for poor performance in handwriting but these were not directed associated with the handwriting outcomes due to individual differences.

When the students' handwriting was assessed on the Writing Checklist and more than 80% of students did have deficits for not writing on the lines and unreadable words. These deficits are commonly seen in students' handwriting and did not correlate with a risk for dysgraphia or handwriting problems. Their writing did present other deficits commonly associated with dysgraphia including "inconsistent letter formations and slant, irregular letter sizes and shapes, unfinished letters and misuse of line and margin" p3 [Crouch and Jakubecy, 2007]. Each of these deficits except size of writing did correlate with a risk for dysgraphia associated with the legibility ARQ. Therefore, higher legibility scores indicated a higher risk of dysgraphia in terms of the presentation of their writing. This finding is not unexpected as 42% of students had handwriting that was below a level that was acceptable in terms of legibility.

The items in the Writing Checklist Subtest 1: *Writing analysis* may indicate issues with fine motor deficit but also need to be observed for possible spatial and visual perceptual problems associated with spatial dysgraphia. It is suggested that students be assessed with tests for fine motor dexterity described above or tests that are standardised for adults for visual perceptual deficits. These tests include the Visual Perceptual Supplemental Test of the Beery Developmental Test of Visual Motor Integration or the Test of Visual Perception Skills-3 to confirm if deficits affecting handwriting are present [Beery, 2010; Martin, 2006].

A high percentage of students referred for handwriting assessment presented with low scores on the Writing Checklist Subtest 2: *Endurance and fatigue.* Deterioration in handwriting over a five-minute period was moderately correlated with risk for dysgraphia. This component, which was associated with the performance skill of Endures, was related to writing endurance [Siegel, 1999b; Summers and Catarro, 2003]. It was unrealistic to assume that the short Handwriting Screening Assessment could effectively assess endurance for writing. However, when deterioration of handwriting occurred in five minutes of starting to write it could be assumed that the student would have problems in longer examinations, particularly if the deterioration in handwriting was associated with pain. This indicates the importance of reviewing test and examination papers written by the student to determine the effect of fatigue on writing over a longer period as part of further assessments. Test or examination answer books should be used to establish the presentation of the writing over time as well as how many questions were not answered. Other assessments for these components based on this short screening assessment are difficult to recommend although in a longer writing task, pinch and grasp strength and the strength of the upper limb may be suggested.

When change in handwriting was observed in Item 9: *deterioration* the type of writing changed from printed to cursive writing. The use of a mixture of printed and cursive writing was found by Graham et al. (1998) to be the fastest in short writing tasks. This writing style also supports legibility in adult writers [Gozzard et al., 2012; van Drempt et al., 2011]. The Rasch analysis indicated that for the students in the current study cursive writing required more ability and was more difficult. However, 50% of students in this sample still used cursive writing. Most were reluctant to change and add printed letters which seems to indicate the inability to change a habituated skill. Therefore, suggesting a change in the type of handwriting is seemingly unrealistic for these students as the type of writing did not correlate with risk for dysgraphia and handwriting problems.

The **Writing Checklist** Subtest 3: *Punctuation* and Subtest 4: *Corrections and spelling* were included in the Handwriting Screening Assessment to identify errors related to attention when writing [Crouch and Jakubecy, 2007; Deuel, 2001]. Scores for punctuation, corrections and spelling for this sample of students correlated moderately with the risk for dysgraphia. These results are supported by the findings of Tops et al. (2013) who found a mean difference for punctuation errors between dyslexic and non-dyslexic university students when summarising a passage [Tops et al., 2013].

All the items in the Writing Checklist Subtest 5 *Missing letters and words* including omitted letters at the end of words, omitted words and omitted lines of text were also strongly or moderately correlated with risk for dysgraphia. These items or components were associated with the performance skills of Heeds and Attends as well as Adjusts. Deficits on these items were related to visual attention although literature indicates they could also be associated with oculomotor function [Farrar et al., 2001; Tassinari and DeLand, 2005]. However, in the current study as discussed in Phase 2 no correlation to oculomotor function on the DEM 2.0 was found. Tops et al. (2013) found similar results for missing words in their study where dyslexic students left out twice as many words as non-dyslexic students when copying [Tops et al., 2013]. They did not suggest the reasons for this, only that they were associated with dyslexia.

Although few students made errors related to punctuation, missing letters and words as well as missing lines of text when copying but these subtests were retained as the presence of errors in these subtests indicate the need for further assessment for spelling and visual attention. Students with deficits on the items on the last three subtests on the Writing Checklist should be referred for assessment for dyslexia using the DAST or other recognised assessments for adult dyslexia.

Handwriting Outcomes

The legibility subtest ARQs in the Handwriting Outcomes section of the Handwriting Screening Assessment, did correlate with risk of dysgraphia and handwriting problems. This indicates the importance of retaining this subtest in the Handwriting Screening Assessment to assist with the identification of the small percentage of students who score 6 or 7 for legibility, which places them at very high risk for dysgraphia or handwriting deficits.

Between 70% and 80% of the sample had scores for WPM for copying speed and LMP for automaticity of writing assessed by the WSAM Alphabet task that were significantly lower than those of the typical students. This supports the use of a standardised handwriting assessment such as the DASH 17+ in the assessment of handwriting deficits in university students requiring extra time. The results indicate however that other components are significantly associated with the risk for dysgraphia that are not assessed in the DASH 17+ so the used of this assessment alone to recommend concessions is inadequate. It is important to provide evidence of the factors influencing the poor handwriting outcomes when suggesting concessions to the stakeholders at Wits and the regulatory boards for accountancy and law who request proof of concessions provided by the university when students write board examinations [Legal Education and Development, 2015; The Colleges of Medicine of South Africa, 2016; The South African Institute of Chartered Accountants, 2015].

In summary, these results show that a number of observations scored on the Observation Checklist can be used to determine deficits in the students referred for handwriting assessment. The components observed not unexpectedly relate to the lack of proximal stability and stability in the hand which are problems commonly described in children with handwriting dysfunction and which appear to remain unresolved in these adults students [Benbow, 2006; Ziviani and Wallen, 2006]. This is also true for the position of the paper, the preferred hand and wrist position [Lohman, 1993; Park, 2013] but components related to posture have not previously been shown to be associated with a risk for dysgraphia or handwriting problems in adults. It was suggested that a number of these deficits may be linked to pain in the hand and arm when writing.

The assessment of head movement under visual function on the Observation Checklist and missing letters, words and lines of text on the Writing Checklist also correlate with the risk for dysgraphia or handwriting problems in this sample of students. It is not clear to what extent these items assess visual inattention or oculomotor function and further investigation with a vison optometrist would be required to establish what aspect of visual function correlates with the risk for dysgraphia and handwriting problems. Aspects of writing on the Writing Checklist such deterioration and other subtests which assess errors when writing were associated with a risk for dysgraphia or handwriting problems in the students. These had only been identified as associated with dyslexia previously [Tops et al., 2013].

For Handwriting Outcomes, Subtest 2: *Legibility* subtest had strong and moderate correlations to the risk for dysgraphia or handwriting problems in this sample of students. Handwriting Outcomes, Subtest 1: *Copying speed and automaticity* did not correlate with the risk for dysgraphia or handwriting deficits, but this subtest has been shown to be a valid measure for these problems in Phase 2 of the current study. Suggestions for further assessments could be made based on the identification of the items which correlated with the risk for dysgraphia or handwriting problems.

This chapter also provides an evaluation of the items and subtests which reflect deficits for these students which need to be revised or reconsidered in terms of their usefulness with identifying handwriting problems. The results of this phase supported retaining subtests which did not indicate significant differences between typical students and those referred for handwriting assessment in Phase 2. These subtests all had items which correlated with the risk for dysgraphia (Appendix W). Even though a small percentage of students were found to have deficits on these items this provided evidence that these students should be assessed further on the components. Only the pen grasp subtest was considered to be redundant and not useful in determining risk for dysgraphia or handwriting deficits.

To improve the usability of the Handwriting Screening Assessment the information about components or items associated with the risk for dysgraphia or handwriting deficits should also be made available to those who administer the assessment to assist with the interpretation of the results.

10.3 Part 2: Utility of the Handwriting Screening Assessment for students with dysgraphia or handwriting deficits

It is also important that the screening assessment is seen to have benefits for the stakeholders who will use it and the target population [Glover and Albers, 2007]. The factors associated with the types of dysgraphia were explored to determine if this could guide those administering the assessment with the recommendations for concessions. The academic outcomes for the students who were awarded extra time concessions were considered to determine if the screening was effective in compensating for their dysgraphia and handwriting problems

10.3.1 Types of Dysgraphia

The second objective for this phase of the study determined the different types of dysgraphia based on the scores of the 50 students identified at risk of handwriting deficits. The scores for spelling errors made, the organisation of letters when writing as well as the writing movements in the hand were compared. Although legibility for copied text should also differ and be more preserved in students with dyslexia dysgraphia, no criteria where given for legibility by those describing types of dysgraphia. Since most research has been done with children learning to write it was assumed that legibility as described by [Berninger et al., 2008a; Deuel, 2001] is related tidy neat handwriting expected in the lower grades [Berninger et al., 2008a; Deuel, 2001]. Since this is not true for adult handwriting which becomes individualised, and can still be legible with deviation from these criteria, legibility was not included in the analysis for this sample of students.

Students were divided into groups according to their scores on the spelling item in the Handwriting Screening Assessment (Table 9.6). A non-significant difference was found between the number of spelling errors and the writing movements in the fingers, hand and thumb for these students. The results indicate that students who made no spelling mistakes had lower scores for the Observation Checklist Item 25: *writing movements* (Figure 9.16). Writing with the fingers and thumb rather than the hand or thumb alone could be directly associated with fine motor control on the Handwriting Screening Assessment. Analysis indicated that the fine motor control was more affected in those who had higher scores for spelling. These students can be considered to present with motor dysgraphia. The opposite is true for dyslexic dysgraphia where students with low scores for spelling had higher scores for their fine motor control. The addition of another fine motor screening such as finger tapping to the Handwriting Screening Assessment should be considered to confirm motor dysgraphia

By understanding what components are affected in different types of dysgraphia various concessions may be recommended for the students in conjunction with extra time. The appropriate concessions which should be considered for motor dysgraphia include rest periods and appropriate seating if writing is associated with poor fine motor and poor postural control which may result in pain. Typing rather than writing examinations is also a concession which can be recommended for students with motor dysgraphia. Research has shown however that typing does not necessarily solve the problem for all students, as this activity may be affected by the same components that affect handwriting such as fine motor control, errors and poor posture resulting in fatigue and pain [Jones, 1999].

Students with dyslexic dysgraphia may need assistance with text to speech software to read examinations questions for them as well as spelling concessions. Exam papers printed in larger font may also be helpful.

To identify spatial dysgraphia, the organisation of letters associated with the spatial element in the writing was analysed. Students with lower scores for Writing Checklist Item 3: *organisation of letters* had higher scores for Observation Checklist Item 25: *writing movements* indicating better fine motor function. These results suggest that those with spatial dysgraphia can be identified if their scores for the organisation of letters in words. Concessions for spatial dysgraphia may include typing concessions as well as extra time with guidance on the presentation of written work.

10.3.2 Academic Outcomes of Extra Time Concessions

The third objective of this phase of the study was to explore the effectiveness of concessions provided, specifically the extra time concessions. These extra time concessions were evaluated according to the academic outcomes of the students only in relation to passing and failing and not their actual marks.

The actual extra time and concessions awarded to each student was known to the researcher but other support and assistance received by the student was not known. In the year students received their concessions there was no significant decrease in the number of students who were required to repeat a year or a course. This indicated that awarding extra time alone may not be an adequate concession for all students. Research on this aspect should consider each individual case however and other support may need to be provided in the form of tutors, provision of notes and training in exam techniques. The provision of concessions in the classroom, with referral to student support structures and an interdisciplinary team approach in addressing handwriting problems also needs to be advocated. While some students did provide positive feedback on the concessions received many did not. One student who was awarded extra time and allowed to type his essay examinations, reported an increase of 30% in his marks which brought his examination marks in line with marks he had been receiving on assignments all year.

Significantly more students passed in the year following the awarding of extra time concessions. This may reflect the results of students who applied for the concession late in the year before when they were already failing. These results also reflect a cohort where students who were not going to achieve at university, had left or been excluded. Therefore, the results of this objective must be interpreted with care as the academic outcomes cannot be directly aligned with the extra time concessions alone and this analysis was completed to explore if there was any possible benefit in screening for handwriting deficits in this sample of students in terms of their academic outcomes.

CHAPTER 11 CONCLUSION

11.1 Main findings of the study

This chapter presents a summary of the findings of the study for each phase. The strengths and contribution of the study as well as the limitation and recommendations for further research are included. The purpose of the current study was to explore the role of deficits related to handwriting in students in higher education and the possibility of developing a screening assessment to identify these deficits in these students. There was little or no evidence for the awarding of concessions, particularly extra time concessions to students who presented with handwriting problems which interfered with their academic outcomes. Dysgraphia has only recently been confirmed as a separate SLD so no formal assessments which screen for various components which may affect handwriting are available for adult students.

Currently in South Africa, at a post-secondary and university level controversy remains as to what assessments and at what level of dysfunction concessions should be awarded for specific learning disabilities, including dysgraphia. The decision to award a concession is, therefore often made without the professional consulted having any specific evidence to support their recommendations [Koenig and Bachman, 2004]. They often have a lack of knowledge about appropriate accommodations and have to use their personal opinion when choosing assessments and making recommendations for academic concessions [Lindstrom, 2007]. This illustrates the need for specific assessments in the assessment of SLD including dysgraphia and other handwriting deficits for students in higher education.

Occupational therapists researching handwriting dysfunction in children have identified the need for a comprehensive assessment that provides the opportunity to observe the abilities of the student during the handwriting task. An analysis of the ability of the person being observed and how this affects the task in terms of the execution and the end product over time particularly in handwriting was required [American Occupational Therapy Association, 2014; Rosenblum et al., 2006]. While this premise has been addressed in a handwriting assessment for children [Erez and Parush, 1999], no screening assessment for adult students which assesses the writer, the presentation of handwriting and the outcomes of the handwriting could be found.

The current study was undertaken to develop and evaluate a handwriting screening assessment for university students requesting concessions for examinations due to handwriting problems. This was based on a need at Wits where a valid and reliable assessment which could identify students at risk for dysgraphia or handwriting problems had been identified. It was preferable that the screening be available to whoever in the target population requested and was referred for assessment of a handwriting problem. The assessment was therefore intended for use at Wits University and other universities in South Africa with the intention that it be integrated into the screening of students for concessions and intervention at student disability services dealing with this population [Andermann et al., 2008]. Students found to be at risk for dysgraphia or handwriting problems could then be referred for further standardised assessments allowing appropriate recommendations for concessions to be made.

The study was completed in three phases.

Phase 1:

Part 1: Development of the Handwriting Screening Assessment

Handwriting is a complex skill which requires the coordination of various client factors related to the different components of handwriting, if a student is to be productive in the academic context. In terms of timed examinations at a university level, the student needs the ability to produce acceptable handwriting over a set period of time. The automaticity of the writing should allow the student's working memory to be available for other cognitive functions related to answering questions.

Since most studies on handwriting are based on children, handwriting components are more commonly presented in relation to a developmental framework or deficits in client factors. There is also little evidence that these components of handwriting which are associated with poor handwriting or dysgraphia in children, affect handwriting in university students. The aim of the screening assessment developed in the current study was to consider not only the outcomes of handwriting in terms of speed, automaticity and legibility but also the components which effect of the student as a writer and the presentation of their writing. The components of handwriting based on a framework of performance skills that could be observed both when the students were writing and in the handwriting, was therefore proposed. Once all the components of handwriting had been presented in the motor and performance skills framework in the OTPF III in the literature review the domains for the Handwriting Screening Assessment based on motor and performance skills were operationalised. Associated handwriting components and client factors were included in the matrix.

The items for Handwriting Screening Assessment were then developed. This was done in three different sections with the students' behaviour while writing being assessed on an Observation Checklist, the presentation of their writing being assessed on a Writing Checklist and performance when writing being assessed in terms of speed, legibility and automaticity on the Handwriting Outcomes. Content validity was established by expert opinion for the Observation Checklist and the Writing Checklist. The Handwriting Outcomes were based on those used in other assessments which had proven validity.

Part 2:

Construct validity was established and factor analysis and Rasch analysis were used to investigate the dimensionality of the Observation Checklist and the Writing Checklist by reviewing the records of 287 students previously referred for handwriting assessment. Further Rasch subtest analysis based on subtests which reflected the motor and process skills associated with components of handwriting was then completed. The conclusion from this pilot study was that the Observation Checklist and the Writing Checklist subtests did fit the Rasch analysis. The components of handwriting showed no local dependency although handwriting could not be assessed as a unidimensional construct. Item validity was established with the exception of two subtests. Based on the limitations of the information available in the records and that the sample consisted of students referred for handwriting assessment it was concluded that the Observation Checklist and the Writing Checklist subtests had satisfactory construct validity and could be further evaluated using typical students as well as those refereed for assessment of their handwriting.

Phase 2: Psychometric properties of the Handwriting Screening Assessment

The items and subtests on the Observation Checklist and the Writing Checklist were further validated using Rasch analysis with data from 298 typical students and 61 students referred for assessment of their handwriting. Both checklists fitted the Rasch subtest analysis although the person separation index was low. Results indicated that the components assessed on the Handwriting Outcomes fell into acceptable ranges. The results provided evidence of construct validity which was further strengthened by studies to determine differences on known factors of age, gender and school attended. The differences in scores on the Observation Checklist, the Writing Checklist and Handwriting Outcomes between typical students and those referred for assessment further supported the construct validity of the Handwriting Screening Assessment. Significant differences were found in the scores of typical students and those referred for handwriting assessment on nine of the 15 subtests. This provided satisfactory validity for the Handwriting Screening Assessment although further research and revision of the subtests was suggested. The subtests where no significant difference between the two groups students were retained for further investigation. This was completed in Phase 3 of the current study where the association of items in the subtests with the risk for dysgraphia and handwriting problems for guiding further assessment was addressed. Reliability studies confirmed satisfactory internal consistency and inter-rater reliability for the subtests on all three sections of the Handwriting Screening Assessment.

Since the low PSI on the Rasch analysis did allow the division of students into different levels of ability on each subtest and only into two groups for the checklists, ARQs were used to identify students at different levels of risk. The use of cut-off points based on normative data of the typical students and ARQs was shown to be valid by determining the difference between typical students and those referred for handwriting assessment when risk for dysgraphia or handwriting problems was analysed. These results also confirmed the need to consider different components of handwriting as not all students presented with risk on all the sections of the Handwriting Screening Assessment. This confirms the importance of using a more inclusive assessment when screening the students' assessment of speed, legibility and automaticity of handwriting was not adequate to all identify students at risk for dysgraphia or handwriting problems.

The validity of the Handwriting Screening Assessment was further confirmed by the specificity based on the cut off points identified using ARQs, except for legibility. Negative predictive values for all sections allowed for 84% and 86% of students whose scores fell below the cut-off points to be excluded with no risk for dysgraphia or handwriting problems. Unfortunately, sensitivity was low so students at risk of dysgraphia and handwriting problems may potentially be missed when using the Handwriting Screening Assessment. These students would be at lower risk for dysgraphia and handwriting problems however.

Convergent and divergent validity confirmed that only the Handwriting Outcomes ARQs were convergent with reference assessments for handwriting speed as well as RAN and oculomotor function. As expected the components of handwriting assessed by the Observation Checklist and the Writing Checklist ARQs were divergent from the reference tests as they measured different components. The two subtests on the Observation Checklist and the Writing Checklist developed to assess visual function were not convergent to oculomotor function assessed by the DEM 2.0. Therefore it is possible that visual attention rather than saccades was assessed on the Handwriting Screening Assessment.

It was concluded that in its present form the Handwriting Screening Assessment had satisfactory validity and reliability to identify students at risk for dysgraphia or handwriting problems. However, the assessment could be improved and re-evaluated in terms of the sensitivity of the items on the Observation Checklist and the Writing Checklist as well as the constructs assessed in relation to visual functioning.

Phase 3: Usability of the Handwriting Screening Assessment for the target population

Further analysis of the results for students referred for handwriting assessment was completed to determine the most common deficits found and which deficits were associated with risk for dysgraphia or handwriting problems. This supported the usability of the screening assessment for stakeholders who administer the assessment and interpret the results as they can be informed about what constitutes risk in these students and what further assessments are required. It was confirmed that pain, visual problems and a previous diagnosis of SLD place students significantly at risk for dysgraphia or handwriting deficits.

The Handwriting Screening Assessment was shown to be valid in identifying factors related to handwriting problems in relation to scores on the Observation Checklist and Handwriting Outcomes and level of risk for dysgraphia. Correlations between items and subtests on the three sections of the Handwriting Screening Assessment and level of risk for dysgraphia or handwriting problems confirmed that risk can be identified in the behaviour observed when writing as well as in the presentation of the writing and the handwriting outcomes. After this phase of the study it was clear that the pen grasp subtest was redundant. The lack of correlation between the Handwriting Outcomes Subtest 1: *copying speed and automaticity* ARQs and the other items on the Handwriting Screening Assessment confirmed that individual differences result in deficits assessed by the Observation Checklist and the Handwriting Checklist cannot be directly associated with these handwriting outcomes. Students in this sample compensated in different ways for their deficits and therefore each student need to if further assessments and concessions suggested are to be defensible.

The utility of the assessment to guide recommendations for concessions were based on identifying trends for types of dysgraphia in the sample of students identified with handwriting deficits. Differences in components related to spelling, writing movements and organisation of letters were useful in differentiating between different types of dysgraphia. These findings are based on a small sample and need to be interpreted with caution but provide evidence that the types of dysgraphia can be identified in these students.

Academic outcomes in terms of the pass rates for students who received extra time to indicate any benefits of identifying and providing concessions was also considered. The outcomes of concessions provided for the students did not show a significant difference in the year they were provided but many factors affect students' ability to pass a course.

The reality is that in the future, handwriting examinations may be replaced with typed examinations, but if the essay type format is retained, students who present with dysgraphia and handwriting dysfunction may well be as compromised due to visual functioning, fine motor control and visual perceptual problems when typing examinations. Therefore, an adjunctive assessment similar to the Handwriting Screening Assessment which assesses behaviour while typing and the quality of layout, spelling and punctuation in typed work can be adapted from the current study.

The Handwriting Screening Assessment developed in the current study did meet the criteria for usability described by Glover and Albers (2007) [Glover and Albers, 2007]. The assessment is low cost and does not take long to administer. The use of this screening assessment could reduce the burden of work as unnecessary formal assessments will not be carried out with students to determine risk for dysgraphia or handwriting problems. The administration of the screening instrument is feasible within the resources of the university and the service is offered to student without financial means who cannot afford to pay for assessments in the private sector. The assessment was suitable for the target group and the setting and the results were accepted by the referring professionals at CHWC as evidence for the need for further assessment. The infrastructure for referral and implementing the recommendations from the results of the screening assessment and providing concessions exists at Wits.

11.2 Strengths of the study

The strength of the study was the development of a screening assessment based on the steps of instrument development and the criteria for developing and evaluating the measurement properties of screening assessments set by AREA [Glover and Albers, 2007]. The screening assessment was developed for a target population, for which no screening assessment for dysgraphia and handwriting deficits existed. A rigorous process of instrument development was followed to examine the psychometric properties of the Handwriting Screening Assessment. The development and evaluation of the psychometric properties of the assessment followed the criteria on the COSMIN checklist. The study incorporated the assessment of an adequate sample of students to complete the Rasch analysis and psychometric analysis of the Handwriting Screening Assessment. Missing data were handled by eliminating those records from the sample. The criteria for the acceptable level of each psychometric test were confirmed from the literature and it was ensured that the statistics matched the distribution of the data and the type of scales represented.

The Handwriting Screening Assessment was multidimensional and had three sections, the Observation Checklist and the Writing Checklist and the Handwriting Outcomes. The checklists were assessed separately with the fit of the subtests on the Observation Checklist and Writing Checklist being confirming by Rasch subtest analysis. All requirements for Rasch analysis was addressed including residual fit, local dependency, DIF and dimensionality.

A number of other methods were used to determine construct validity and the reliability of the Handwriting Screening Assessment to including the Handwriting Outcomes, to ensure that the assessment measured components related to handwriting deficits. The study included content validity, construct validity (assessed by differences between known group factors and typical students and those referred for handwriting assessments on the subtests and ARQs and clinical accuracy) as well as the convergent and divergent validity against reference tests for handwriting speed and oculomotor function. These differences were confirmed when using ARQs to identify students at risk for dysgraphia and handwriting problems. The validity of the cut-off points and ARQs were supported by negative predictive values and specificity scores which excluded those students without dysgraphia and handwriting deficits.

Convergence to reference tests was found for copying speed and automaticity of handwriting. This confirms the value of the Handwriting Screening Assessment for assessing these components. The divergence of the subtests of the Observation

Checklist and the Writing Checklist to the reference tests indicate the importance of the Handwriting screening Assessment in determining deficits in other components of handwriting which the current study confirmed require assessment in students referred for handwriting if further assessments and concessions are to be justified for these students.

Normative data for the typical students in higher education for comprehensive components of handwriting, which had not previously been reported, was determined. The current study showed the importance of assessing these components which support the identification of risk for dysgraphia and handwriting deficits relative to typical peers for observation of the writer and the presentation of handwriting. Copying speed scores and legibility scores for South African students in higher education who had been referred for handwriting assessment had also not previously been reported. Based on the results of Phase 2 of the current study the Observation Checklist and Writing Checklist and the Handwriting Outcomes were found to have satisfactory validity and reliability.

The interpretability of the Handwriting Screening Assessment was addressed in Phase 3 of the study when the usability was considered, providing new knowledge about the students in higher education referred for handwriting assessment and the characteristics of the deficits with which they present. The population fit or demographic profile for students referred for assessment related was established

The current study confirmed that the presence of pain and problems related to visual function resulted in low scores on the Handwriting Screening Assessment and place this sample of students in higher education at significant risk for dysgraphia or handwriting problems. The importance of these two aspects need to be emphasised and considered when assessing handwriting deficits or dysgraphia. As suggested by COSMIN the percentage of students with the lowest and highest score on each item of the Handwriting Screening Assessment were described. This allowed the previously unknown characteristics of handwriting deficits in students in higher education to be determined. This confirmed that components such as the position of the paper on the table were associated with a high risk for dysgraphia in students in higher education. These components, for which a low percentage of students had deficits, were therefore retained when screening students for handwriting as their presence is likely to identify dysgraphia of handwriting deficits.

The component of holding and using the pen were divided into three different clearly defined subtests with no local dependency. In previous research, no such distinction was made and these different aspects were all considered under pen grasp. Other subtest which had not previously been reported in relation to handwriting assessment for students in higher education included posture and fixation of the paper with the non-writing hand on the Observation Checklist.

On the Writing Checklist errors divided into subtests for corrections and spelling which is related to orthographic coding, and punctuation and capital letters which are related to allographic mechanisms had previously been reported in relation to dyslexia [Tops et al., 2013]. The subtest analysis also indicated that these components were separate constructs which needed to be assessed separately.

Another strength of the current study was the use of the framework of motor and performance skills to frame the analysis of the handwriting components in relation to adults, in an occupational therapy context. This allowed the development of an observation based assessment in which the process of handwriting writing could be observed which had not previously been described. The domains operationalised using this framework supported the division of handwriting components into subtests which were found to valid in the assessments of different components of handwriting.

It was found that differences in deficits in students' fine motor control, spelling and organisation of letters when writing could be used to indicate the type of dysgraphia with which they present. This finding could be used to improve the utility of the assessment for those who administer the assessment in guide appropriate concessions.

11.3 Limitations of the Study

The limitations of the study over the three phases are presented. In Phase 1 of the study the data used was a record review and although the records for all students were available, not all aspects on the items in the Handwriting Screening

Assessment were fully described in the records. Therefore, although there was no missing data some of the scoring on items may have presented a score which was inaccurate. Therefore, a second prospective study where more accurate data could be collected was used to confirm the validity of the Handwriting Screening Assessment.

It was understood that by including a larger range of variables in the Handwriting Screening Assessment which considers more than just the one clear construct such as handwriting speed and legibility, accuracy in the measurement may be sacrificed. It was however, important to extend the assessment of handwriting to a larger number of variables not scored in other tests so this limitation was accepted. According to Cheng et al. (2008) when the test is analysed with several subtests it can still be assumed to measure a single construct or trait and can be analysed as a whole but fidelity may be compromised [Cheng et al., 2008]. Therefore, although subtests were used, and did fit the Rasch model this is at the expense of PSI which was low for both subtests [Andrich, 2005]. The results also indicated that for the Handwriting Screening Assessment as with all assessments there was some lack of precision which needs to be addressed. This includes the clustering of person scores on the Rasch analysis as well as the low sensitivity of the Observation Checklist and the Writing Checklist. This can be improved by addressing the scale and scoring used in the items.

This also resulted in a lack of significant differences in all sections of the Handwriting Screening Assessment between the typical students and those referred for assessment. This was accommodated to some extent by identifying the students' specific deficits using cut-off points and ARQs [Fawcett and Nicolson, 1998]. A review of certain items which also affected the reliability of the study is required as outlined in the discussion of Phase 2 and Phase 3.

Therefore, the overall the validity of the Handwriting Screening Assessment appears to have been affected by a lack of sensitivity which may be related to the small scale used in each item. This aspect of the assessment needs to be reviewed as well as the Handwriting Outcomes Subtest 6: *visual function.* This subtest should be evaluated in terms of the descriptors used as well as the components it assesses. Further research into the assessment of the performance skills of Attends and Notice and Responds is required as well as how the role of oculomotor dysfunction in writing and copying in adults.

Other limitations for this phase of the study included the need to use convenience rather than stratified sampling. Although contact was made with various departments logistically it was not possible to find a time when students would be available to be assessed on a one to one basis that was also suitable for the researcher and research assistant. It proved easier to recruit and engage student in times when they were not busy with their academic programme. This resulted in a lack of representation of students in the different faculties that was reflective either of the percentage of students enrolled in each faculty or the number of students referred from each faculty for assessment. Factors related to the inconsistent use of various venues also meant that the ergonomic factors in relation to the furniture used could not be controlled to ensure all students were accommodated in terms of the size of the furniture.

There was no check made other than self-reporting by typical students that they had no history of learning problems or previous concessions. Since no names or student numbers were recorded this could not be checked. Certain components related to anxiety and psychosocial components were not included in the current study. This is a shortcoming of the study as these components also play a role in writing examinations and may affect handwriting. The role of these components does require investigation in the future.

The study was limited by a small sample size of student referred for assessment in Phase 2 and Phase 3. This placed the results at risk of a type I error and increasing the significance of differences reported for some aspects. This is true when the students were divided into groups for further analysis such as types of dysgraphia. The sample size was limited by the small number of students referred for assessment of handwriting at Wits and the findings for this phase of the study must be considered as exploratory. Further studies based on the Handwriting Screening Assessment should be considered over a period of time and at other universities to accommodate this limitation. This would improve the generalisability the assessment and confirm if the students at risk for dysgraphia present with similar characteristics in terms of factors related to handwriting problems at other South African IHL.

Bias may have been introduced in the administration of the screening assessment. The researcher assessed all students referred for handwriting deficits as well as half the typical students. This could have affected the scoring of the descriptors although the use of the descriptors was developed in an attempt to make the assessment objective when observing behaviour. The assessment of some aspects of the handwriting could have been affected by the assessment done by the researcher. Only the unreadable words, errors for punctuation, spelling, capital letters, corrections and missing letters and words were assessed by a blinded research assistant.

The generalisation of findings of the short Handwriting Screening Assessment to deficits in writing long examinations and the need for assessment of test or examination papers written by the students is limited. It is suggested that the observation of an examination or test paper become a standard part of the screening process so these aspects can be addressed in recommending further assessment for the students referred for handwriting assessment.

These findings are based on a screening assessment, in which the validity and reliability were found to satisfactory, but which could be made more sensitive with further revision and evaluation. It has been found that the component of pen grasp as defined by the current study is redundant in the assessment for risk of dysgraphia but that other descriptors and components do need to be researched, particularly in terms of pain and the visual function component.

11.4 Recommendations

11.4.1 Revision of the Handwriting Screening Assessment

As discussed in Phase 2 and 3 of the study the Handwriting Screening Assessment still has aspects of validity and reliability that could be improved. Revision of certain items and scoring and re-evaluation is therefore recommended in the future.

The scoring on the items limited the range of options that were observed and this affected the sensitivity of some items. The sensitivity in the descriptors will be reviewed to determine if more detailed descriptors improve the differentiation between typical students and those referred for handwriting assessment on items where no difference was found. This will be evaluated before items are made redundant.

To improve identification of deficits, other descriptors could be added. Components that could be considered for the Observation Checklist are the paper moving while writing, increased wrist extension, visual acuity as well as items to address oculomotor function and an increased amount of extension at the wrist. Visual motor integration was not included as this appears not to affect older learners in determining handwriting dysfunction, but visuospatial factors should have been considered, especially the use of margins and space on the paper as deficits relating to these components were noted in some students. The sensitivity in the descriptors will be reviewed before items are removed including items in the pen grasp subtest as items in this subtest for pen slant and the number of fingers on the pen do differentiate students referred for handwriting from typical students. Pain behaviour items can be extended from those that observe shaking the hand when writing to include students reporting the site and severity of pain and how this changes throughout the assessment period. Evidence of pain in other movements can be confirmed as well as observation of facial expression.

The components in certain items show no correlation with other standardised tests which were thought to measure similar components. Therefore, further research into establishing what is being observed, how this affects handwriting deficits in examinations is required especially for the Observation Checklist Subtest 6: *Visual function* and Writing Checklist Item 5: *missing letters, words and lines.* It seems that visual attention and fixation rather than saccadic oculomotor function is observed in the Handwriting Screening Assessment and deficits in these subtests would still require referral for visual function assessment irrespective of the type of eye movements being assessed.

11.4.2 Further research on the Handwriting Screening Assessment

From the results related to the students' academic performance, the need for a comprehensive multi-disciplinary approach to handwriting problems is needed. The university provides student support services to assist with study skills, counselling and reading skills. There is a need to lobby for services from other departments, to work with the Disability Rights Unit to formalise assessment for concessions. There is a need to continue to educate staff on support needed for students with dysgraphia and handwriting problems and to refer appropriately and timeously.

The need for some remediation as well as recommendations for concessions were indicated by the screening assessment, and these may include suggesting a change in pen grasp or a change in writing size and the type of writing from cursive to printing to improve legibility. A student required to make any change in pen grasp and the type of writing used, should be referred to student support services, followed up, and to allow for adaptation may require extra time for examinations.

Further studies on the effectiveness of concessions awarded for examinations is required, particularly in terms of the amount of extra time given as this has been extended internationally by some universities to more than 15 minutes an hour. The role of technology such as text readers and voice recognition software should be considered.

Once the subtests and items have been finalised the assessment should be recommended for use in other universities to assist with providing concessions to students compromised by handwriting dysfunction and dysgraphia.

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APPENDIX A Ethical Clearance Certificates

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Mrs Denise Franzsen

CLEARANCE CERTIFICATE	M10M101105
PROJECT	The Development of a Handwriting Sreening Assessment for Academic Accommodations in Students at the University of Witwatersrand
INVESTIGATORS	Mrs Denise Franzsen.
DEPARTMENT	Department of Occupational Therapy
DATE CONSIDERED	26/11/2010
DECISION OF THE COMMITTEE*	Approved unconditionally

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

DATE 25/01/2011 CHAIRPERSON ....
(Professor PE Cleaton-Jones)

UNIVERSITY OF THE WITWATERSRAND
PROF AJ WOODIWISS
Co - Chair
2011 -01- 28
HREC (Medical)
JOHANNESBURG

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor : Prof A Stewart

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...

R14/49 Mrs Denise Franzsen

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M160875

NAME: **(Principal Investigator)**	Mrs Denise Franzsen
DEPARTMENT:	Occupational Therapy
PROJECT TITLE:	The Development of a Handwriting Screening Assessment for Academic Accomodations at the University of the Witwatersrand
DATE CONSIDERED:	26/08/2016
DECISION:	Approved unconditionally
CONDITIONS:	Renewal for the Period August 2016 - August 2021 Previously M101105
SUPERVISOR:	Prof A Stewart

APPROVED BY: Professor P Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 29/08/2016

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

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 10004, 10th floor, Senate House/2nd Floor, Phillip Tobias Building, Parktown, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in August and will therefore be due in the month of August each year.

Principal Investigator Signature ____________ Date ____________

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX B Permission letter

Occupational Therapy

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

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

1.11.2011

TO WHOM IT MAY CONCERN

Permission is hereby granted to Denise Franzsen to access the records of the results of assessments for extra time held in the Occupational Therapy Department at the University of the Witwatersrand.

The records from Jan 2007 to Oct 2011 will be made available to her for a retrospective record review as requested.

PA de Witt

Prof PA de Witt

Head of Department

THERAPEUTIC Sciences

APPENDIX C Permission to do research

Occupational Therapy

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

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

Mrs P Coopoo,

Dean of Students

Wits University

Dear Mrs Coopoo,

My name is Denise Franzsen, a postgraduate student from the Department of Occupational Therapy. I am interested in handwriting and the effect this has on academic performance in university students.

I am requesting permission to approach Deans of faculties and Heads of Schools and Departments to request that some students in 1st and 3rd year complete a short writing exercise to evaluate the speed and legibility of university students' handwriting. Participation is entirely voluntary, and refusal to participate will not affect the students in anyway.

The research involves students completing three writing exercises over a 15 minute period. During this time the students will be observed and aspects related to writing like posture, pen grasp and the position of their arms will be noted. This is not a test but simply an opportunity to establish norms for handwriting speed and legibility. There are no risks involved and other students may benefit if the results allow handwriting dysfunction to be identified.

Confidentiality is assured as no names or identifying information is required. Feedback from the study is available on request

If you have any questions please feel free to contact me

Denise Franzsen (0117173701

or for any ethical queries or complaints please contact the secretary of the Human Research Ethics Committee. Anisa Keshav
(011) 7171234

Thank you

Denise Franzsen

THERAPEUTIC Sciences

Deputy Registrar: Academic

Private Bag 3, Wits 2050, South Africa • Tel: +27 (0) 11 717-1204 • Fax: +27 (0) 86 553 3695 • E-mail: nita.lawton-misra@wits.ac.za

E-mail nita.lawton-misra@wits.ac.za
Fax 086 553 3695
Tel +27 (0)11 717-1204

20 August 2012

TO WHOM IT MAY CONCERN

"The Development of a Handwriting Screening Assessment for Academic Accommodations at the University of the Witwatersrand"

It is hereby confirmed that the enclosed research material has been distributed in accordance with the University's approval procedures for such a project. Please be advised that it is your right to withdraw from participating in the process if you find the contents intrusive, too time-consuming, or inappropriate. The necessary ethical clearance has been obtained.

Should the University's internal mailing system be the mechanism whereby this questionnaire has been distributed, this notice serves as proof that permission to use it has been granted.

Students conducting surveys must seek permission in advance from Heads of Schools or individual academics concerned should surveys be conducted during teaching time.

NLMisra

Nita Lawton-Misra
Deputy Registrar: Academic

4/6/2012 Approved by Dean

INFORMATION SHEET

Hello,

My name is Denise Franzsen, a postgraduate student from the Department of Occupational Therapy. I am interested in handwriting and the effect this has on academic performance in university students.

I am inviting you to take part in a study to evaluate the awarding of extra time or other concessions for handwriting dysfunction on academic achievement. Participation is entirely voluntary, and refusal to participate will not affect you in anyway. Even if you agree to participate and wish to withdraw or discontinue with the exercise at any time there will be no consequences to you.

The research involves you giving permission for the result of your application for extra time for examinations or other accommodations to be recorded and used as part of the research study. It also includes giving permission to establish whether you passed your courses or not this year to establish if students with accommodations are successful academically.

Confidentiality is assured as no names or identifying information will be used on the data sheets. All records with your name and identifying information will be kept separate in a secure location by the researcher and will be available only to the researcher. All data from the researcher will be retained for a period of six years before being destroyed in line with HPCSA regulations.

Feedback from the study is available on request

If you have any questions please feel free to contact me
Denise Franzsen (0117173701
Or for any ethical queries or complaints please contact the secretary of the Human Research Ethics Committee
Anisa Keshav (011) 7171234

Thank you
Denise Franzsen

APPENDIX D Permission to do research in Occupational Therapy and Physiotherapy Departments

Occupational Therapy

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

Prof P de Witt,/ Prof Hellen Myezwa

Head of Department,

Occupational Therapy/ Physiotherapy

Wits University

Dear Pat,

My name is Denise Franzsen, a postgraduate student from the Department of Occupational Therapy. I am interested in handwriting and the effect this has on academic performance in university students.

I am requesting permission to approach staff coordinating 1st and 3rd year students and students to request that some students complete a short writing exercise to evaluate the speed and legibility of university students' handwriting. Participation is entirely voluntary, and refusal to participate will not affect the students in anyway.

The research involves 10 students from each class completing three writing exercises over a 15 minute period. During this time the students will be observed and aspects related to writing like posture, pen grasp and the position of their arms will be noted. This is not a test but simply an opportunity to establish norms for handwriting speed and legibility. There are no risks involved and other students may benefit if the results allow handwriting dysfunction to be identified.

Confidentiality is assured as no names or identifying information is required. Feedback from the study is available on request

If you have any questions please feel free to contact me

Denise Franzsen (011) 7173701

or for any ethical queries or complaints please contact the chair of the Human Research Ethics Committee Prof P Cleaton Jones at Anisa.Keshav @wits.ac.za

Thank you

Denise Franzsen Denise Franzsen

THERAPEUTIC Sciences

PERMISSION

I P.ADE KLITT give permission for data collection with students for the study The development of a handwriting screening assessment for academic accommodations at the University of Witwatersrand

Signature

Date 5.05 2012

PERMISSION

I HELLEN MMEZWA give permission for data collection with students for the study The development of a handwriting screening assessment for academic accommodations at the University of Witwatersrand

Signature

Date 8/05/2012

APPENDIX E Information Sheet Typical Students

Hello,

My name is Denise Franzsen, a postgraduate student from the Department of Occupational Therapy. I am interested in handwriting and the effect this has on academic performance in university students.

I am inviting you to take part in a short writing test to evaluate the speed and legibility of university students' handwriting. Participation is entirely voluntary, and refusal to participate will not affect you in anyway. Even if you agree to participate and wish to withdraw or discontinue with the exercise at any time there will be no consequences to you.

The research involves you completing three writing exercises over a 20 minute period. During this time you will be observed and aspects related to writing like your posture, pen grasp and the position of your arms will be noted. This is not a test but simply an opportunity to establish norms for handwriting speed and legibility. There are no risks involved and other students may benefit if the results allow handwriting dysfunction to be identified.

Confidentiality is assured as no names or identifying information is required from you. All data from the researcher will be retained for a period of six years before being destroyed in line with HPCSA regulations

Feedback from the study is available on request

If you have any questions please feel free to contact me

Denise Franzsen (0117173701

Or for any ethical queries or complaints please contact the secretary of the Human Research Ethics Committee

Anisa Keshav (011) 7171234

Thank you

Denise Franzsen

APPENDIX F Signed informed consent for Typical students

INFORMED CONSENT

I _______________________________ have read the information sheet and am willing to participate in the study to establish speed and legibility of students' handwriting.

APPENDIX G -Information sheet for students referred for handwriting assessment

Hello,

My name is Denise Franzsen, a postgraduate student from the Department of Occupational Therapy. I am interested in handwriting and the effect this has on academic performance in university students.

I am inviting you to take part in a study to evaluate the awarding of extra time or other concessions for handwriting dysfunction on academic achievement. Participation is entirely voluntary, and refusal to participate will not affect you in anyway. Even if you agree to participate and wish to withdraw or discontinue with the exercise at any time there will be no consequences to you.

The research involves you giving permission for the result of your application for extra time for examinations or other accommodations to be recorded and used as part of the research study. It also includes giving permission to establish whether you passed your courses or not this year and next year to establish if students with accommodations are successful academically.

Confidentiality is assured as no names or identifying information will be used on the data sheets. All records with your name and identifying information will be kept separate in a secure location by the researcher and will be available only to the researcher. All data from the researcher will be retained for a period of six years before being destroyed in line with HPCSA regulations.

Feedback from the study is available on request

If you have any questions please feel free to contact me

Denise Franzsen (0117173701

Or for any ethical queries or complaints please contact the secretary of the Human Research Ethics Committee

Anisa Keshav (011) 7171234

Thank you

Denise Franzsen

APPENDIX H Signed informed consent for students referred for handwriting assessment

INFORMED CONSENT

I ________________________________ have read the information sheet and am willing to agree that the result of the application for a concession for extra time or other accommodations can be used in the study.

Signature ___________________________

Date ___________________

APPENDIX I Demographic questionnaire Study 1

DEMOGRAPHIC QUESTIONNAIRE –STUDY 1
Code ______________________

DEMOGRAPHICS

1. Age ____________________ years
2. Gender :___M =_1____F = 2________
3. School Attended: Type private = 1, public advantaged (pa) = 2 public disadvantaged (pd) = 3
4. Year completed matric/NSC: __________________________

UNIVERSITY HISTORY

Course registered for: _Faculty______________________________

1. Year Started at Wits: _____________
2. Present Year of study ____________ No of years in course ☐
3. Years repeated: ☐
4. Courses repeated: ☐

WRITING

1. Diagnosed with a SLD Yes ☐ =1 No ☐ =2
2. Previous therapy Yes ☐ =1 No☐ =2
3. Previous assessment Yes ☐ =1 No☐ =2
4. Previous therapy for SLD Yes ☐ =1 No☐ =2
5. Previously had extra time Yes ☐ =1 No☐ =2
6. Medication for concentration Yes ☐ =1 No☐ =2
7. Medication for pain Yes ☐ =1 No☐ =2
8. Other illness Yes ☐ =1 No☐ =2
9. Assessment for illness Yes ☐ =1 No☐ =2

10. Type of illness

____

11. Medication –other Yes ☐ =1 No☐ =2

12. Pain in your hand when writing tests and exams Yes ☐ =1 No☐ =2

13. Pain in your arm when writing tests and exams Yes ☐ =1 No☐ =2

14. Problems taking notes in class Yes ☐ =1 No☐ =2

15. Glasses/contacts Yes ☐ =1 No☐ =2

16. Preferred type of pen /pencil for writing Yes ☐ =1 No☐ =2

17. Have you had an injury to your hand Yes ☐ =1 No☐ =2

18. Abnormal strength in hand Yes ☐ =1 No☐ =2

APPENDIX J Study 1 Corrected version of the checklist after content validity pilot study

OBSERVATION CHECKLIST

Code __________

Performance skill - Positions

1. Position of paper on the table
   - 01 in front of student with top point in the midline - slanting upwards towards non -preferred hand
   - 02 vertical
   - 03 parallel to edge of table

2. Position of paper in relation to the student is
   - 01 in front of student
   - 02 to side of preferred hand
   - 03 to side of non-preferred hand

4. Position of paper being copied from
   - 01 to the side of the non-preferred hand
   - 02 above paper being written on directly in front of student
   - 03 side of the preferred hand

5. The hand -writing
   - 01 rests on the table
   - 02 entire forearm rests on the table
   - 03 does not rest on the table

Performance skill - Flows

5. Started writing with preferred hand-
   - 01 the right hand
   - 02 the left hand
   - 03 alternately both hands

6. The wrist of the writing hand is
   - 01 extended
   - 02 neutral position
   - 03 flexed

Performance skill - Calibrates

7. The PIP of the index finger is
   - 01 flexed up to 90^o
   - 02 flexed > 90^o +++
   - 01 extended or in hyperextension

8. The DIP of the index finger is
   - 01 flexed
   - 02 extended
   - 01 in hyperextension

9. The IP of the thumb is
   - 01 flexed , 90^o
   - 02 flexed > 90^o +++
   - 03 extended or in hyperextension

10. The finger closest to the tip of the pen is the
    - 01 thumb
    - 02 index finger
    - 03 other finger (middle, ring, little)

11. The fingers are
    - 01 at a functional distance from the tip of the pencil
    - 02 too close to the paper
    - 03 spread over the shaft

12. Students grasp on the pen is
    - 01 not loose or tight
    - 02 loose
    - 03 tight (blanching of fingers)

13. The web space of the writing hand is
    - 01 pen
    - 02 narrowed
    - 03 completely close

Performance skill – Manipulates

14. Student keeps grip
    01 on pen all the time
    02 repositions pen in fingers occasionally
    03 repositions pen in fingers after a few words

15. Movement in writing hand
    01 maintains same grasp throughout
    02 repositions pen in hand / stretches fingers (time after starting_____)
    03 shakes hand (time after starting_____)

16 The writing movements are conducted with
    01 the fingers and thumb
    02 the thumb
    03 the hand

17. The radial and ulnar sides of the hands are disassociated
    01 only the thumb and index and middle fingers move
    02 All fingers move
    03 the ring and little finger move in a different patent to the radial side of the hand

Performance skill – Coordinates

18. The hand – not writing
    01 fixates the paper
    02 fixates the paper some of the time
    03 does something else

Performance skill – Grips

19. The thumb is
    01 the thumb is aligned with the tip of the index finger
    03 not rotated
    04 extended (thumb nail parallel to finger nail)

20. The pen is held against the
    01 middle finger
    02 index finger
    03 ring finger/little finger

21. Fingers resting on the pen
    01 index finger
    02 index and middle
    03 no fingers

22. The thumb supports the pen
    01 in a tripod pinch
    02 in a lateral pinch
    01 by lying over or under the index and middle fingers

23. Pen slant
    01 back towards student
    02 upright
    03 forward away from student

24. Pen is at level of the index finger
    01 MP joint
    02 Web space
    03 PIP joint

Performance skill – Aligns

25. The student's writing posture is
    01 Symmetrical
    01 flexed to the side
    03 rotated

26. The hand –not writing
    01 rests on the table
    02 entire forearm rests on the table
    03 does not rest on the table

27. The student's position while writing
    01 neck flexed

02 neck and trunk flexed
03 flexed to within 20cm of table

28. The student
01 remains still
02 moves trunk
03 moves lower limbs

Performance skill – Notice/Responds and Accommodates

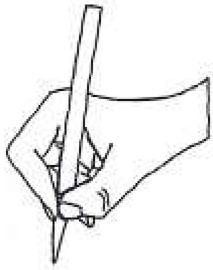
29. Student head movement when copying
01 not noticeable
02 turns to look every 1-2 words
03 turns to look before a word is complete

30. The student follows text to be copied
01 with no difficulty
02 with finger some of the time - with finger all of the time
03 using a ruler

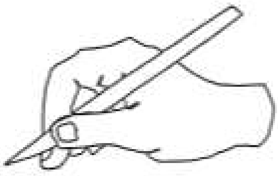
31. Student copies text
01 silently
02 mouths word silently
03 reading aloud

Pen Grasp
Open Web space

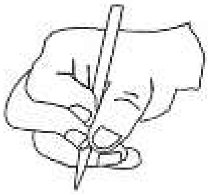
01 Tripod to middle finger dynamic(3 finger)



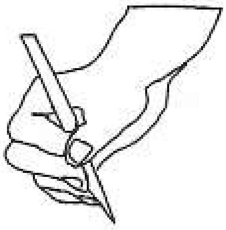
02 Lateral to middle finger
(3 finger)



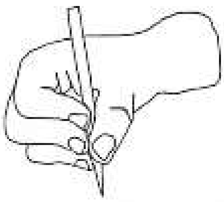
03 Quadrapod to ring finger



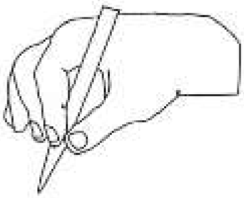
04 Lateral to ring finger



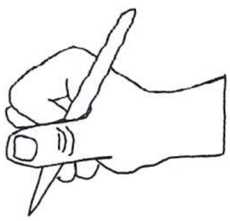
05.Four Finger to little finger



06 Extended finger grasp

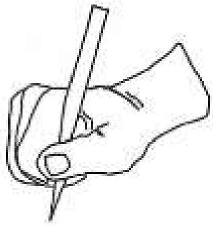


07 Lateral Thumb Wrap or tuck (open web space)

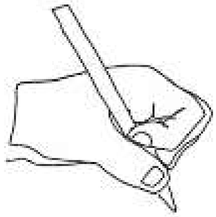


Closed web Space

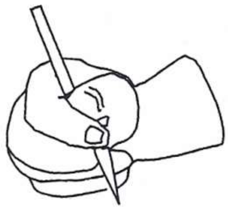
08 lateral grasp
(closed web space)



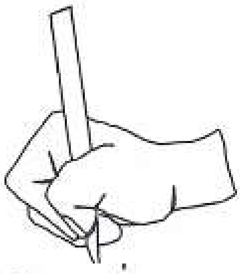
09 Lateral -flexed index finger around pen



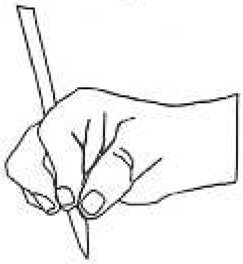
10 Lateral- thumb Wrap or tuck (web space close)



11 Lateral-thumb parallel to hand



12 Between finger grasp



13 Static – writes with hand movement

WRITING CHECKLIST

Code ____________

Performance skill- Flows and organises

1. Writing in relation to lines
   01 on the line
   02 above or below the line
   03 above and below the line

2. Percentage of letters that could not be read out of context
   01 None
   02 <20%
   03 >20%

3. Organisation of letters
   01 evenly spaced letters
   02 letters spread out or crowded
   03 letters unevenly spaced

4. Slant of letters
   01 to the right or upright
   02 straight or to the left
   03 inconsistent

5. Organisation of words
   01 evenly spaced words
   02 words spread out or cramped
   03 words unevenly spaced

6. Size of writing
   01 adequate
   02 large
   03 small

Performance skill- Calibrates

7. Pressure used to write
   01 one
   02 felt at back of page
   03 seen on the next page

Performance skill- Endures

8. Deterioration of writing
   01 one
   02. by end of passage
   03 change in writing

9. Type of writing
   01 printing
   02 cursive
   03 mixed print and cursive

Performance skill- Heeds, Adjusts and Accommodates

10. Missing letters from end of words
    01 None
    02 1-4
    03 more than 4

11. Missing or added words in copied text
    01 none
    02 1-4
    03 more than 4

12. Missing or added lines of text in copied text
    01 none
    02 1
    03 more than 1

13. Spelling in copied written work
    01 no mistakes
    02 1-3 mistakes
    03 more than 3

14. Punctuation
    01 correct
    02 1-3 mistakes
    03 4 or more mistakes

15. Capital letters
    01 correct
    02 missing
    03 appear in the middle of words

16. Corrections to letters and words copied written work
    01 No corrections
    02 1-3 corrections
    03 more than 3 corrections

Code ____________

WRITING SPEED AND ACCURACY MEASUREMENT (Alphabet task)

No of words written in 3 minutes _____/3_____wpm

LEGIBILITY SCORE

(Circle the appropriate number)

1	very legible writing	every letter clear and - read 100% of letters
2	legible writing	not every letter clear - can read 95% of letters (31-60 out of 601 letters illegible)
3	partially legible writing	some letters not clear--can read 90% of letters (61-119 out of 601 letters illegible)
4	mixed legible and illegible writing	some letters not clear -can read more than 80% of letters (120-179 out of 601 letters illegible)
5	partially illegible writing	some letters not clear -can read less than 70% of letters (180- 239 out of 601 letters illegible)
6	illegible writing	some letters not clear —can read less than 60% of letters (240-293 out of 601 letters illegible)
7	very illegible writing	few letters clear – can read less than 50% of letters (294+ out of 601 letters illegible)

1   2   3   4   5   6

APPENDIX K Passage to be copied

Although they lack nervous systems and sense organs, plants are able to react to external stimuli. *Irritability* is one of the characteristic properties of protoplasm involving sensitivity to stimuli and a reaction or response to these stimuli. A *stimulus* is an environmental factor which exerts an effect on living protoplasm. The *principal stimuli* which initiate plant responses are light, chemical agents, water, gravity, gases and contact. By reacting to stimuli plants adjust themselves to events and factors in their environment. Plant reactions or movements are usually too slow to be observed by the human eye, and have to be observed at intervals of several hours, or days, noting change in position of the various organs

APPENDIX L Handwriting Screening Assessment -initial version

OBSERVATION CHECKLIST

Code

____

Performance Skill -Positions

1. Position of paper to be written on
   01 in front of student slanting upwards towards non -preferred hand
   02 straight
   03 parallel to edge of table

2. Position of paper to be written on is
   01 in front of student
   02 to side of preferred hand
   03 to side of non-preferred hand

3. Position of paper being copied from
   01 to the side of the non-preferred hand
   02 above paper being written on directly in front of student
   03 side of the preferred hand

Performance skill Flows

4. Writing with
   01 the right hand
   02 the left hand
   03 alternately both hands

5. The wrist of the writing hand is
   01 extended
   02 neutral position
   03 flexed

6. The wrist of the writing hand is
   01 ulnar deviated
   02 neutral position
   03 radial deviated

Performance skill-Manipulates

7. The writing movements are conducted with
   01 the fingers and or the thumb
   02 the hand
   03 the arm

8. Movement in writing hand
   01 no extra movements
   02 repositions pen in hand
   03 stretches fingers (time after starting_____)
   03 shakes hand (time after starting_____)

9. In writing the pen point
   01 is lifted between words
   02 is lifted during the writing of a word
   03 is lifted after each letter

Performance skill-Calibrates

10. The PIP of the index finger is
    01 flexed up to 90^o
    02 flexed > 90^o +++
    03 extended or in hyperextension

11. The DIP of the index finger is
    01 flexed
    02 extended
    03 in hyperextension

12. The IP of the thumb is
    01 flexed , 90^o
    02 flexed > 90^o +++
    03 extended or in hyperextension

13.The fingers are
01 at a functional distance from the tip of the pencil
02 too close to the paper
01 spread over the shaft

14 Students grasp on the pen is
01 firm
02 loose
03 tight (blanching of fingers)

15 The web space of the writing hand is
01 open
02 narrowed
03 completely close

16. Pressure of fingers of the non-writing hand on the paper is
01 firm
01 oose
03 tight (blanching of fingers)

Performance skill- Aligns

17 The writing hand
01 rests on the table
02 entire forearm rests on the table
03 does not rest on the table

18. The non-writing hand
01 rests on the table
02 entire forearm rests on the table
03 does not rest on the table

19. The student's writing posture is
01 Symmetrical
02 flexed to the side
03 rotated

20. The student's position while writing
01 neck flexed
02 neck and trunk flexed
03 flexed to within 20cm of table

Performance skill - Coordinates

21. The non-writing hand
01 fixates the paper
02 fixates the paper some of the time
03 does something else.(rests in the lap/ supports head etc)

Performance skill – Grips

22. The finger closest to the tip of the pen is the
01 thumb
02 index finger
03finger (middle, ring, little)

23. Pen Grasp
Do you consider the student's pen grasp
01 functional pinch (tripod, lateral)
02 dysfunctional pinch (closed web space)
03 not a pinch (thumb wrap, between fingers)

24. The thumb is
01 Rotated 90^0 to the fingers
02 not rotated
03 extended (thumb nail parallel to finger nail)

25. The pen is held against the
01 middle finger
02 ring finger/little finger
03 index finger

26. the thumb supports the pen
01 in a tripod pinch
02 in a lateral pinch
03 by lying over or under the index and middle fingers

27. Pen slant
01 back towards student
02 upright
03 forward away from student

28. Pen is at level of the index finger
01 MP joint
02 Web space
03 PIP joint

Performance skill - Notice/Responds

29. The student follows text to be copied
01 with no difficulty
02 with finger some of the time/ with finger all of the time
03 hesitates and looks for place

30. Student head movement when copying
01 not noticeable
02 turns to look every 1-2 words
03 turns to look before a word is complete

Performance skill - Accommodates

31. Student copies text
01 silently
02 mouths word silently
03 reading aloud

HANDWRITING CHECKLIST

Code ____________

Performance skill -Flows and Organises

1. Writing in relation to lines
   01 on the line
   02 above or below the line
   03 above and below the line

2. Percentage of letters that could not be read out of context
   01 None
   02 <20%
   03 >20%

3. Organisation of letters
   01 evenly spaced letters
   02 letters spread out or crowded
   03 letters unevenly spaced

4. Slant of letters
   01 to the right or upright
   02 straight or to the left
   03 inconsistent

5. Organisation of words
   04 evenly spaced words
   02 words spread out or cramped
   03 words unevenly spaced

Performance skill -Calibrates

6. Pressure used to write (number of pages writing is visible on under the page written on
   01 none
   02 felt at back of page
   03 seen on the next page

Performance skill -Endures

7. Deterioration of writing
   01 none
   02 by end of passage
   03 change in writing

Performance skill -Adjusts and Accommodates

8. Size of writing
   03 adequate
   02 large
   03 small

9. Type of writing
   01 printing
   02 cursive
   03 mixed print and cursive

Performance skill -Heeds, Adjusts and Attends

10. Missing letters –end of words
    01 None
    02 1-4
    03 more than 4

11. Missing or added words in copied text
    01 none
    02 1-4
    03 more than 4

12. Missing or added lines of text in copied text
    04 none
    05 1
    03 more than 1

13. Spelling in copied written work
    01 no mistakes
    02.1-3 mistakes
    03 more than 3

14. Punctuation
    01 correct
    02 1-3 mistakes
    03 4 or more mistakes

15. Capital letters
    02 correct
    02 missing
    03 appear in the middle of words

16. Corrections to letters and words copied written work
    01 No corrections
    02 1-3 corrections
    03 more than 3 corrections

HANDWRITING OUTCOMES

Code ___________

WRITING SPEED AND ACCURACY MEASUREMENT (Alphabet task)

No of words written in 3 minutes ______/3 =_______wpm

LEGIBILITY SCORE

(Circle the appropriate number)

32. very legible writing	every letter clear and - read 100% of letters
33. legible writing	not every letter clear - can read 95% of letters (31-60 out of 601 letters illegible)
34. partially legible writing	some letters not clear--can read 90% of letters (61-119 out of 601 letters illegible)
35. mixed legible and illegible writing	some letters not clear -can read more than 80% of letters (120-179 out of 601 letters illegible)
36. partially illegible writing	some letters not clear -can read less than 70% of letters (180- 239 out of 601 letters illegible)
37. illegible writing	some letters not clear —can read less than 60% of letters (240-293 out of 601 letters illegible)
38. very illegible writing	few letters clear – can read less than 50% of letters (294+ out of 601 letters illegible)

1 2 3 4 5 6 7

APPENDIX M Correlation Study 1 Observation Checklist and Writing Checklist

Variable	Correlations (Study 1) Marked correlations are significant at $p < .050$ n=287												
	Means	Std.Dev.	Paper table	Paper student	Paper copies	Writing hand pos	Preferred hand	Wrist position 1	PIP index finger	DIP index finger	IP thumb	Finger close tip	Distance from tip
Paper table	1.16	0.42	1.00	-0.07	0.07	-0.04	0.08	0.09	0.00	-0.01	0.06	0.04	0.02
Paper student	1.09	0.30	-0.07	1.00	0.37	0.02	-0.04	0.05	-0.04	0.01	-0.06	0.08	0.12
Paper copied	1.03	0.19	0.07	0.37	1.00	0.01	-0.05	-0.06	0.12	0.04	0.02	0.09	0.06
Writing hand pos	1.41	0.49	-0.04	0.02	0.01	1.00	0.00	0.01	0.10	0.12	0.10	0.06	-0.04
Preferred hand	1.12	0.35	0.08	-0.04	-0.05	0.00	1.00	0.21	0.11	-0.14	-0.02	-0.07	-0.05
Wrist position 1	1.21	0.57	0.09	0.05	-0.06	0.01	0.21	1.00	-0.07	-0.11	0.09	-0.08	0.03
PIP index finger	1.13	0.42	0.00	-0.04	0.12	0.10	0.11	-0.07	1.00	0.05	0.04	0.09	0.08
DIP index finger	2.11	0.91	-0.01	0.01	0.04	0.12	-0.14	-0.11	0.05	1.00	0.25	-0.02	0.00
IP thumb	1.59	0.60	0.06	-0.06	0.02	0.10	-0.02	0.09	0.04	0.25	1.00	0.07	0.07
Finger close tip	1.66	0.60	0.04	0.08	0.09	0.06	-0.07	-0.08	0.09	-0.02	0.07	1.00	0.07
Distance from tip	1.51	0.68	0.02	0.12	0.06	-0.04	-0.05	0.03	0.08	0.00	0.07	0.07	1.00
Firmness of grasp	2.66	0.66	0.15	0.09	0.06	0.00	-0.14	-0.04	0.03	0.12	0.13	0.11	0.05
Grip and reposition	1.27	0.60	0.01	0.03	-0.01	0.00	0.10	0.08	0.05	0.07	-0.05	-0.02	0.07
Web space	2.16	0.71	0.02	0.03	-0.06	-0.07	0.16	0.07	0.12	0.01	0.15	0.05	0.09
P of thumb	1.81	0.40	0.00	-0.03	-0.01	-0.05	0.11	0.05	0.10	0.06	0.18	0.05	0.09
Finger pen held to	1.38	0.77	0.06	-0.05	-0.03	-0.20	0.05	0.10	0.03	0.01	0.04	-0.05	0.00
No fingers on pen	1.14	0.41	0.03	-0.02	-0.06	-0.10	-0.07	0.02	0.06	-0.01	0.02	-0.08	0.05
Thumb support	1.96	0.59	-0.02	0.04	-0.02	-0.03	0.14	0.04	0.07	0.02	0.14	0.05	0.13
Pen slant	1.20	0.46	0.12	0.12	0.01	-0.06	0.16	0.07	-0.04	-0.08	0.04	0.12	0.08
Joint level of pen	1.76	0.43	0.05	0.02	0.01	0.08	0.01	0.11	0.17	0.03	0.16	0.07	0.05
Movement hand	1.40	0.75	0.08	0.00	-0.04	0.07	0.04	0.04	0.14	0.10	0.03	-0.02	0.01
Writing movements	1.34	0.73	-0.09	0.09	0.12	0.05	-0.07	-0.07	0.01	-0.13	-0.06	0.13	0.17
Non-writing hand	1.74	0.59	0.09	-0.09	-0.02	-0.02	0.08	-0.06	0.01	0.01	0.07	0.02	-0.09
Fixates paper	1.82	0.74	0.04	-0.05	-0.08	0.09	0.03	-0.04	0.04	0.02	0.04	0.01	0.07
Dis-association	1.05	0.29	-0.04	0.07	0.10	-0.07	0.08	-0.06	-0.02	0.07	-0.03	-0.15	0.14
Posture	1.69	0.62	0.06	-0.01	-0.04	0.05	0.10	0.06	0.00	0.08	0.01	-0.05	0.02
Posture - flexion	2.02	0.80	0.06	0.00	0.04	0.02	-0.08	-0.16	0.04	0.08	0.05	0.00	0.02
Maintains position	1.28	0.60	-0.04	0.05	0.01	0.20	-0.01	0.03	0.08	-0.04	-0.11	-0.01	0.01
Head movement	1.98	0.70	0.01	0.09	-0.05	0.07	-0.11	0.06	-0.08	0.03	0.04	0.03	0.09
Follows text	2.17	0.83	-0.05	-0.05	-0.03	0.16	-0.13	-0.03	-0.03	0.01	0.15	-0.02	0.11
Reading type	1.16	0.42	1.00	-0.07	0.07	-0.04	0.08	0.09	0.00	-0.01	0.06	0.04	0.02

Variable	Correlations (Study 1) Marked correlations are significant at p < .050 N=287												
	Firmness of grasp	Grip and reposition	Web space	Alignment of thumb	Finger pen held to	No fingers on pen	Thumb support	Pen slant	Joint level of pen	Movement hand	Writing movements	Non-writing hand	Fixates paper
Paper table	0.15	0.01	0.02	0.00	0.06	0.03	-0.02	0.12	0.05	0.08	-0.09	0.09	0.04
Paper student	0.09	0.03	0.03	-0.03	-0.05	-0.02	0.04	0.12	0.02	0.00	0.09	-0.09	-0.05
Paper copied	0.06	-0.01	-0.06	-0.01	-0.03	-0.06	-0.02	0.01	0.01	-0.04	0.12	-0.02	-0.08
Writing hand pos	0.00	0.00	-0.07	-0.05	-0.20	-0.10	-0.03	-0.06	0.08	0.07	0.05	-0.02	0.09
Preferred hand	-0.14	0.10	0.16	0.11	0.05	-0.07	0.14	0.16	0.01	0.04	-0.07	0.08	0.03
Wrist position 1	-0.04	0.08	0.07	0.05	0.10	0.02	0.04	0.07	0.11	0.04	-0.07	-0.06	-0.04
PIP index finger	0.03	0.05	0.12	0.10	0.03	0.06	0.07	-0.04	0.17	0.14	0.01	0.01	0.04
DIP index finger	0.12	0.07	0.01	0.06	0.01	-0.01	0.02	-0.08	0.03	0.10	-0.13	0.01	0.02
IP thumb	0.13	-0.05	0.15	0.18	0.04	0.02	0.14	0.04	0.16	0.03	-0.06	0.07	0.04
Finger close tip	0.11	-0.02	0.05	0.05	-0.05	-0.08	0.05	0.12	0.07	-0.02	0.13	0.02	0.01
Distance from tip	0.05	0.07	0.09	0.09	0.00	0.05	0.13	0.08	0.05	0.01	0.17	-0.09	0.07
Firmness of grasp	1.00	-0.02	0.05	0.17	-0.06	-0.04	0.06	-0.05	0.11	0.05	0.13	-0.13	0.04
Grip and reposition	-0.02	1.00	0.06	0.04	0.00	-0.04	0.04	-0.02	0.02	0.35	-0.06	0.04	0.03
Web space	0.05	0.06	1.00	0.74	0.21	0.14	0.76	0.31	0.60	0.10	0.09	0.01	0.13
Rotation of thumb	0.17	0.04	0.74	1.00	0.17	0.12	0.76	0.15	0.67	0.08	0.10	0.00	0.11
Finger pen held to	-0.06	0.00	0.21	0.17	1.00	0.84	0.22	0.20	0.10	-0.06	-0.10	-0.01	0.12
No fingers on pen	-0.04	-0.04	0.14	0.12	0.84	1.00	0.17	0.11	0.06	-0.05	-0.09	-0.02	0.12
Thumb support	0.06	0.04	0.76	0.76	0.22	0.17	1.00	0.39	0.57	0.02	0.09	0.03	0.17
Pen slant	-0.05	-0.02	0.31	0.15	0.20	0.11	0.39	1.00	0.12	-0.02	0.07	0.12	0.07
Joint level of pen	0.11	0.02	0.60	0.67	0.10	0.06	0.57	0.12	1.00	0.13	0.01	0.05	0.08
Movement hand	0.05	0.35	0.10	0.08	-0.06	-0.05	0.02	-0.02	0.13	1.00	-0.08	0.03	0.04
Writing movements	0.13	-0.06	0.09	0.10	-0.10	-0.09	0.09	0.07	0.01	-0.08	1.00	-0.03	-0.09
Non-writing hand	-0.13	0.04	0.01	0.00	-0.01	-0.02	0.03	0.12	0.05	0.03	-0.03	1.00	0.20
Fixates paper	0.04	0.03	0.13	0.11	0.12	0.12	0.17	0.07	0.08	0.04	-0.09	0.20	1.00
Dis-association	-0.12	0.11	0.03	0.08	0.04	0.06	0.05	0.06	0.07	-0.01	0.02	0.10	0.08
Posture	0.15	0.01	0.02	0.00	0.06	0.03	-0.02	0.12	0.05	0.08	-0.09	0.09	0.04
Posture - flexion	0.09	0.03	0.03	-0.03	-0.05	-0.02	0.04	0.12	0.02	0.00	0.09	-0.09	-0.05
Maintains position	0.06	-0.01	-0.06	-0.01	-0.03	-0.06	-0.02	0.01	0.01	-0.04	0.12	-0.02	-0.08
Head movement	0.00	0.00	-0.07	-0.05	-0.20	-0.10	-0.03	-0.06	0.08	0.07	0.05	-0.02	0.09
Follows text	-0.14	0.10	0.16	0.11	0.05	-0.07	0.14	0.16	0.01	0.04	-0.07	0.08	0.03
Reading type	-0.04	0.08	0.07	0.05	0.10	0.02	0.04	0.07	0.11	0.04	-0.07	-0.06	-0.04

Variable	Correlations (Study 1) Marked correlations are significant at p < .05000 N=287						
	Dis-association	Posture	Posture - flexion	Maintains position	Head movement	Follows text	Reading type
Paper table	-0.04	0.06	0.06	-0.04	0.01	-0.05	0.02
Paper student	0.07	-0.01	0.00	0.05	0.09	-0.05	0.08
Paper copied	0.10	-0.04	0.04	0.01	-0.05	-0.03	0.00
Writing hand pos	-0.07	0.05	0.02	0.20	0.07	0.16	0.02
Preferred hand	0.08	0.10	-0.08	-0.01	-0.11	-0.13	0.06
Wrist position 1	-0.06	0.06	-0.16	0.03	0.06	-0.03	-0.02
PIP index finger	-0.02	0.00	0.04	0.08	-0.08	-0.03	-0.04
DIP index finger	0.07	0.08	0.08	-0.04	0.03	0.01	-0.05
IP thumb	-0.03	0.01	0.05	-0.11	0.04	0.15	0.05
Finger close tip	-0.15	-0.05	0.00	-0.01	0.03	-0.02	0.09
Distance from tip	0.14	0.02	0.02	0.01	0.09	0.11	0.08
Firmness of grasp	-0.12	0.02	0.09	-0.11	0.11	0.17	0.07
Grip and reposition	0.11	0.00	-0.01	0.01	0.11	0.01	-0.02
Web space	0.03	0.08	0.11	-0.14	-0.04	0.04	-0.06
Rotation of thumb	0.08	0.05	0.11	-0.20	-0.09	0.03	-0.05
Finger pen held to	0.04	0.06	-0.02	-0.07	-0.07	0.05	-0.03
No fingers on pen	0.06	0.02	-0.01	-0.02	0.00	0.13	-0.01
Thumb support	0.05	0.07	0.08	-0.15	-0.07	0.01	-0.04
Pen slant	0.06	0.07	0.04	-0.02	-0.05	-0.05	0.09
Joint level of pen	0.07	-0.01	0.14	-0.24	-0.04	0.05	-0.04
Movement hand	-0.01	-0.02	0.03	0.00	0.13	0.14	-0.04
Writing movements	0.02	0.02	-0.04	0.02	0.07	-0.04	0.10
Non-writing hand	0.10	-0.04	-0.05	-0.05	-0.04	-0.08	-0.07
Fixates paper	0.08	-0.04	0.06	0.01	0.11	0.44	0.06
Dis-association	1.00	-0.07	-0.04	-0.06	0.02	0.01	-0.05
Posture	-0.07	1.00	0.06	0.09	0.01	-0.06	0.04
Posture - flexion	-0.04	0.06	1.00	0.04	0.03	0.14	0.11
Maintains position	-0.06	0.09	0.04	1.00	0.00	-0.07	-0.05
Head movement	0.02	0.01	0.03	0.00	1.00	0.38	0.11
Follows text	0.01	-0.06	0.14	-0.07	0.38	1.00	0.14
Reading type	-0.05	0.04	0.11	-0.05	0.11	0.14	1.00

Correlation Study 1 Writing Checklist

Variable	Correlations (Study 1) Marked correlations are significant at p < .050 n=287										
	Means	Std.Dev.	Lines	Letters unreadable	Percentage illegible letters	Pressure	Deterioration	Organisation letters	Slant letters	Corrections copy	Size of writing
Lines	2.52	0.57	1.00	0.19	0.19	0.06	0.19	0.26	0.27	0.09	0.01
Letters unreadable	2.28	0.45	0.19	1.00	0.77	-0.08	0.11	0.32	0.15	0.05	0.05
Percentage illegible letters	19.59	13.99	0.19	0.77	1.00	-0.05	0.12	0.34	0.18	0.12	0.05
Pressure	2.00	0.80	0.06	-0.08	-0.05	1.00	0.01	0.10	0.07	0.07	0.04
Deterioration	1.56	0.64	0.19	0.11	0.12	0.01	1.00	0.29	0.24	-0.01	-0.02
Organisation letters	2.05	0.86	0.26	0.32	0.34	0.10	0.29	1.00	0.37	0.14	0.03
Slant letters	2.08	0.96	0.27	0.15	0.18	0.07	0.24	0.37	1.00	0.06	0.03
Corrections copy	1.96	0.70	0.09	0.05	0.12	0.07	-0.01	0.14	0.06	1.00	0.05
Size of writing	1.71	0.77	0.01	0.05	0.05	0.04	-0.02	0.03	0.03	0.05	1.00
Missing add letter	2.08	0.76	0.07	0.18	0.21	-0.05	0.08	0.14	0.21	0.07	-0.06
Missing add words	1.44	0.73	0.04	0.09	0.12	-0.05	0.00	0.07	0.10	0.06	-0.02
Missing add lines	1.17	0.45	-0.01	0.02	0.05	-0.05	-0.10	-0.03	0.10	0.03	0.03
Organise of words	1.92	0.88	0.29	0.36	0.34	0.12	0.13	0.47	0.26	0.09	-0.08
Spelling copied	1.96	0.70	0.13	0.27	0.31	0.07	0.07	0.25	0.23	0.12	-0.04
Punctuation	1.19	0.43	-0.02	0.09	0.07	0.09	0.06	0.10	0.04	0.01	-0.03
Capital letters	1.27	0.56	-0.11	-0.06	-0.01	0.07	0.06	0.03	-0.06	0.02	0.03
Type of writing	1.69	0.82	0.15	0.30	0.36	0.00	0.26	0.32	0.21	0.12	0.08

Variable	Correlations (Study 1) Marked correlations are significant at p < .05000 N=287 (Casewise deletion of missing data)							
	Missing add letter	Missing add words	Missing add lines	Organise of words	Spelling copied	Punctuation	Capital letters	Type of writing
Lines	0.07	0.04	-0.01	0.29	0.13	-0.02	-0.11	0.15
Letters unreadable	0.18	0.09	0.02	0.36	0.27	0.09	-0.06	0.30
Percentage illegible letters	0.21	0.12	0.05	0.34	0.31	0.07	-0.01	0.36
Pressure	-0.05	-0.05	-0.05	0.12	0.07	0.09	0.07	0.00
Deterioration	0.08	0.00	-0.10	0.13	0.07	0.06	0.06	0.26
Organisation letters	0.14	0.07	-0.03	0.47	0.25	0.10	0.03	0.32
Slant letters	0.21	0.10	0.10	0.26	0.23	0.04	-0.06	0.21
Corrections copy	0.07	0.06	0.03	0.09	0.12	0.01	0.02	0.12
Size of writing	-0.06	-0.02	0.03	-0.08	-0.04	-0.03	0.03	0.08
Missing add letter	1.00	0.62	0.46	0.09	0.56	0.23	0.12	0.03
Missing add words	0.62	1.00	0.76	-0.04	0.12	0.13	0.06	0.01
Missing add lines	0.46	0.76	1.00	-0.12	0.09	0.24	0.14	-0.03
Organise of words	0.09	-0.04	-0.12	1.00	0.18	0.05	-0.07	0.11
Spelling copied	0.56	0.12	0.09	0.18	1.00	0.17	0.13	0.15
Punctuation	0.23	0.13	0.24	0.05	0.17	1.00	0.15	-0.03
Capital letters	0.12	0.06	0.14	-0.07	0.13	0.15	1.00	-0.08
Type of writing	0.03	0.01	-0.03	0.11	0.15	-0.03	-0.08	1.00

APPENDIX N: Initial Exploratory Factor Analysis Observation Checklist and Writing Checklist in Study 1

Variable	Factor Loadings (Varimax normalized) (Study 1) Extraction: (Marked loadings are >.40)											
	Fact. 1	Fact. 2	Fact. 3	Fact. 4	Fact. 5	Fact. 6	Fact. 7	Fact. 8	Fact. 9	Fact. 10	Fact. 11	Fact. 12	Fact 13
Web space	0.88	0.00	-0.10	-0.03	0.06	0.00	0.03	0.01	0.04	-0.02	-0.02	0.05	-0.01
Rotation of thumb	0.88	-0.00	-0.04	-0.04	0.01	-0.01	-0.06	-0.12	-0.03	0.08	0.02	0.06	0.06
Thumb support	0.88	0.00	-0.12	0.01	-0.01	-0.00	0.10	0.03	0.02	0.00	0.00	0.10	-0.05
Joint level of pen	0.78	0.06	0.03	0.05	0.05	0.04	-0.04	-0.13	-0.05	0.10	-0.03	-0.09	0.14
Fixates paper	0.13	0.67	-0.11	-0.06	-0.01	-0.07	0.34	0.05	0.07	-0.03	0.09	-0.06	0.10
Head movement	-0.11	0.51	0.03	0.03	0.29	0.10	-0.13	0.01	-0.01	0.07	-0.08	0.20	-0.33
Follows text	0.01	0.84	-0.06	-0.04	0.04	0.00	-0.14	-0.04	0.01	0.07	0.05	0.03	-0.02
Finger pen held to	-0.14	-0.00	0.92	0.02	0.03	0.03	0.22	0.00	0.02	0.00	0.04	0.21	0.09
No fingers on pen	-0.07	-0.11	0.92	0.02	0.05	0.03	0.03	0.00	0.05	-0.01	0.00	0.00	-0.04
Paper student	0.04	0.00	0.01	0.80	0.05	0.01	-0.08	0.10	-0.01	-0.06	-0.06	0.09	-0.20
Paper copied	-0.04	-0.07	0.02	0.78	-0.06	0.00	0.00	-0.06	0.04	0.07	0.07	0.04	0.22
Grip and reposition	0.02	-0.01	0.01	0.01	0.78	-0.11	0.07	0.03	0.00	-0.03	-0.04	0.08	-0.02
Movement hand	0.08	0.11	0.06	-0.03	0.76	0.07	-0.03	0.00	0.02	0.05	-0.01	-0.10	0.13
Finger close tip	0.04	-0.00	0.04	0.12	-0.01	0.68	0.22	0.00	0.02	0.00	0.04	0.21	0.09
Firmness of grasp	0.10	0.14	0.06	0.08	0.05	0.37	-0.34	-0.27	0.19	0.24	0.13	0.08	0.00
Disassociation	-0.03	-0.04	0.02	-0.20	-0.07	0.63	-0.27	0.18	0.10	-0.08	-0.06	-0.28	-0.01
Pen slant	0.33	-0.06	-0.19	0.15	-0.04	0.10	0.42	0.16	0.33	-0.12	-0.05	0.13	-0.27
Non-writing hand	-0.00	0.02	0.05	-0.08	0.04	0.01	0.79	-0.07	0.01	0.09	0.05	-0.09	0.01
Writing hand position	0.01	0.30	0.26	0.05	-0.05	0.12	0.02	0.54	-0.16	0.24	-0.13	-0.08	0.19
Posture	0.07	-0.22	-0.07	-0.17	0.02	-0.07	-0.14	0.48	0.36	0.23	0.03	0.12	-0.20
Maintains position	-0.21	-0.01	-0.03	0.07	0.05	0.03	0.00	0.71	-0.07	-0.13	0.03	0.00	0.11
Paper table	-0.05	-0.06	-0.08	0.05	0.14	0.21	0.14	-0.21	0.60	0.12	-0.08	-0.16	0.14
Reading type	-0.07	0.27	0.08	0.01	-0.16	0.00	-0.11	0.00	0.51	-0.09	0.06	0.26	-0.06
IP thumb	0.10	-0.03	-0.06	0.02	0.12	0.07	0.01	0.08	-0.08	0.77	0.22	-0.05	-0.04
DIP index finger	0.00	-0.06	-0.02	0.04	0.15	-0.09	0.06	-0.09	0.10	0.69	-0.21	0.02	0.07
Preferred hand	-0.15	0.10	-0.10	0.08	-0.03	0.31	-0.18	-0.11	-0.41	0.21	0.42	0.04	-0.23
Wrist position 1	-0.09	-0.01	0.067	-0.04	-0.07	0.03	0.16	-0.07	-0.14	0.00	0.78	0.11	0.10
Distance from tip	0.04	0.11	-0.07	0.07	0.08	-0.11	-0.07	-0.04	0.10	0.09	-0.03	0.70	0.13
Writing movements	0.10	-0.06	0.14	0.05	-0.11	0.24	-0.03	0.05	-0.11	-0.15	0.06	0.65	-0.03
PIP index finger	0.10	-0.03	-0.06	0.02	0.12	0.07	-0.03	0.13	0.02	0.02	0.06	0.10	0.82

Writing Checklist							
Variable	Factor Loadings (Varimax normalized) (Study 1)Extraction: (Marked loadings are >.40)						
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Letters unreadable	0.84	0.04	0.13	-0.07	-0.05	0.01	0.03
No of illegible letters	0.97	0.03	0.09	0.02	0.01	0.04	0.07
Percentage illegible letters	0.97	0.06	0.09	0.02	0.01	0.04	0.06
Missing add letter	0.15	0.74	0.16	-0.01	-0.21	0.31	0.05
Missing add words	0.06	0.91	0.02	0.01	0.02	0.01	-0.01
Missing add lines	-0.01	0.86	-0.07	-0.02	0.12	0.09	-0.07
Organise of words	0.33	-0.14	0.67	-0.07	-0.16	0.08	-0.10
Organisation letters	0.29	-0.01	0.58	0.09	0.02	0.16	0.34
Slant letters	0.06	0.19	0.60	-0.01	0.03	-0.01	0.33
Lines	0.12	0.06	0.61	0.01	0.02	-0.20	0.10
Corrections copy	0.10	0.11	0.16	0.76	0.17	-0.04	-0.01
Size of writing	0.07	0.01	-0.05	-0.04	0.86	-0.01	0.04
Pressure	-0.13	-0.18	0.41	0.14	0.33	0.42	-0.30
Spelling copied	0.30	0.26	0.29	0.04	-0.19	0.44	0.05
Punctuation	0.04	0.18	0.04	-0.06	-0.07	0.60	-0.05
Capital letters	-0.03	0.03	-0.27	0.06	0.11	0.70	0.18
Type of writing	0.36	0.00	0.15	0.04	0.23	-0.13	0.56
Deterioration	0.02	-0.07	0.20	-0.05	-0.08	0.14	0.79

Initial Exploratory Factor Analysis Handwriting Outcomes 2

Variable	Factor Loadings (Unrotated) (CORRECT SUBTEST 2 AND 3) Extraction: Principal components (Marked loadings are >.700000)	
	Factor 1	Factor 2
Words per min	0.842566	0.150777
Legibility score	0.020220	0.985111
Alphabet	0.839029	-0.175153

Value	Eigenvalues (CORRECT SUBTEST 2 AND 3) Extraction: Principal components			
	Eigenvalue	% Total variance	Cumulative Eigenvalue	Cumulative %
1	1.414296	47.14321	1.414296	47.14321
2	1.023855	34.12851	2.438152	81.27172

APPENDIX O Analysis of components to create items for the Handwriting Screening Assessment and Initial Handwriting Screening Assessment

ITEMS ACCORDING TO CLIENT FACTORS AND PERFORMANCE SKILLS FOR THE INITIAL HANDWRITING SCREENING ASSESSMENT

Item	Performance skill	Client factors
OBSERVATION CHECKLIST		
Position of paper		
Item 1: Position of paper to be written on		
01 in front of student slanting upwards towards non -preferred hand	Positions Accommodates	Writing movements Posture
02 straight		
03 parallel to edge of table		
Item 2: Position of paper to be written on is		
01 in front of student		Writing movements Mid line crossing
02 to side of preferred hand		
03 to side of non-preferred hand		
Item 3: Position of paper being copied from		
01 to the side of the non-preferred hand		Visual Function Eye dominance
02 above paper being written on directly in front of student		
03 side of the preferred hand		
Preferred hand and wrist position		
Item 4 Writing with		
01 the right hand	Flows	Hand dominance
02 the left hand		
03 alternately both hands		
Item 5: The wrist of the writing hand is		Writing movements Fine motor control
01 extended		
02 neutral position		
03 flexed		
Item 6: The wrist of the writing hand is		
01 ulnar deviated		
02 neutral position		
03 radial deviated		
Movements in the hand		
Item 7: The writing movements are conducted with		
01 the fingers and or the thumb	Manipulates Coordination Positions	Praxis In hand manipulation Writing movements Fine motor control Muscle strength Bilateral integration
02 the hand		
03 the arm		
Item 8: The non-writing hand		
01 fixates the paper		
02 fixates the paper some of the time		
03 does something else.(rests in the lap/ supports head etc)		
Item 9: Movement in writing hand		
01 no extra movements		
02 repositions pen in hand		
03 stretches fingers (time after starting_____)		

Item 10 In writing the pen point		
01 is lifted between words		
02 is lifted during the writing of a word		
03 is lifted after each letter		
Stability of grasp		
Item 11:The PIP of the index finger is		
01 flexed up to 90^o	Calibrates	Proprioception, Kinaesthesia and haptic sensation Fine motor control
02 flexed > 90^o +++		
03 extended or in hyperextention		
Item 12:The DIP of the index finger is		
01 flexed		
02 extended		
03 in hyperextention		
Item 13: The IP of the thumb is		
01 flexed , 90^o		
02 flexed > 90^o +++		
03 extended or in hyperextention		
Item 14 The web space of the writing hand is		
01 open		
02 narrowed		
03 completely close		
Item 15 Students grasp on the pen is		
01 firm		
02 loose		
03 tight (blanching of fingers)		
Item 16: Pressure of fingers of the non-writing hand on the paper is		
01 firm		
02 loose		
03 tight (blanching of fingers)		
Pen grasp		
Item: 17 The finger closest to the tip of the pen is the		
01 thumb	Grips	In hand manipulation Fine motor control Proprioception, Kinaesthesia and haptic sensation In hand manipulation Muscle strength
02 index finger		
03 other finger (middle, ring, little)		
Item 12: The fingers are		
01 at a functional distance from the tip of the pencil		
02 too close to the paper		
03 spread over the shaft		
Item 18 Pen Grasp function		
Do you consider the student's pen grasp		
01 functional pinch (tripod, lateral)		
02 dysfunctional pinch (closed web space)		
03 not a pinch (thumb wrap, between fingers)		
Item 19 The thumb is		
01 Rotated 90^0 to the fingers		
02 not rotated		
03 extended (thumb nail parallel to finger nail)		
Item 20 The pen is held against the		
01 middle finger		
02 ring finger/little finger		
03 index finger		
Item 21 The thumb supports the pen		
01 in a tripod pinch		

02 in a lateral pinch		
03 by lying over or under the index and middle fingers		
Item 22: Pen slant		
01 back towards student		
02 upright		
04 forward away from student		
Item 23 Pen is at level of the index finger		
01 MP joint		
02 Web space		
03 PIP joint		
Posture		
Item 24: The student's writing posture is	Aligns	Postural control
01 Symmetrical		
02 flexed to the side		
04 rotated		
Item 25: The student's position while writing		
01 neck flexed		
02 neck and trunk flexed		
03 flexed to within 20cm of table		
Item 26: The writing hand		
01 rests on the table		
02 entire forearm rests on the table		
03 does not rest on the table		
Item 27: The non-writing hand		
01 rests on the table		
02 entire forearm rests on the table		
Visual Function		
Item 286: The student follows text to be copied		
01 with no difficulty	Notice/ responds Attends Accommodates	Visual function Attention
02 with finger some of the time/ with finger all of the time		
03 hesitates and looks for place		
Item 29: Student head movement when copying		
01 not noticeable		
02 turns to look every 1-2 words		
03 turns to look before a word is complete		
Item 30: Student copies text		
01 silently		
02 mouths word silently		
03 reading aloud		

Item	Performance skill	Client factors
WRITING CHECKLIST		
Quality of handwriting		
Item 1: Writing in relation to lines		
01 on the line	Flows Organises	Writing movements Fine motor control Writing movements Visual perception
02 above or below the line		
03 above and below the line		
Item 2: Percentage of letters that could not be read out of context		
01 None		
02 <20%		
03 >20%		
Item 3: Organisation of letters		
01 evenly spaced letters		
02 letters spread out or crowded		
03 letters unevenly spaced		
Item 4: Slant of letters		
01 to the right or upright		
02 straight or to the left		
03 inconsistent		
Item 5: Organisation of words		
05 evenly spaced words		
02 words spread out or cramped		
03 words unevenly spaced		
Item 6:Size of writing		
06 adequate		
02 large		
03 small		
Deterioration in writing		
Item 7: Pressure used to write		
01 none	Calibrates Adjusts Endures Accommodation	Proprioception, Kinaesthesia and haptic sensation Fine motor control Muscle power Muscle endurance Pain Writing movements Allographic mechanisms Visual perception
02 on back the page written on		
03 next page		
Item 8: Deterioration of writing		
01 none		
02 by end of passage		
03 change in writing		
Item 9:Type of writing		
01 printing		
02 cursive		
03 mixed print and cursive		
Item 10: Missing letters end of words		
01 None	Heeds Attends Adjusts	Attention Visual function Attention Visual function Attention Dyslexia
02 1-4		
03 more than 4		
Item 11:Missing or added words in copied text		
01 none		
02 1-4		
03 more than 4		
Item 11:Missing or added lines of text in copied text		
02 none		

03 1		
03 more than 1		
Item 7: Corrections		
01 No corrections	Heeds	Attention Dyslexia Allographic mechanisms Orthographic coding
02 1-3 corrections		
03 more than 3 corrections		
Item 13: Spelling in copied written work		
01 no mistakes		
02.1-3 mistakes		
03 more than 3		
Item 14: Punctuation		
01 correct		
02 1-3 mistakes		
03 4 or more mistakes		
Item 16 Capital letters		
01 correct		
02 missing		
03 appear in the middle of words		

Item	Performance skill	Client factors
HANDWRITING OUTCOMES		
Words per minute	Paces	Any of those listed above
Legibility	Flows Organises	
WSAM alphabet task -Automaticity	Paces Flows	

APPENDIX P Demographic Questionnaire for Typical Students

DEMOGRAPHICS

Code ________________________

Age _____________________

Gender :____________________

High School Attended: Name: ____________________________

City/Town: ________________________

Year completed matric/NSC: _________________________

UNIVERSITY HISTORY

Course registered for: ______________________________

Year Started at Wits: ____________

Present Year of study ___________

Years repeated:_____________________________

Courses repeated: _____________________________

WRITING

Have you ever been diagnosed with a learning disability

Yes ☐ No☐

1. Do you have handwriting problems

   Yes ☐ No☐

   If yes please describe

   ____

   Does your handwriting problem affect your ability to write exams

   Yes ☐ No☐

   If yes please describe

   ____

2. Do you have pain in your hand or arm when writing tests and exams

   Yes ☐ No☐

   If so how long can you write without Pain _____________ minutes

Indicate on a scale of 1-10 the severity of your pain when writing

No pain Severe pain

1	2	3	4	5	6	7	8	9	10

3. Does your hand get so tired when writing test of exams that you have to stop

   Yes ☐ No☐

4. Do you stop and shake your hand when writing tests and exams

   Yes ☐ No☐

5. Do you have problems seeing when you write tests and exams

   Yes ☐ No☐

6. Do your eyes get sore and tired when writing exams

   Yes ☐ No☐

7. Do you have a preferred type of pen /pencil for writing

   Yes ☐ No☐ IF yes what type of pen/pencil

   ____

APPENDIX Q History of Handwriting Problems Questionnaire -Students Referred for Assessment

DEMOGRAPHIC QUESTIONNAIRE

Name ____________________

Age ____________________

Gender :____________________

High School Attended: Name: ____________________________

City/Town: ________________________

Year completed matric/NSC: _________________

UNIVERSITY HISTORY

Course registered for: ______________________________

Year Started at Wits: ____________

Present Year of study ___________

Years repeated:_____________________________

Courses repeated: _____________________________

HISTORY OF HANDWRITING PROBLEMS QUESTIONNAIRE

1. Have you ever been diagnosed with a learning disability

   Yes ☐ No☐

   If yes – What learning disability _________________________________

   Who diagnosed the learning disability __________________

   When was it diagnosed _________________

2. Are you under the care of a medical practitioner in relation to your learning disability at present

   Yes ☐ No☐

   If yes – who ____________________________

3. Have you ever had therapy for problems related to handwriting?

   Yes ☐ No☐

   If yes what and when

   ____

4. Have you been diagnosed with any other condition that affects you handwriting

   Yes ☐ No☐

If yes What and who are you consulting about this condition

____

5. Do you take any medication

   Yes ☐ No☐

   If yes what and how much

   ____

6. Do you feel that your handwriting is problematic

   Yes ☐ No☐

   If yes please describe

   ____

7. Does your handwriting affect your ability to take notes in class

   Yes ☐ No☐

   If yes – what is the problem and how do you get notes to study from

   ____

8. Does your handwriting problem affect your ability to write examinations?

   Yes ☐ No☐

   If yes please describe

   ____

9. Do you have pain in your hand or arm when writing tests and exams

   Yes ☐ No☐

   If so how long can you write without Pain ____________ minutes

   Indicate on a scale of 1-10 the severity of your pain when writing

   ____

10. Does your hand get so tired when writing test of exams that you have to stop

    Yes ☐ No☐

11. Do you stop and shake your hand when writing tests and exams

    Yes ☐ No☐

12. Do you wear glasses or contact lenses

    Yes ☐ No☐

    If yes why were the glasses/contact lenses prescribed and how long have you been wearing them

____

13. Do you have problems seeing when you write tests and exams

    Yes ☐ No☐

14. Do your eyes get sore and tired when writing exams

    Yes ☐ No☐

15. Do you have any weakness in your hands

    Yes ☐ No☐

16. Do you have a preferred type of pen /pencil for writing

    Yes ☐ No☐ IF yes what type of pen/pencil

    ____

PREVIOUS CONCESSIONS

1. Have you had previous assessment s for concessions for examinations

   Yes ☐ No☐

2. If yes

   When were you assessed?___________________________________

   Who completed the assessment?______________________________

What concessions did you receive? _____________________

APPENDIX R Revised Handwriting Screening Assessment

OBSERVATION CHECKLIST

Code ___________

Sub test 1: Position and fixation of paper	
1. Position of paper on the table	
01 in front of student with top point in the midline - slanting upwards towards non - preferred hand	2
02 vertical or horizontal	1
2. Position of paper in relation to the student is	
01 in front of student	3
02 to side of preferred hand	2
03 to side of non-preferred hand	1
3. Position of paper being copied from	
01 to the side of the non-preferred hand	2
02 above paper being written on directly in front of student	1
4. The hand – not writing	
01 fixates the paper	2
02 does something else	1
Sub test 1 :Total	**/9**

Subtest 2: Maintenance of Posture	
5. The hand -writing	
01 rests on the table	3
02 entire forearm rests on the table	2
03 does not rest on the table	1
6. The hand –not writing	
01 rests on the table	3
02 entire forearm rests on the table	2
03 does not rest on the table	1
7. The student's writing posture is	
01 Symmetrical	3
02 flexed to the side	2
03 rotated	1
8. The students posture is	
01 neck flexed	3
02 neck and trunk flexed	2
03 flexed to within 20 cm of table	1
9. The student's position while writing	
01 remains still	2
02 moves	1
Sub test 2 :Total	**../14**

Subtest 3: Stability of grasp	
10. The PIP of the index finger is	
01 flexed or extended	2
02 flexed > 90^o +++	1
11. The DIP of the index finger is	
01 flexed	3
02 extended	2
03 in hyperextension	1
12. The IP of the thumb is	
01 flexed , 90^o	3
01 flexed > 90^o +++	2
03 extended or in hyperextension	1
13. Students grasp on the pen is	
01 not loose or tight	3
02 tight (blanching of fingers)	2
03 loose	1
14. The fingers are	
01 at a functional distance from the tip of the pencil	3
02 too close to the paper	2
03 too far from tip/spread over the shaft	1
15. The web space of the writing hand is	
01 open or narrowed	2
02 completely close	1
Subtest 3:Total	**/16**

Subtest 4: Pen grasp	
16. The finger closest to the tip of the pen is the	
01. thumb	3
02. index finger	2
03. other finger (middle, ring, little)	1
17. The thumb is	
01 aligned with the tip of the index/middle finger	3
02 against the side of the index/middle finger	2
03 extended(thumb nail parallel to finger nail)	1
18. the thumb supports the pen	
01 in a tripod pinch	3
02 in a lateral pinch	2
03 by lying over or under the index and middle fingers	1
19. Pen slant	
01 back towards student	2
02 upright or forward away from student	1
20. The pen is held against the	
01 middle finger	3
02 ring finger/little finger	2
03 index finger	1
21. Fingers resting on the pen	
01 index finger	3
02 index and middle	2
03 no fingers	1

22. Pen on the index finger is	
01 above or below the MP joint	3
02 in the base of the web space	2
03 above or at the PIP joint	1
Subtest 4:Total	**/20**

Subtest 5: Movement in fingers and hand	
23. Student keeps grip	
01 on pen all the time	2
02 repositions pen in fingers	1
24. Movement in writing hand	
01 maintains same grasp throughout	2
02 stretches and/or shakes fingers/hand/upper limb (time after starting_____)	1
25. The writing movements are conducted with	
01 the fingers and thumb	3
02 the hand	2
03 the thumb	1
26. The radial and ulnar sides of the hands are disassociated	
01 only the thumb and index and middle fingers move	2
02 all fingers move	1
Subtest 5:Total	**/9**

Subtest 6: Visual perception	
27. Student head movement when copying	
01 not noticeable	3
02 turns to look every 1-2 words	2
03 turns to look before a word in completed	1
28. The student follows text to be copied	
01 with no difficulty	3
02 with finger	2
03 hesitates and looks for place	1
29. Student copies text	
01 silently	2
02 reading silently/aloud	1
Subtest 6:Total	**/8**

Subtest 7: Preferred hand	
30. Started writing with preferred hand-	
01 the right hand	3
02 the left hand	2
03 alternately both hands	1
31. The wrist of the writing hand is	
01 extended	2
03 flexed	1
Subtest 7:Total	**/5**

WRITING CHECKLIST

Code ____________

Subtest 1: Writing analysis	
1. Writing in relation to lines	
01 on the line	3
02 above or below the line	2
03 above and below the line	1
2. Percentage of words that could not be read out of context	
01 None	3
02 <20%	2
03.>20%	1
3. Organisation of letters	
01 Evenly spaced letters	2
02 letters spread out or crowded	1
4. Slant of letters	
01 upright or slanted	2
03 inconsistent	1
5. Size of writing	
01 adequate	3
02 large	2
03 small	1
6. Organisation of words	
01 evenly spaced words	2
02 inconsistent	1
Subtest 1: Total	**..\15**

Subtest 2: Endurance and Fatigue	
7. Type of writing	
01 printing	3
02 mixed print and cursive	2
03 cursive	1
8. Pressure used to write	
01 none	3
03 felt at back of page	2
03 to the next page	1
9. Deterioration of writing	
01 none	3
02 by end of passage	2
03 change in writing	1
Subtest 2: Total	**..\9**

Subtest 3: Punctuation	
10. Capital letters	
01 correct	2
02 missing or in the middle of words	1
11. Punctuation	
01 correct	3
02 1-3 mistakes	2
03 4 or more mistakes	1
Subtest 3: Total	**..\5**

Subtest 4: Corrections and spelling	
12. Corrections to letters and words copied written work	
01 no mistakes	3
02.1-3 mistakes	2
03 more than 3	1

13. Spelling in copied written work	
01 no mistakes	3
02.1-3 mistakes	2
03.more than 3	1
Subtest 4: Total	**..\6**

Subtest 5: Missing letters and words	
14. Missing or added letters from end of words	
01 None	3
02 1-4	2
03 more than 4	1
15. Missing or added words in copied text	
02 none	2
01-or more	1
16. Missing or added lines of text in copied text	
01 None	2
02 1 or more	1
Subtest 5: Total	**..\7**

SPEED SCORE
Automaticity- WSAM Alphabet Task
Number of letters written in 1 minute.
____

Copied Paragraph

No of words written in 3 minutes ______/3 =_______wpm

LEGIBILITY SCORE
(Circle the appropriate number)

8	very legible writing	every word clear and - read 100% of words
9	legible writing	not every word clear - can read 95% of words (1-11 out of 115 words illegible)
10	partially legible writing	some words not clear--can read 90% of words (11-22 out of 115 words illegible)
11	mixed legible and illegible writing	some words not clear -can read more than 80% of words (23-33 out of 115 words illegible)
12	partially illegible writing	some words not clear -can read less than 70% of words (34 -45 out of 115 words illegible)
13	illegible writing	some words not clear —can read less than 60% of words (46-56 out of 115 words illegible)
14	very illegible writing	few words clear – can read less than 50% of words (57+ out of 115 words illegible)

1 2 3 4

APPENDIX S Detailed Assessment of Handwriting Speed 17+

Detailed Assessment of Speed of Handwriting 17+ (DASH 17+)

Record Form

Name: Gender: M/F

School/College/University: Year of Study:

Location: Hand used for writing: R/L

Administered by:

Test setting: individual/group

	Year	Month	Day
Date of Test:			
Date of Birth:			
Age:			

Core Scores

Task	Raw Score*	Standard Score
1. Copy Best (CB) Words per minute		
2. Alphabet Writing (AW) Number of letters		
3. Copy Fast (CF) Words per minute		
4. Free Writing (FW) Words per minute		
Total Score (Sum of Standard Scores 1-4)		
Total Standard Score		Confidence Interval [illegible] to / Percentile

*Round words per minute scores to a whole number: round down for decimals below .5; round up for decimals of .5 and above

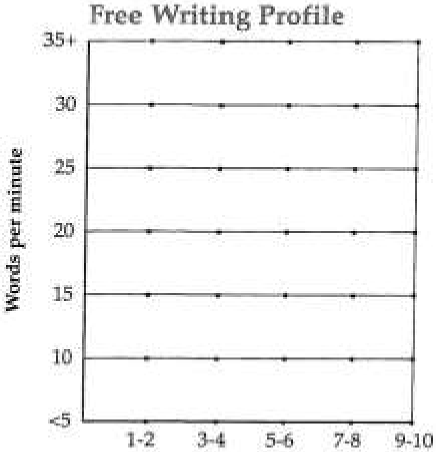
Supplementary Scores

Task		Raw Score	Standard Score
Graphic Speed	Number of correct Xs		

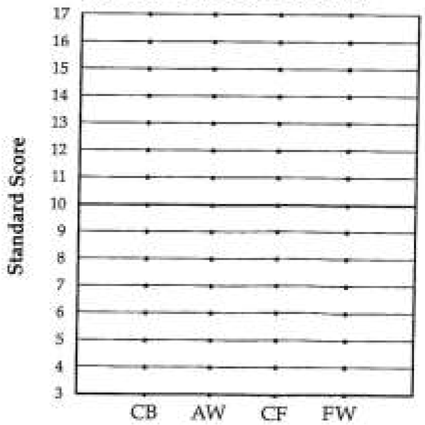
Copy Speed Difference		Percentile 15th or below for age?** Y/N

**See Table 5.6 on p.75 of the DASH 17+ manual

Free Writing Profile



Standard Score Profile



APPENDIX T Developmental Eye Movement Test

DEM Scoresheet

Name____________________ DOB________________ Age _____________

Articulation Pre-Test Y N   Number Knowledge Pre-Test Y N

/ = substitution error   o= omission error

a = addition error   <or> = transposition error

Test A		Test B		Test C				
3	4	6	7	2	5	9	4	3
7	5	3	9	4	5	2	7	8
5	2	2	3	3	5	7	4	9
9	1	9	9	8	7	9	5	7
8	7	1	2	3	7	1	4	5
2	5	7	1	6	1	4	6	2
5	3	4	4	9	3	7	2	6
7	7	6	7	7	2	4	6	3
4	4	5	6	6	3	2	9	1
6	8	2	3	7	4	6	5	2
1	7	5	2	5	3	7	4	8
4	4	3	5	4	5	2	1	7
7	6	7	7	7	9	3	9	2
6	5	4	4	1	4	7	6	3
3	2	8	6	2	5	7	4	6
7	9	4	3	3	7	5	9	8
9	2	5	7					
3	3	2	5					
9	6	1	9					
2	4	7	8					

____sec   ____sec

Time: ______ sec

____ substitution (s) errors   ____ ommision (o) errors

____ addition (a) errors   ____ transposition (t) errors

Adjusted Time = Time X $\frac{80}{(80 - o + a)}$

Total Time : ____ sec

Adjusted Time = ____ sec

Errors : _____

Adjusted Time = ______sec

Total Errors (s + o + a +t) = ____

DEM Ratio = $\frac{\text{Horizontal Adj Time}}{\text{Vertical Adj Time}}$ = ______

DEM1 *(Copyrighted Bernell Corporation 2011)*

APPENDIX U Example of Guidelines for Administration and scoring of the Handwriting Screening Assessment

Student should be sitting on a chair and at a desk of correct height with enough space for two pieces of paper on the desk. The writing needs to be done on an exam pad or book with a few pages to press on with lines in feint rule.

They can write with a preferred pencil or pen. The examiner should sit directly opposite the student in order to observe all aspects directly   The student should be instructed to write the alphabet letters in lower case in sequence for 1 minute. They should then be timed in seconds while copying the paragraph presented to them on a separate sheet. The observation checklist will be completed while they are writing and the greatest deficit for each item scored ie if they fixate the paper for some of the time the score will be for does something else which is 1. Therefore the student must be observed throughout the writing process and scores adjusted if necessary.

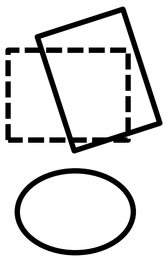
OBSERVATION CHECKLIST

Sub test 1 (Total 9)

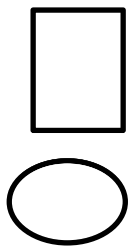
1 Position of paper on the table.

Observe the position of the paper on the table – it should be in front of student with top point in the midline slanted towards the the non-preferred hand. Scores of 1 if the paper is straight on the table with no slant = vertical which requires extra repositioning of the arm while writing

2

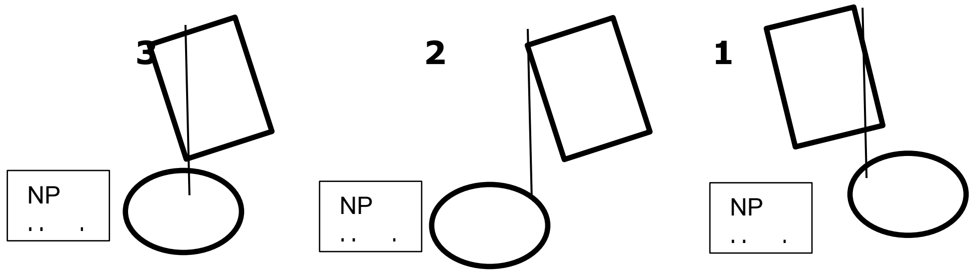


1

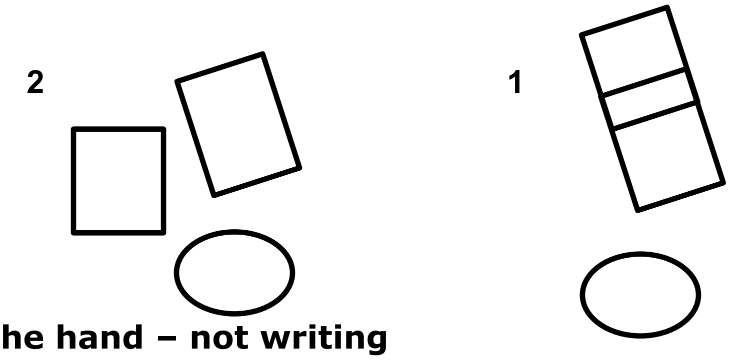


2 Position of paper in relation to the student

Observe if the paper is in front of the student – this means that is the edge of the paper on the side of the non-preferred hand should be in front of the trunk towards the midline of the trunk to determine if the student is crossing their midline.
Score 2 if paper to side of preferred hand – the edge of the paper on the side of the preferred hand is not in line with the trunk or 1 if the paper is on the side of non-preferred hand.



3 **Position of paper being copied from**
Observe where the paper being copied from is placed which should be to the side of the non-preferred hand. Score 1 if placed above paper being written on directly in front of student



4 **The hand – not writing**
Observe if the non-writing hand fixates the paper all the time. If at any time the hand is then used to do something else or lies on the table or in the lap not fixating the paper score a 1. This is possibly due to problems with bilateral integration as well as possible low postural tone if the hand is used to prop up the head while writing which is aligned with subtest 2.

Subtest 2: Maintenance of Posture (Total 12)

5 **The hand –writing**
Observe if just the lower part of the forearm, wrist and hand rest on the table or score 2 if the student leans on the entire forearm and elbow on the table to support themselves while writing. Score 1 if they keep their arm above the table and do not rest it on the table

6 **The hand –not writing**
Observe if just the lower part of the forearm, wrist and hand rest on the table or score 2 if the student leans on the entire forearm on the table to support themselves while writing, particularly if they are resting on both forearms. Score 1 if their arm is not placed on the table and is placed elsewhere

7 **The student's writing posture is**

Observe for symmetrical upright posture and note if flexed to the side or score 1 if rotated trunk while sitting.

8 The student's posture is

Observe if only the neck is flexed. If the trunk is also flexed as well as the neck score 2 If the face is flexed to within 20cm of table or lower score 1 and look for other signs of either low postural tone or visual problems.

9 The student's position while writing

Observe if the student remains still during the assessment or whether they move either their trunk, limbs or both. Look for other signs of low postural tone requiring movement to stabilise the trunk, distractibility and a history of ADHD or enquire about pain in the back or limbs.

Subtest 3: Stability of grasp (16)

10 The PIP of the index finger is

Observe if the PIP joint of the index finger is flexed or extended with flexion up to 90^0. If the joint is excessively flexed past 90^o +++ usually with obvious blanching of the joint and pressure in hold the pen score 1.

11 The DIP of the index finger is

Observe if the DIP joint of the index finger is flexed with flexion up to 90^0. If the joint is extended and in a straight line score 2 and if the joint is hyperextended usually with obvious blanching of the joint and pressure in hold the pen score 1.

12 The IP of the thumb is

Observe if the IP joint of the thumb is flexed with flexion up to 90^0. If the joint is excessively flexed past 90^o +++ usually with obvious blanching of the joint and pressure in hold the pen score 2 and if the joint is extended in a straight line or hyperextended usually with a lateral pinch score 1

13 Students grasp on the pen is

The grasp on the pen should be firm enough so that it can be pulled from the hand with some resistance and should be not loose or tight. Observe if it is tight (blanching of fingers) and is difficult to pull out of the fingers. When the pen is held loosely it moves backwards and forwards as the student writes and is easily pulled from the hand which scores 1.

14 The fingers are

The fingers should be approximately 2.5 cms from the tip of the pen which is a functional distance from the tip of the pen. If the finger are within 2 cms of the tip of the pen they are too close to the paper and score 2. If the pen is held 3cm or more from the tip this is scored 1 as too far from tip as well as if the fingers are spread up the shaft of the pen

15 **The web space of the writing hand is**
open or narrowed completely close

Subtest 4: Pen grasp (20)

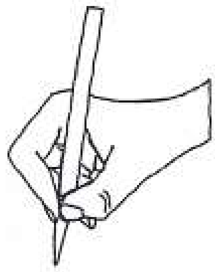
16 **The finger closest to the tip of the pen is the**

Observe which digit is closest to the tip of the pen which should be the thumb. Score 2 if it the index finger and 1 for other fingers (middle, ring, little).

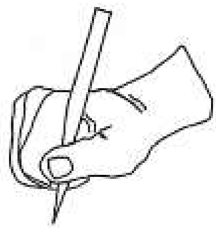
17 **The thumb is**

Observe if the thumb is aligned with the tip of the index/middle finger. If it is held against the side of the index/middle finger then score 2 and if it is held unrotated at the side of the index finger with the nail facing upwards the score 1

1



2



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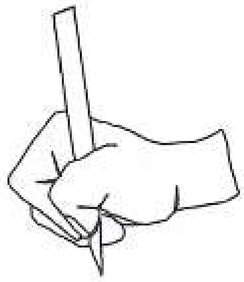
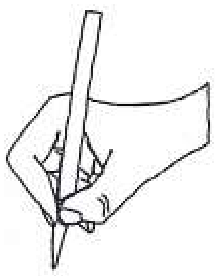


18 **The thumb supports the pen**

Observe a a tripod pinch where the top of the index finger and thumb approximate each other or a lateral pinch to the side of the index finger which scores 2. A thumb wrap or thumb tuck pinch with the thumb lying over or under the index and middle fingers scores 1.

3



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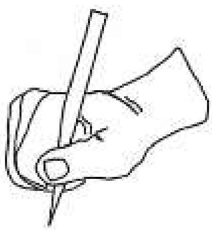
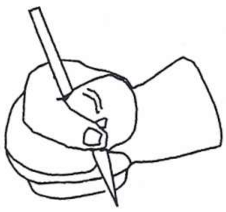
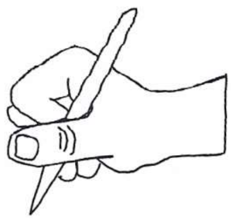


1





19 **P**
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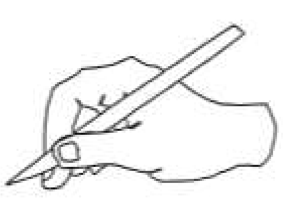
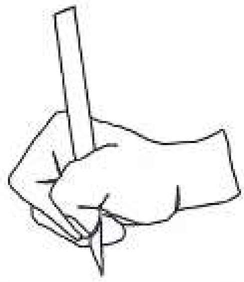
Observe if the pen slants back towards the student or if it is held upright or slanting forward away from the student

2



1



20 The pen is held against the

Observe which finger the pen is held against which should be the middle finger. If held against the ring or little finger score 2 and if the pen is held against the index finger score 1.

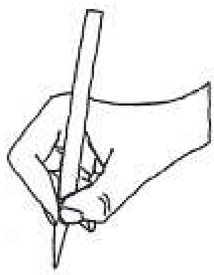
21 Fingers resting on the pen

Observe which fingers are resting on the pen which should be the index finger. If both the index and middle fingers are resting on the pen score 2 and if no fingers as it is held against the side of the index finger score 1.

22 Pen on the index finger

Observe the joint level of the pen on the index finger as it should be above or below the MP joint. If the pen is lower in the base of the web space then score 2 and it is further up the finger at the PIP or above the PIP joint score 1

3



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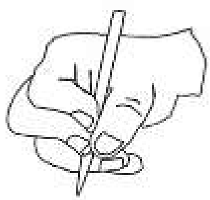
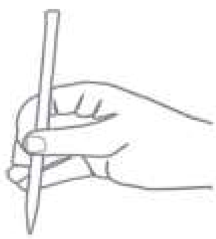


1



Subtest 2: Endurance and Fatigue (9)

1 Type of writing

Printing is scored if all letters are separate, mixed writing consists of separate and connected letters and cursive writing all letters in words are connected.

2 Pressure used to write

The pressure used to write is assessed by feeling the back of page. If no indentations are felt score none. If the writing can be felt on the back of the page but there is no evidence of indentations on the next page score 2. If evidence of indentations can be seen on the next page score 3.

3 Deterioration of writing

Compare the letter formation and spacing of a word at the start of the paragraph (organs) with the last word of the paragraph. Note a deterioration in letter formation, spacing and size as well as the type of writing and score 2 if any of these aspects have changed by end of paragraph change in writing

Subtest 3: Punctuation (5)

4 Capital letters

If capital letters are correct score 1 and if they are missing or in the middle of words score 2.

5 Punctuation

Check for commas, full stops and hyphens. If they are correct score 1 with a score of 2 for 1-3 mistakes and a score of 3 for 4 or more mistakes. Mistakes include omissions or added commas and full stops as well as inappropriate use of hyphens in words.

Although they lack nervous systems and sense organs, plants are able to react to external stimuli. *Irritability* is one of the characteristic properties of protoplasm involving sensitivity to stimuli and a reaction or response to these stimuli. A *stimulus* is an environmental factor which exerts an effect on living protoplasm. The *principal stimuli* which initiate plant responses are light, **chemical agents, water, gravity, gases and contact. By reacting to stimuli plants adjust themselves to events and factors in their environment. Plant reactions or movements are usually too slow to be observed by the human eye, and have to be observed at intervals of several hours, or days, noting change in position of the various organs**

APPENDIX V Scoring Sheets for Handwriting Screening Assessment

Summary score

Observation Checklist subtests	**-3 SD**	**-2 SD**	**-1 SD**	**Mean**	**+1-+3**	**Writing Checklist subtests**	**-3 SD**	**-2 SD**	**-1 SD**	**Mean**	**+1-+3**
Subtest 1 ***Position and fixation of paper***	4	5-6	7	8	9	**Subtest 1** ***Writing***	5	6-7	8-9	10-11	12-15
Subtest 2 ***Maintenance of posture***	6	7- 8	9-10	11	12-14	**Subtest 2** ***Endurance and fatigue***	3	4-5	6	7	8-9
Subtest 3 ***Stability of grasp***	7	8-9	10-11	12-13	14-16	**Subtest 3** ***Punctuation***	3	4		5	
Subtest 4 ***Pen Grasp***	9	10-11	12-14	15-17	18-20	**Subtest 4** ***Corrections and Spelling***	2	3	4	5	6
Subtest 5 ***Movement in fingers and hand***	4	5	6	7-8	9	**Subtest 5** ***Missing letters and words***	3	4	5	6	7
Subtest 6 ***Visual perception***	4	5	6	7	8-9	**Speed score**	11 and less	12-15	16-19	20-24	25-27+
Subtest 7 ***Preferred hand***	3	4		5		**Legibility score**	7	6	4-5	3	1-2
						Alphabet Scores	28 and less	29-46	47-65	66-92	93-100+

Observation and Writing Checklist - Final z scores

+3 - 0														
A -1														
B -2														
C -3														
	Observation Checklist							**Writing Checklist**					**Handwriting Outcomes**	
													Speed and automaticity	**Legibility**
	1 Position and fixation of paper	**2 Maintenance of posture**	**3 Stability of grasp**	**4 Pen Grasp**	**5 Movement in hand and fingers**	**6 Visual perception**	**7 Preferred hand**	**1 Writing analysis**	**2 Endurance and fatigue**	**3 Punctuation**	**4 Corrections and spelling**	**5 Missing and added words**	**WSAN Alphabet task (automaticity)**	**Speed**	**Legibility**

Observation Checklist **Writing Checklist** **Automaticity**

A x 1= ______ A x 1= ______ **Speed score copy**

B x 2 = ______ B x 2 = ______

C x 3 = ______ C x 3 = ______ **F........../2 = ______**

D /7 = _____ **E /5 = ______** **Legibility _______**

At risk	Cut off 0.6	Cut off 0.8	Speed and automaticity	Cut off 0.6	Legibility	Cut off 1
At high risk	Cut off 0.7	Cut off 1	Speed and automaticity	Cut off 0.8	Legibility	Cut off 2
At very high risk	Cut off 0.9	Cut off 1.2	Speed and automaticity	Cut off 1	Legibility	Cut off 3

APPENDIX W Mann-Whitney U Test all items on the Handwriting Screening Assessment for typical students and students referred for concessions

Vriable	Mann-Whitney U Test								
	Rank Sum	Rank Sum	U	Z	p-value	Z	p-value	Valid N	Valid N
	Group 1	Group 2				adjusted		Group 1	Group 2
OBSERVATION SUBTESTS									
Sub test 1 Position anf Fixation of paper									
Paper table	55911.50	8708.50	6817.50	3.08	0.00	4.93	0.00**	298	61
Paper copied	51931.00	12689.00	7380.00	-2.31	0.02	-2.90	0.00**	298	61
Fixates paper	57630.50	6989.50	5098.50	5.40	0.00	6.45	0.00**	298	61
Total /9	56608.00	8012.00	6121.00	4.02	0.00	4.30	0.00**	298	61
Subtest 2 Maintenance of posture									
Writing hand pos	55909.50	8351.50	6460.50	3.53	0.00	4.19	0.00**	297	61
Non-writing hand	52312.00	12308.00	7761.00	-1.80	0.07	-1.99	0.05*	298	61
Posture	55187.00	9433.00	7542.00	2.09	0.04	2.36	0.02**	298	61
Maintains position	55424.50	9195.50	7304.50	2.42	0.02	6.39	0.00**	298	61
Total /14	55063.50	9556.50	7665.50	1.93	0.05	1.98	0.05*	298	61
Subtest 3 Stability of Grasp									
DIP index finger	55713.00	8907.00	7016.00	2.81	0.01	3.08	0.00**	298	61
IP thumb	55572.50	9047.50	7156.50	2.62	0.01	3.01	0.00**	298	61
Total /16	55310.50	9309.50	7418.50	2.26	0.02	2.31	0.02*	298	61
Subtest 4 Pen Grasp									
Pen slant	54675.00	9586.00	7756.00	1.62	0.11	2.57	0.01**	298	60
Finger pen held to	52121.50	12498.50	7570.50	-2.06	0.04	-2.67	0.01**	298	61
No fingers on pen	52117.50	12502.50	7566.50	-2.06	0.04	-2.68	0.01**	298	61
Subtest 5 Movement in hand and fingers									
Movement hand-shake	54214.00	8621.00	7025.00	1.88	0.06	2.68	0.01**	298	56

Writing movements	55600.00	9020.00	7129.00	2.65	0.01	3.33	0.00**	298	61
Dis-association	51889.00	12731.00	7338.00	-2.37	0.02	-2.74	0.01**	298	61
Total /9	55571.50	9048.50	7157.50	2.61	0.01	2.72	0.01**	298	61
Subtest 6 Visual function									
Head movement	59552.00	4709.00	2879.00	8.29	0.00	9.25	0.00**	298	60
Follows text	59052.00	5209.00	3379.00	7.60	0.00	8.87	0.00**	298	60
Reading type	54507.50	9395.50	7625.50	1.61	0.11	3.95	0.00**	298	59
Total /8	60701.50	3918.50	2027.50	9.56	0.00	9.96	0.00**	298	61
WRITING CHECKLIST									
Subtest 1 Analysis of writing									
Lines	56947.00	7673.00	5782.00	4.48	0.00	5.55	0.00**	298	61
Slant letters	55195.00	9425.00	7534.00	2.11	0.04	2.45	0.01**	298	61
Total /15	55501.50	9118.50	7227.50	2.52	0.01	2.55	0.01**	298	61
Subtest 2 Endurance and fatigue									
Type of writing	55275.00	9345.00	7454.00	2.21	0.03	2.39	0.02**	298	61
Pressure	57329.00	7291.00	5400.00	4.99	0.00	5.35	0.00**	298	61
Deterior-ation	56160.00	8460.00	6569.00	3.41	0.00	4.75	0.00**	298	61
Total /9	58088.50	6531.50	4640.50	6.02	0.00	6.15	0.00**	298	61